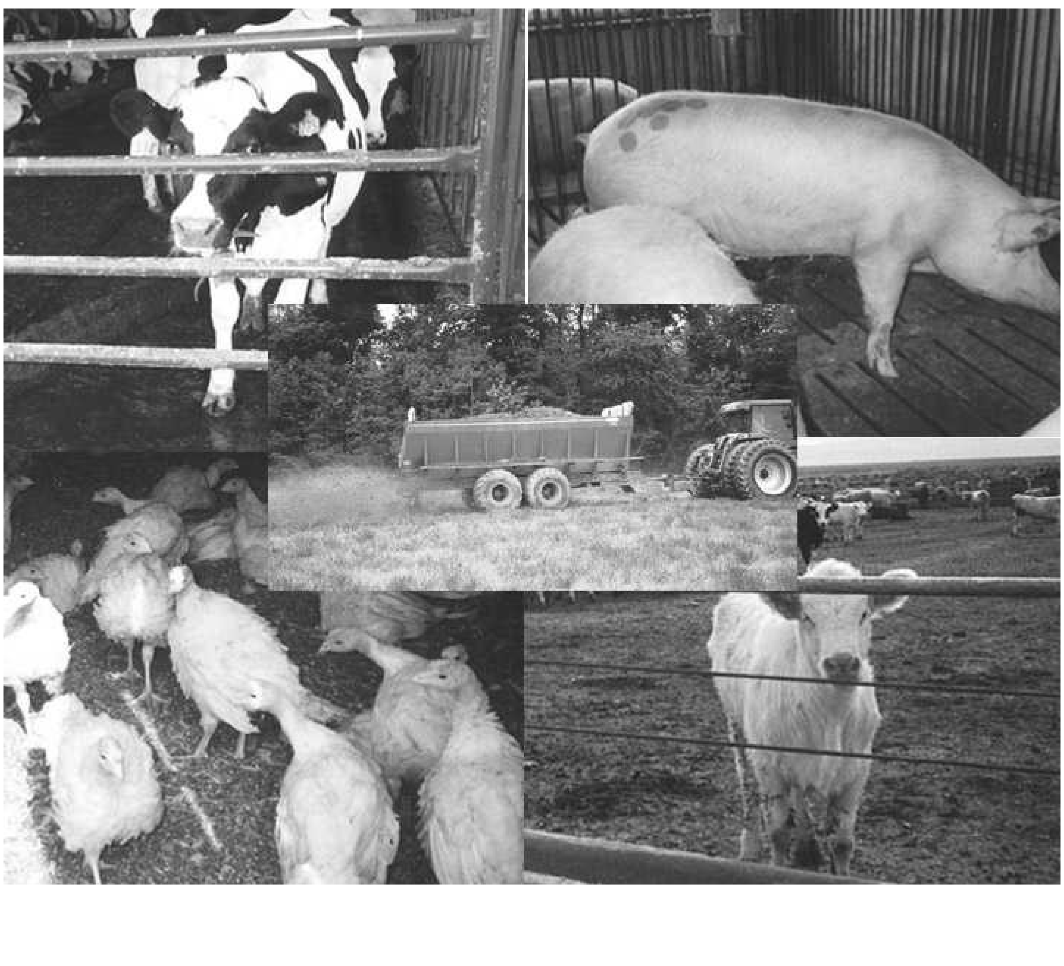
United States
Environmental Protection
Agency

Office of Water (4303)
Washington, DC 20460

EPA-821-R-01-003
January 2001

Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations



Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations

Carol M. Browner
Administrator

J. Charles Fox
Assistant Administrator, Office of Water

Sheila E. Frace
Director, Engineering and Analysis Division

Donald F. Anderson
Chief, Commodities Branch

Janet Goodwin
Project Manager

Paul H. Shriner
Project Engineer

Engineering and Analysis Division
Office of Science and Technology
U.S. Environmental Protection Agency
Washington, D.C. 20460

January 2001

ACKNOWLEDGMENTS AND DISCLAIMER

This report has been reviewed and approved for publication by the Engineering and Analysis Division, Office of Science and Technology. This report was prepared with the support of Tetra Tech, Inc., and Eastern Research Group, Inc., under the direction and review of the Office of Science and Technology.

CONTENTS

LIST OF TABLES

List of Figures

CHAPTER 1

INTRODUCTION AND LEGAL AUTHORITY

1.0 INTRODUCTION AND LEGAL AUTHORITY

This chapter presents an introduction to the regulations being revised for the concentrated animal feeding operations (CAFOs) industry and describes the legal authority that the U.S. Environmental Protection Agency (EPA) has to revise these regulations. Section 1.1 describes the Clean Water Act; Section 1.2 reviews the Pollution Prevention Act; and Section 1.3 describes the Regulatory Flexibility Act.

1.1 Clean Water Act (CWA)

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Section 101(a)). The CWA gives EPA the authority to regulate point source discharges (including CAFOs) into waters of the United States through the National Pollutant Discharge Elimination System (NPDES) permitting program. Under the CWA, EPA issues effluent limitations guidelines, pretreatment standards, and new source performance standards for point sources, other than publicly owned treatment works (POTWs). Direct dischargers must comply with effluent limitations in NPDES permits, while indirect dischargers must comply with pretreatment standards. The remainder of this section describes the NPDES and effluent limitations guidelines and standards, as they apply to the CAFOs industry.

On October 30, 1989, Natural Resources Defense Council, Inc., and Public Citizen, Inc., filed an action against EPA in which they alleged, among other things, that EPA had failed to comply with CWA Section 304(m). *Natural Resources Defense Council, Inc., et al.* v. *Reilly*, Civ. No. 89-2980 (RCL) (D.D.C.). Plaintiffs and EPA agreed to a settlement of that action in a consent decree entered on January 31, 1992. The consent decree, which has been modified several times, established a schedule by which EPA is to propose and take final action for eleven point source categories identified by name in the decree and for eight other point source categories identified only as new or revised rules, numbered 5 through 12. After completing a preliminary study of the feedlots industry under the decree, EPA selected the swine and poultry portion of the feedlots industry as the subject for New or Revised Rule #8, and the beef and dairy portion of that industry as the subject for New or Revised Rule #9. Under the decree, as modified, the Administrator was required to sign a proposed rule for both portions of the feedlots industry on or before December 15, 2000, and must take final action on that proposal no later than December 15, 2002. As part of EPA's negotiations with the plaintiffs regarding the deadlines for this rulemaking, EPA entered into a settlement agreement dated December 6, 1999, under which EPA agreed, by December 15, 2000, to also propose to revise the existing NPDES permitting regulations under 40 CFR Part 122 for CAFOs. EPA also agreed to perform certain evaluations, analyses, or assessments and to develop certain preliminary options in connection with the proposed CAFO rules. (The Settlement Agreement expressly provides that nothing in the Agreement requires EPA to select any of these options as the basis for its proposed rule.)

1.1.1 National Pollutant Discharge Elimination System (NPDES)

The NPDES permit program regulates the discharge of pollutants from point sources to waters of the United States. The term "point source" is defined in the Clean Water Act (Section 502(14)) as a discernible, confined, and discrete conveyance from which pollutants are or may be discharged. CAFOs are explicitly defined as point sources in Section 502(14).

EPA promulgated the current NPDES regulations for CAFOs in the mid-1970s (see 41 F.R. 11458, March 18, 1976). Changes to the NPDES regulations for CAFOs are discussed in Section 9.

1.1.2 Effluent Limitations Guidelines and Standards

EPA promulgated effluent limitations guidelines and standards for the Feedlots Point Source Category in 1974 (40 CFR Part 412) (see 39 F.R. 5704, February 14, 1974). EPA is proposing to revise these regulations as discussed in Section 2.2.

Effluent limitations guidelines and standards for CAFOs are being proposed under the authority of Sections 301, 304, 306, 307, 308, 402, and 501 of the CWA, 33 U.S.C. 1311, 1314, 1316, 1317, 1318, 1342, and 1361. Effluent limitations guidelines and standards are summarized briefly below for direct and indirect dischargers.

Direct Dischargers

- Best Practicable Control Technology Currently Available (BPT) (304(b)(1) of the CWA) - In the guidelines for an industry category, EPA defines BPT effluent limits for conventional, toxic, and non-conventional pollutants. In specifying BPT, EPA looks at a number of factors. EPA first considers the cost of achieving effluent reductions in relation to the effluent reduction benefits. The Agency also considers the age of the equipment and facilities, the processes employed and any required process changes, engineering aspects of the control technologies, non-water quality environmental impacts (including energy requirements), and such other factors as the Agency deems appropriate (CWA 304(b)(1)(B)). Traditionally, EPA establishes BPT effluent limitations based on the average of the best performances of facilities within the industry of various ages, sizes, processes, or other common characteristics. Where existing performance is uniformly inadequate, EPA may require higher levels of control than currently in place in an industrial category if the Agency determines that the technology can be practically applied.

- Best Available Technology Economically Achievable (BAT) (304(b)(2) of the CWA) - In general, BAT effluent limitations represent the best existing economically achievable performance of direct discharging plants in the industrial subcategory or category. The factors considered in assessing BAT include the cost of achieving BAT effluent reductions, the age of equipment and facilities involved, the processes employed, engineering aspects of the control technology, potential process changes, non-water quality environmental impacts (including energy requirements), and such factors as the Administrator deems appropriate. The Agency retains considerable discretion in assigning the weight to be accorded to these factors. An additional statutory factor considered in setting BAT is economic achievability. Generally, the achievability is determined on the basis of the total cost to the industrial subcategory and the overall effect of the rule on the industry's financial health. BAT limitations may be based on effluent reductions attainable through changes in a facility's processes and operations. As with BPT, where existing performance is uniformly inadequate, BAT may be based on technology transferred from a different subcategory within an industry or from another industrial category. BAT may be based on process changes or internal controls, even when these technologies are not common industry practice.

- Best Conventional Pollutant Control Technology (BCT) (304(b)(4) of the CWA) - The 1977 amendments to the CWA required EPA to identify effluent reduction levels for conventional pollutants associated with BCT technology for discharges from existing industrial point sources. BCT is not an additional limitation, but replaces Best Available Technology (BAT) for control of conventional pollutants. In addition to other factors specified in Section 304(b)(4)(B), the CWA requires that EPA establish BCT limitations after consideration of a two part "cost-reasonableness" test. EPA explained its methodology for the development of BCT limitations in July 1986 (51 F.R. 24974). Section 304(a)(4) designates the following as conventional pollutants: biochemical oxygen demand (BOD5), total suspended solids (TSS), fecal coliform, pH, and any additional pollutants defined by the Administrator as conventional. The Administrator designated oil and grease as an additional conventional pollutant on July 30, 1979 (44 F.R. 44501).

- New Source Performance Standards (NSPS) (306 of the CWA) - NSPS reflect effluent reductions that are achievable based on the best available demonstrated control technology. New facilities have the opportunity to install the best and most efficient production processes and wastewater treatment technologies. As a result, NSPS should represent the greatest degree of effluent reduction attainable through the application of the best available demonstrated control technology for all pollutants (i.e., conventional, non-conventional, and priority pollutants). In establishing NSPS, EPA is directed to take into consideration the cost of achieving the effluent reduction and any non-water quality environmental impacts and energy requirements.

Indirect Dischargers

- Pretreatment Standards for Existing Sources (PSES) (307(b) of the CWA) - PSES are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTWs. The CWA authorizes EPA to establish pretreatment standards for pollutants that pass through POTWs or interfere with treatment processes or sludge disposal methods at POTWs. Pretreatment standards are technology-based and analogous to BAT effluent limitations guidelines for removal of priority pollutants. EPA retains discretion not to issue such standards where the total amount of pollutants passing through a POTW is not significant.

  The General Pretreatment Regulations, which set forth the framework for the implementation of categorical pretreatment standards, are found at 40 CFR Part 403. Those regulations contain a definition of pass-through that addresses localized rather than national instances of pass-through and establish pretreatment standards that apply to all domestic dischargers (see 52 F.R. 1586, January 14, 1987).

- Pretreatment Standards for New Sources (PSNS) (307(b) of the CWA) - Like PSES, PSNS are designed to prevent the discharges of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTWs. PSNS are to be issued at the same time as NSPS. New indirect dischargers have the opportunity to incorporate into their facilities the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS as it considers in promulgating NSPS. EPA retains discretion not to issue such standards where the total amount of pollutants passing through a POTW is not significant.

1.2 Pollution Prevention Act (PPA)

In the Pollution Prevention Act of 1990 (42 U.S.C. 13101 et seq., Pub. Law 101-508, November 5, 1990), Congress declared pollution prevention a national policy of the United States. The PPA declares that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner whenever feasible; pollution that cannot be prevented or recycled should be treated; and disposal or other release into the environment should be chosen only as a last resort and should be conducted in an environmentally safe manner. This proposed regulation for animal feeding operations was reviewed for its incorporation of pollution prevention as part of the Agency effort. Pollution prevention practices applicable to animal feeding operations are described in Chapters 4 and 8.

1.3 <u>Regulatory Flexibility Act (RFA) as Amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA)</u>

In accordance with Section 603 of the Regulatory Flexibility Act (RFA) (5 U.S.C. 601 et seq.), EPA prepared an initial regulatory flexibility analysis (IRFA) that examines the impact of the proposed rule on small entities along with regulatory alternatives that could reduce that impact. The IRFA (available in Chapter 9 of Economic Analysis of the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations) concludes that the economic affect of regulatory options being considered might significantly impact a substantial number of small livestock and poultry operations.

As required by Section 609(b) of the RFA, as amended by SBREFA, EPA also conducted outreach to small entities and convened a Small Business Advocacy Review Panel to obtain the advice and recommendations of representatives of the small entities that potentially would be subject to the rule's requirements. Consistent with the RFA/SBREFA requirements, the panel evaluated the assembled materials and small entity comments on issues related to the elements of the IRFA. Participants included representatives of EPA, the Small Business Administration (SBA), and the Office of Management and Budget (OMB). Participants from the farming community included small livestock and poultry producers as well as representatives of the major commodity and agricultural trade associations. A summary of the panel's activities and recommendations is provided in the Final Report of the Small Business Advocacy Review Panel on EPA's Planned Proposed Rule on National Pollutant Discharge Elimination System (NPDES) and Effluent Limitations Guideline (ELG) Regulations for Concentrated Animal Feeding Operations (April 7, 2000). This document is included in the public record.

CHAPTER 2

SUMMARY AND SCOPE OF PROPOSED REGULATION

2.0 SUMMARY AND SCOPE OF PROPOSED REGULATION

The proposed regulations described in this document include revisions of two regulations that ensure manure, wastewater, and other process waters for concentrated animal feeding operations (CAFOs) do not impair water quality. These two regulations are the National Pollutant Discharge Elimination System (NPDES) described in Section 2.1 and the Effluent Limitations Guidelines and Standards for feedlots (beef, dairy, swine, and poultry) described in Section 2.2, which establish the technology-based standards that are applied to CAFOs. Both regulations were originally promulgated in the 1970s. EPA proposes revisions to these regulations to address changes that have occurred in the animal industry sectors over the last 25 years, to clarify and improve implementation of CAFO permit requirements, and to improve the environmental protection achieved under these rules.

2.1 National Pollutant Discharge Elimination System (NPDES)

As noted in Section 1, CAFOs are "point sources" under the Clean Water Act. The regulation at 40 CFR 122.23 specifies which animal feeding operations are CAFOs and therefore are subject to the NPDES program on that basis.

2.1.1 Applicability of the Proposed Regulation

The existing NPDES regulation uses the term "animal unit," or AU, to identify facilities that are CAFOs. The term AU is a metric unit established in the 1970 regulations that attempted to equate the characteristics of the wastes produced by different animal types. The existing regulation defines facilities with 1,000 animal units or more as CAFOs. The regulation also states that facilities with 300 to 1,000 animal units are CAFOs if they meet certain conditions.

The proposed rule presents two alternatives for how to structure the revised NPDES program for CAFOs, each of which offers comparable environmental benefits but differs in the administrative approach. Additional approaches considered but not proposed are described in Section 9. The first alternative proposal is a two-tier applicability structure that simplifies the definition of which facilities are CAFOs by establishing a single threshold for each animal sector. This proposal establishes a single threshold at the equivalent of 500 AU, above which operations are defined as CAFOs, and below which facilities become CAFOs only if designated by the permit authority. The 500 AU equivalent for each animal sector is as follows:

- 500 cattle (excluding mature dairy cattle or veal calves);
- 500 veal calves;
- 350 mature dairy cattle (whether milked or dry);
- 1,250 mature swine weighing over 55 pounds;
- 5,000 immature swine weighing 55 pounds or less;
- 50,000 chickens;
- 27,500 turkeys;
- 2,500 ducks;
- 250 horses; and/or
- 5,000 sheep or lambs.

The second alternative retains the three-tier applicability structure of the existing regulation:

1) All operations with 1,000 AUs or more are defined as CAFOs.

2) Operations with 300 to 1,000 AU would be CAFOs only if they meet certain conditions or if designated by the permitting authority.

3) Operations with fewer than 300 AU would be CAFOs only if designated by the permitting authority.

All facilities with 300 to 1,000 AU must either certify that they do not meet the conditions for being defined as a CAFO or else apply for a permit. The 300 to 1,000 AU equivalent numbers of animals for each sector are presented in Table 2-1.

Table 2-1. Number of Animals by Sector for 300 and 1,000 AU Equivalents

Animal Type	1,000 AU Equivalent (Number of Animals)	300 AU Equivalent (Number of Animals)
Cattle (excluding mature dairy or veal)	1,000	300
Veal	1,000	300
Mature dairy cattle	700	200
Swine weighing more than 55 pounds	2,500	750
Swine weighing 55 pounds or less	10,000	3,000
Chickens	100,000	30,000
Turkeys	55,000	16,500
Ducks	5,000	1,500
Horses	500	150
Sheep or lambs	10,000	3,000

The proposed rule also includes all types of poultry operations, regardless of manure handling system or watering system, and stand-alone immature swine and heifer operations.

2.1.2 Summary of Proposed Revisions to NPDES Regulations

EPA proposes to simplify the criteria for being designated as a CAFO by eliminating two specific criteria that have proven difficult to implement: the "direct contact" criterion and the "man-made device" criterion; however, the proposal retains the existing requirement for the permitting authority to consider a number of factors to determine whether the facility is a significant contributor of pollution to the waters of the United States. The proposal also retains the requirement for an on-site inspection in order to make this determination. EPA proposes to clarify its authority to designate facilities in states with NPDES authorized programs.

EPA also proposes to eliminate the 25-year, 24-hour storm event permit exemption and to impose a duty to apply for an NPDES permit. Under the current rule, an operation that otherwise meets the definition of a CAFO but that discharges only in the event of a 25-year, 24-hour storm is exempt from being defined as a CAFO. Currently, there are many operations that believe that they do not need to apply for a permit on this basis. EPA believes, however, that many operators have underestimated their discharges of manure and wastewater from the feedlot, manure storage areas, wastewater containment areas, and land application areas and have not applied for a permit when, in fact, they needed one. Under this proposal, all operations meeting the definition of a CAFO under either of the two applicability alternatives described in Section 2.1.1 would be required to apply for a permit. However, under this proposal, if the operator could demonstrate to the permitting authority that the facility has no potential to discharge, then the operator could request not to be issued a permit by the permitting authority.

Under the two-tier applicability structure, EPA estimates that approximately 26,000 operations will be required to apply for a NPDES permit. Under the three-tier applicability structure, EPA estimates that approximately 13,000 operations will be required to apply for a permit, and an additional 26,000 operations could either certify that they are not a CAFO or apply for a permit. Under the existing regulation, EPA estimates that about 12,000 facilities should be permitted, but only 2,530 have actually applied for a permit.

Under this proposal, the definition of a CAFO would explicitly include the production area (animal confinement area, manure storage area, waste containment area) as well as the land application area that is under the control of the CAFO owner or operator. Recent industry trends show more and larger feedlots with less cropland for application of manure, often resulting in significant manure excesses. EPA is concerned that as a result of these trends, manure is taking on the characteristic of a waste and is being applied to land in excess of agricultural uses, causing runoff or leaching into waters of the United States. The permit will address practices at the production area as well as the land application area, and will impose certain other record keeping requirements with regard to transfer of manure off site.

EPA further proposes to clarify that entities which exercise "substantial operational control" over the CAFO would be required to obtain a permit along with the CAFO operator. This provision is intended to address the increasing trend towards specialized animal production under contract with processors, packers, and other such integrators. Especially in the swine and poultry sector, the processor provides the animals, feed, medication, specifies growing practices, or a combination of these. This trend has resulted in growing concentrations of excess manure beyond agricultural needs in certain geographic areas. By making both parties liable for compliance with the terms of the permit as well as responsible for the excess manure generated by CAFOs, EPA intends that manure will be managed to prevent environmental harm.

In summary, the following components describe the general revisions that EPA is proposing to make to the NPDES regulations:

- Require the CAFO operator to develop a Permit Nutrient Plan for managing manure and wastewater at both the production area and the land application area;
- Require certain record keeping, reporting, and monitoring;
- Revise the definition of an animal feeding operation (AFO) to clarify coverage of winter feeding operations;
- Eliminate the term "animal unit" and eliminate the mixed-animal type calculation to simplify the regulation;
- Clarify the applicability of the regulation where there is ground water with a direct hydrological connection to surface water;
- Clarify how the exemptions in the Clean Water Act for storm water-related discharges relate to runoff associated with the land application of manure both at the CAFO and off site;
- Reiterate the existing CWA requirements that apply to dry weather discharges at AFOs;
- Require permit authorities to include special conditions in permits to:

    - require retention of a permit until proper facility closure;

    - establish the method for operators to calculate the allowable manure application rate;

    - specify restrictions on application of manure and wastewater to frozen, snow covered, or saturated land to prevent impairment of water quality;

- address risk of contamination via ground water with a direct hydrological connection to surface water;

- require that the CAFO operator obtain a certification from off-site recipients of CAFO manure that the recipients will properly manage the manure; and

- establish design standards to account for chronic storm events.

2.2 Effluent Limitations Guidelines and Standards

The proposed effluent limitations guidelines and standards regulations will establish the Best Practicable Control Technology (BPT), Best Conventional Pollutant Control Technology (BCT), and the Best Availability Technology (BAT) limitations as well as New Source Performance Standards (NSPS) on discharges from the production area as well as the land application areas at CAFOs. Section 2.2.1 describes the applicability of the proposed regulation; Section 2.2.2 summarizes proposed revisions to effluent limitations guidelines and standards.

2.2.1 Applicability of the Proposed Regulation

EPA has subcategorized the CAFOs Point Source Category based primarily on animal type. See Section 5 for a discussion of the basis considered for subcategorization. These subcategories are listed and described in Table 2-2.

Table 2-2. Basis Considered for Subcategorization of CAFOs

Subpart	Subcategory	Description
A	Horses, Sheep, and Lambs	CAFOs under 40 CFR 122.23 which confine horses, sheep, or lambs
B	Ducks	CAFOs under 40 CFR 122.23 which confine ducks
C	Beef and Dairy	CAFOs under 40 CFR 122.23 which confine mature dairy cows (either milking or dry) and cattle other than mature dairy or veal
D	Swine, Poultry, and Veal	CAFOs under 40 CFR 122.23 with swine, each weighing 55 pounds or more; swine, each weighing less than 55 pounds; veal calves; chickens, and/or turkeys

EPA is not proposing to revise the effluent guidelines requirements or the applicability for subcategory A (horses, sheep, and lambs) and subcategory B (ducks), even though the definition of a CAFO for these subcategories has changed.

The effluent guidelines requirements for subcategory C (beef and dairy) and subcategory D (swine, poultry, and veal) apply to any operations that are defined as CAFOs under either the two-tier or three-tier applicability structure of the NPDES regulation described in Section 2.1.

Under the two-tier applicability structure, the requirements apply to all operations defined as CAFOs having at least as many animals as listed below:

- 500 cattle (excluding mature dairy cattle or veal calves);
- 500 veal calves;
- 350 mature dairy cattle (whether milked or dry);
- 1,250 swine weighing over 55 pounds;
- 5,000 swine weighing 55 pounds or less;
- 50,000 chickens; or
- 27,500 turkeys.

Under the three-tier applicability structure, the requirements apply to all operations defined as CAFOs having at least as many animals as listed below:

- 300 cattle (excluding mature dairy cattle or veal calves);
- 300 veal calves;
- 200 mature dairy cattle (whether milked or dry);
- 750 swine weighing over 55 pounds;
- 3,000 swine weighing 55 pounds or less;
- 30,000 chickens; or
- 16,500 turkeys.

EPA is proposing several changes to the applicability of the existing regulation:

1) *Chickens* - Chickens refer to laying hens, pullets, broilers, breeders, and other meat-type chickens. EPA is proposing to clarify the effluent guidelines to ensure coverage of broiler and laying hen operations that do not use liquid manure handling systems or continuous overflow watering. EPA thus proposes to regulate chicken operations regardless of the type of watering system or manure handling system used.

2) *Mixed Animal Types* - EPA proposes to eliminate provisions in the existing regulation that apply to mixed animal operations. As discussed in Section 9, this will simplify the regulation. Note that once a facility is defined as a CAFO, the manure associated with all animals in confinement would be subject to NPDES requirements.

3) Immature Animals - EPA proposes to apply national technology-based standards to swine nurseries and to operations that confine immature dairy cows or heifers apart from the dairy.

EPA proposes to include stand-alone heifer operations under the subcategory C (Beef and Dairy). Any feedlot that confines heifers along with cattle for slaughter would also be subject to the subcategory C requirements. Furthermore EPA proposes to include swine facilities that confine swine weighing under 55 pounds each under the subcategory D.

4) *Veal Operations* - EPA proposes to establish a new subcategory that applies to the production of veal cattle. Veal production is included in the existing regulation as slaughter steer. However, veal production practices and wastewater and manure handling are very different from the practices used at beef feedlots, and meet a different BAT performance standard than beef feedlots. Therefore EPA proposes to establish a separate subcategory for veal.

2.2.2 Summary of Proposed Revisions to Effluent Limitations Guidelines and Standards

CAFOs in the beef, dairy, swine, poultry, and veal subcategories that meet the definition of a CAFO under either the two-tier or three-tier applicability structure of NPDES would be required under this rule to comply with the effluent limitations guidelines and standards. The proposed guidelines establish BPT, BCT, BAT, and NSPS by requiring effluent limitations and standards and specific best management practices that ensure that manure storage and handling systems are inspected and maintained adequately as described in the following subsections. EPA evaluated the following eight regulatory options for the proposed guidelines:

- Option 1: Nitrogen-Based Application;
- Option 2: Phosphorus-Based Application;
- Option 3: Phosphorus-Based Application + Ground Water Protection;
- Option 4: Phosphorus-Based Application + Ground Water Protection + Surface Water Protection;
- Option 5: Phosphorus-Based Application + Drier Manure;
- Option 6: Phosphorus-Based Application + Anaerobic Digestion;
- Option 7: Phosphorus-Based Application + Timing Restrictions; and
- Option 8: Phosphorus-Based Application + Minimized Potential for Discharge.

These options are described in detail in Section 10.0.

2.2.2.1 Best Practicable Control Technology (BPT)

EPA is proposing BPT limitations based on Option 2 for the beef and dairy subcategories and the swine, poultry, and veal subcategories. Table 2-3 shows the technology basis of BPT for these subcategories. Under BPT, EPA proposes zero discharge from the production area with an overflow due to catastrophic or chronic storms allowed. If the CAFO uses a liquid manure handling system, it must have a liquid storage structure or lagoon that is designed, constructed, and maintained to capture all process wastewater and manure, plus all of the storm water runoff from a 25-year, 24-hour storm.

BPT includes specific requirements on the application of manure and wastewater to land that is owned or under the operational control of the CAFO. CAFOs are required to apply their manure at a rate calculated to meet the requirements of the crop for either nitrogen or phosphorus, depending on the soil conditions for phosphorus. Livestock manure tends to be phosphorus-rich, meaning that if manure is applied to meet the nitrogen requirements of a crop, then the phosphorus is being applied at rates higher than needed by the crop. Repeated application of manure on a nitrogen basis may build up phosphorus levels in the soil, and result in saturation, thus contributing to the contamination of surface waters. Therefore, EPA also proposes that manure must be applied to cropland at rates not to exceed the crop requirements for nutrients and the ability of the soil to absorb any excess phosphorus.

BPT establishes specific record keeping requirements associated with ensuring the limitations are met for the production area and that the application of manure and wastewater is done in accordance with land application requirements. EPA also proposes to require the CAFO to maintain records on any excess manure that is transported off site. The CAFO must provide the recipient with information on the nutrient content of the manure transferred and the CAFO must keep these records on site.

2.2.2.2 Best Control Technology (BCT)

EPA proposes BCT equivalent to BPT for the beef and dairy subcategories and the swine, poultry, and veal subcategories. Table 2-3 shows the technology bases of BCT for these subcategories.

2.2.2.3 Best Available Technology (BAT)

EPA proposes BAT limitations based on Option 3 for the Beef and Dairy Subcategories and Option 5B for the Swine, Poultry, and Veal Subcategories. Table 2-1 shows the technology bases of BAT for these subcategories.

BAT limitations for the beef and dairy subcategories are based on the proposed BPT technology requirements with the additional requirement to achieve zero discharge via ground water beneath the production area, whenever the ground water has a direct hydrological connection to surface water. The proposed BAT requirements for the swine, poultry, and veal subcategories eliminate the allowance for overflow in the event of a chronic or catastrophic storm. CAFOs in these subcategories typically house their animals under roof instead of in open areas, thus avoiding or minimizing contaminated storm water and the need to contain storm water.

2.2.2.4 New Source Performance Standards (NSPS)

EPA proposes NSPS based on Option 3 for the beef and dairy subcategories and a combination of Option 3 and Option 5B for the swine, poultry, and veal subcategories. Table 2-3 shows the technology bases of NSPS for these subcategories.

EPA proposes to revise NSPS based on the same technology requirements as BAT for the beef and dairy subcategories. For the swine, poultry, and veal subcategories, EPA added to the BAT requirements that there be no discharge of pollutants through ground water beneath the production area, when the ground water has a direct hydrological connection to surface water. Both the BAT and NSPS requirements have the same land application and record keeping requirements as proposed for BPT.

Table 2-3. Summary of Technology Basis for CAFO Industry

Technology Basis	BPT and BCT		BAT		NSPS	
	Beef and Dairy Subcategory	Swine, Poultry, and Veal Subcategories	Beef and Dairy Subcategory	Swine, Poultry, and Veal Subcategories	Beef and Dairy Subcategory	Swine, Poultry, and Veal Subcategories
Zero discharge with a 25-year, 24-hour storm exemption	✓	✓	✓		✓	
Zero discharge with no allowance for overflow				✓		✓
Phosphorus-based Permit Nutrient Plan (where necessary, Nitrogen based elsewhere)	✓	✓	✓	✓	✓	✓
Hydrologic link assessment and zero discharge to groundwater beneath production area			✓		✓	✓
Additional Measures						
Periodic inspections	✓	✓	✓	✓	✓	✓
Depth marker for lagoons	✓	✓	✓	✓	✓	✓
Mortality handling requirements	✓	✓	✓	✓	✓	✓
100-foot land application setback	✓	✓	✓	✓	✓	✓
Manure samples at least once per year	✓	✓	✓	✓	✓	✓
Soil test every three years	✓	✓	✓	✓	✓	✓
Record keeping	✓	✓	✓	✓	✓	✓

CHAPTER 3

DATA COLLECTION ACTIVITIES

3.0 DATA COLLECTION ACTIVITIES

EPA collected and evaluated data from a variety of sources during the course of developing the proposed effluent limitations guidelines and standards for the concentrated animal feeding operations (CAFO) industry. These data sources include EPA site visits, industry trade associations, the U.S. Department of Agriculture, published literature, previous EPA Office of Water studies of the Feedlots Point Source Category, and other EPA studies of animal feeding operations. Each of these data sources is discussed below, and analyses of the data collected by EPA are presented throughout the remainder of this document.

3.1 Summary of EPA's Site Visit Program

The Agency conducted approximately 110 site visits to collect information about animal feeding operations (AFOs) and waste management practices. Specifically, EPA visited swine, poultry, dairy, beef, and veal AFOs throughout the United States. In general, the Agency visited a wide range of AFOs, including those demonstrating centralized treatment or new and innovative technologies. The majority of facilities were chosen with the assistance of the following industry trade associations:

- National Pork Producers Council;
- United Egg Producers and United Egg Association;
- National Turkey Federation;
- National Cattlemen's Beef Association;
- National Milk Producers Federation; and
- Western United Dairymen.

EPA also received assistance from environmental groups, such as the Natural Resources Defense Council and the Clean Water Network. The Agency contacted university experts, state cooperatives and extension services, and state and EPA regional representatives when identifying facilities for site visits. EPA also attended USDA-sponsored farm tours, as well as industry, academic, and government conferences.

Table 3-1 summarizes the number of site visits EPA conducted by animal industry sector, site locations, and size of animal operations.

Table 3-1. Number of Site Visits Conducted by EPA for the Various Animal Industry Sectors

Animal Sector	Number of Site Visits	Location(s)	Size of Operations
Swine	30	NC, PA, OH, IA, MN, TX, OK, UT	900 - 1 million head
Poultry	6 (broiler)	GA, AR, NC, VA, WV, MD, DE, PA, OH, IN, WI	20,000 - 1 million birds
	12 (layer)		
	6 (turkey)		
Dairy	25	PA, FL, CA, WI, CO	40 - 4,000 cows
Beef	30	TX, OK, KS, CO, CA, IN, NE, IA	500 - 120,000 head
Veal	3	IN	500 - 540 calves

In general, the Agency considered several factors when identifying representative facilities for site visits, including the following:

- Type of animal feeding operation;
- Location;
- Feedlot size; and
- Current waste management practices.

Facility-specific selection criteria are contained in site visit reports (SVRs) prepared for each facility visited by EPA. The SVRs are contained in the administrative record for this rulemaking.

During the site visits, EPA typically collected the following types of information:

- General facility information, including size and age of facility, number of employees, crops grown, precipitation information, and proximity to nearby waterways;

- Animal operation data, including flock or herd size, culling rate, and method for disposing dead animals;

- Description of animal holding areas, such as barns or pens, and any central areas, such as milking centers;

- Manure collection and management information, including the amount generated, removal methods and storage location, disposal information, and nutrient content;

- Wastewater collection and management information, including the amount generated, runoff information, and nutrient content;

- Nutrient management plans and any best management practices (BMPs); and

- Available wastewater discharge permit information.

This information, along with other site-specific information, is documented in the SVRs for each facility visited.

3.2 Industry Trade Associations

EPA contacted the following industry trade associations during the development of the proposed rule.

National Pork Producers Council (NPPC). NPPC is a marketing organization and trade association made up of 44 affiliated state pork producer associations. NPPC's purpose is to increase the quality, production, distribution, and sales of pork and pork products.

United Egg Producers and United Egg Association (UEP/UEA). UEP/UEA promotes the egg industry in the following areas: price discovery, production and marketing information, unified industry leadership, USDA relationships, and promotional efforts.

National Turkey Federation (NTF). NTF is the national advocate for all segments of the turkey industry, providing services and conducting activities that increase demand for its members' products.

National Chicken Council (NCC). NCC represents the vertically integrated companies that produce and process about 95 percent of the chickens sold in the United States. The association provides consumer education, public relations, and public affairs support, and is working to seek a positive regulatory, legislative, and economic environment for the broiler industry.

National Cattlemen's Beef Association (NCBA). NCBA is a marketing organization and trade association for cattle farmers and ranchers, representing the beef industry.

National Milk Producers Federation (NMPF). NMPF is involved with milk quality and standards, animal health and food safety issues, dairy product labeling and standards, and legislation affecting the dairy industry.

American Veal Association (AVA). AVA represents the veal industry, and advances the industry's concerns in the legislative arena, coordinates production-related issues affecting the industry, and handles other issues relating to the industry.

Western United Dairymen (WUD). WUD, a dairy organization in California, promotes legislative and administrative policies and programs for the industry and consumers.

Professional Dairy Heifer Growers Association (PDHGA). PDHGA is an association of heifer growers who are dedicated to growing high-quality dairy cow replacements. The association offers educational programs and professional development opportunities, provides a communication network, and establishes business and ethical standards for the dairy heifer grower industry.

All of the above organizations, along with several of their state affiliates, assisted EPA's efforts to understand the industry by helping with site visit selection, submitting supplemental data, and reviewing descriptions of the industry and waste management practices. These organizations also participated in and hosted meetings with EPA for the purpose of exchanging information with the Agency. EPA also obtained copies of membership directories and conference proceedings, which were used to identify contacts and obtain additional information on the industry.

3.3 U.S. Department of Agriculture (USDA)

EPA obtained data from several agencies within the USDA, including the National Agricultural Statistics Service (NASS), the Animal and Plant Health Inspection Service (APHIS), Natural Resources Conservation Service (NRCS), and the Economic Research Service (ERS) in order to better characterize the AFO industry. The collected data include statistical survey information and published reports. Data collected from each agency are described below.

3.3.1 National Agricultural Statistics Service (NASS)

NASS is responsible for objectively providing important, usable, and accurate statistical information and data support services of structure and activities of agricultural production in the United States. Each year NASS conducts hundreds of surveys and prepares reports covering virtually every facet of U.S. agricultural publications. The primary source of data is the animal production facility. NASS collects voluntary information using mail surveys, telephone and in-person interviews, and field observations. NASS is also responsible for conducting a Census of Agriculture, which is currently performed once every 5 years; the last census occurred in 1997. EPA gathered information from the following published NASS reports:

- *Hogs and Pigs: Final Estimates 1993 - 1997;*
- *Chickens and Eggs: Final Estimates 1994 - 1997;*
- *Poultry Production and Value: Final Estimates 1994 - 1997;*
- *Cattle: Final Estimates 1994 - 1998;*
- *Milking Cows and Production: Final Estimates 1993 - 1997; and*
- *1997 Census of Agriculture.*

The information EPA collected from these sources is summarized below.

Hogs and Pigs: Final Estimates 1993 - 1997
EPA used data from this report to augment the swine industry profile. The report presents inventory, market hogs, breeding herd, and pig crops. Specifically, the report provides the number of farrowings, sows, and pigs per litter. This report presents the number of operations with hogs; however, EPA did not use this report to estimate farm counts because the report provided limited data. Instead, EPA used the 1997 Census of Agriculture data to estimate farm counts, as discussed later in this section.

Chickens and Eggs: Final Estimates 1994 - 1997
EPA used data from this report to augment the poultry industry profile. The report presents national and state-level data for the top-producing states on chickens and eggs, including the number laid and production for 1994 through 1997.

Poultry Production and Value: Final Estimates 1994 - 1997
EPA also used data from this report to augment the poultry industry profile. The report presents national and state-level data for the top producing states on production (number and pounds produced/raised), price per pound or egg, and value of production of broilers, chickens, eggs, and turkeys for 1994 through 1997.

Cattle: Final Estimates 1994 - 1998
EPA used data from this report to augment the beef industry profile. The report provides the number and population estimates for beef feedlots that have a capacity of over 1,000 head of cattle, grouped by size and geographic distribution. This report provides national and state-level data for the 13 top-producing beef states, which include the number of feedlots, cattle inventory, and number of cattle sold per year by size class. The report also provides the total number of feedlots that have a capacity of fewer than 1,000 head of cattle, total cattle inventory, and number of cattle sold per year for these operations. EPA did not use this report to estimate farm counts because the report provided limited data. Instead, EPA used the 1997 Census of Agriculture data to estimate farm counts, as discussed later in this section.

Milking Cows and Production: Final Estimates 1993 - 1997
EPA used data from this report to augment the dairy industry profile. The report presents national and state-level estimates of dairy cattle inventory and the number of dairy operations by size group. This particular report presents data for all dairy operations with over 200 mature dairy cattle in one size class. EPA did not use this report to estimate farm counts because the report provided limited data. Instead, EPA used the 1997 Census of Agriculture data to estimate farm counts, as discussed below.

1997 Census of Agriculture
The Census of Agriculture is a complete accounting of U.S. agricultural production and is the only source of uniform, comprehensive agricultural data for every county in the nation. The census is conducted every 5 years. Prior to 1997, the Bureau of the Census conducted this activity. Starting with the 1997 Census of Agriculture, the responsibility passed to USDA NASS. The census includes all farm operations from which $1,000 or more of agricultural

products are produced and sold. The most recent census occurred in late 1997 and is based on calendar year 1997 data.

The census collects information relating to land use and ownership, crops, livestock, and poultry. This database is maintained by USDA; data used for this analysis were compiled with the assistance of staff at USDA NASS. (USDA periodically publishes aggregated data from these databases and also compiles customized analyses of the data for members of the public and other government agencies. In providing such analyses, USDA maintains a sufficient level of aggregation to ensure the confidentiality of any individual operation's activities or holdings.)

Several size groups were developed to allow tabulation of farm counts by farm size using different criteria than those used in the published 1997 Census of Agriculture. EPA developed algorithms to define farm size in terms of capacity, or number of animals likely to be found on the farm at any given time. To convert sales of hogs and pigs and feeder pigs into an inventory, EPA divided total sales by the number of groups of pigs likely to be produced and sold in a given year. EPA estimates that the larger grow-finish farms produce 2.8 groups of pigs per year. Farrow-finish operations produce 2.0 groups of pigs per year. Nursery operations produce up to 10 groups per year. Data used to determine the groups of pigs produced per year were obtained from a survey performed by USDA APHIS (1999).

For beef operations, EPA estimates the larger feedlots produce up to 3.5 groups of cattle per year, while the smaller operations produce only 1 to 1.5 groups per year (ERG, 2000b). The newly aggregated data better depict the size and geographic distribution of AFOs needed for EPA's analysis, particularly smaller beef feedlots (fewer than 1,000 head capacity) and larger dairies (more than 200 mature dairy cattle). EPA used the census data to gather more details on the larger dairies, such as the number of operations and number of head for additional size classes (200 to 499, 500 to 999, and more than 1,000 head).

USDA NRCS also compiled and performed analyses on census data that EPA used for its analyses. These data identify the number of feedlots, their geographical distributions, and the amount of cropland available to land apply animal manure generated from their confined feeding operations (based on nitrogen and phosphorus availability relative to crop need). EPA used these estimates to identify feedlots that may not own sufficient land to apply all of the animal manure to the land. EPA used the results of this analysis to estimate the number of AFOs that may incur additional manure transportation costs under the various regulatory options considered under the proposed rule (see Chapter 10).

3.3.2 Animal and Plant Health Inspection Service (APHIS)/National Animal Health Monitoring System (NAHMS)

APHIS provides leadership in ensuring the health and care of animals and plants, improving agricultural productivity and competitiveness, and contributing to the national economy and public health. One of its main responsibilities is to enhance the care of animals. In 1983, APHIS initiated the National Animal Health Monitoring System (NAHMS) as an information-gathering program to collect, analyze, and disseminate data on animal health, management, and productivity across the United States. NAHMS conducts national studies to gather data and generate descriptive statistics and information from data collected by other industry sources. NAHMS has published national study reports for various food animal populations (e.g., swine, dairy cattle).

EPA gathered information from the following NAHMS reports:

- *Swine '95 Part I: Reference of 1995 Swine Management Practices*;
- *Swine '95 Part II: Reference of Grower/Finisher Health & Management Practices*;
- *Layers '99 Parts I and II: Reference of 1999 Table Egg Layer Management in the U.S.*;
- *Dairy '96 Part I: Reference of 1996 Dairy Management Practices*;
- *Dairy '96 Part III: Reference of 1996 Dairy Health and Health Management*;
- *Beef Feedlot '95 Part I: Feedlot Management Practices; and*
- *Feedlot '99 Part I: Baseline Reference of Feedlot Management Practices*.

EPA also collected information from NAHMS fact sheets, specifically the *Swine '95* fact sheets, which describe biosecurity measures, vaccination practices, environmental practices/ management, and antibiotics used in the industry.

Swine '95 Part I: Reference of 1995 Swine Management Practices

This report provides references on productivity, preventative and vaccination practices, biosecurity issues, and environmental programs (including carcass disposal). The data were obtained from a sample of 1,477 producers representing nearly 91 percent of the U.S. hog inventory from the top 16 pork-producing states. Population estimates are broken down into farrowing and weaning, nursery, grower/finisher, and sows.

Swine '95 Part II: Reference of Grower/Finisher Health & Management Practices

This report provides additional references on feed and waste management, health and productivity, marketing, and quality control. The data were collected from 418 producers with operations having 300 or more market hogs (at least one hog over 120 pounds) and represent about 90 percent of the target population. NAHMS also performed additional analyses for EPA that present manure management information for the swine industry by two size classes (fewer than 2,500 marketed head and more than 2,500 marketed head) and three regions (Midwest, North, and Southeast) (USDA APHIS, 1999).

Layers '99 Parts I and II: Reference of 1999 Table Egg Layer Management in the U.S.

The Layers '99 study is the first NAHMS national study of the layer industry. Data were obtained from 15 states, which account for over 75 percent of the table egg layers in the United States. Part I of this report provides a summary of the study results, including descriptions of farm sites and flocks, feed, and health management. Part II of this report provides a summary of biosecurity, facility management, and manure handling.

Dairy '96 Part I: Reference of 1996 Dairy Management Practices and Dairy '96 Part III: Reference of 1996 Dairy Health and Health Management

These reports present the results of a survey that was distributed to dairies in 20 major states to collect information on cattle inventories; dairy herd management practices; health management; births, illness, and deaths; housing; and biosecurity. The results represent 83 percent of U.S. milk cows, or 2,542 producers. The reports also provide national data on cattle housing, manure and runoff collection practices, and irrigation/land application practices for dairies with more than 200 or fewer than 200 mature dairy cattle. NAHMS provided the same information to EPA with the results reaggregated into three size classes (fewer than 500, 500 to 699, and more than 700 mature dairy cattle) and into three regions (East, West, and Midwest) (ERG, 2000a).

Beef Feedlot '95 Part I: Feedlot Management Practices

This report contains information on population estimates, environmental programs (e.g., ground water monitoring and methods of waste disposal), and carcass disposal at small and large beef feedlots (fewer than and more than 1,000 head capacity). The data were collected from 3,214 feedlots in 13 states, representing almost 86 percent of the U.S. cattle-on-feed inventory.

Feedlot '99 Part I: Baseline Reference of Feedlot Management Practices

This report also contains information on population estimates, environmental programs, and carcass disposal at beef feedlots. The data were collected from 1,250 feedlots in 12 states, representing 77 percent of all cattle on feed in the United States.

3.3.3 Natural Resources Conservation Services (NRCS)

NRCS provides leadership in a partnership effort to help people conserve, improve, and sustain our natural resources and the environment. NRCS relies on many partners to help set conservation goals, work with people on the land, and provide assistance. Its partners include conservation districts, state and federal agencies, NRCS Earth Team volunteers, agricultural and environmental groups, and professional societies.

NRCS publishes the *Agricultural Waste Management Field Handbook*, which is an agricultural/engineering guidance manual that explains general waste management principles, and provides detailed design information for particular waste management systems. The handbook reports specific design information on a variety of farm production and waste management practices at different types of feedlots. The handbook also reports runoff calculations under normal and peak precipitation as well as information on manure and bedding characteristics. EPA used this information to develop its cost and environmental analyses. NRCS personnel also contributed technical expertise in the development of EPA's estimates of compliance costs and environmental assessment framework by providing EPA with estimates of manure generation in excess of expected crop uptake.

3.3.4 Economic Research Service (ERS)

ERS provides economic analyses on efficiency, efficacy, and equity issues related to agriculture, food, the environment, and rural development to improve public and private decision making. ERS uses data from the Farm Costs and Returns Survey (FCRS) to examine farm financial performance (USDA ERS, 1997). This report developed 10 regions that were intended to group agricultural production into broad geographic regions of the United States: Pacific, Mountain, Northern Plains, Southern Plains, Lake States, Corn Belt, Delta, Northeast, Appalachian, and Southern. EPA further consolidated the 10 sectors into 5 regions in order to analyze aggregated Census of Agriculture data.

ERS is also responsible for the Agricultural Resource Management Study (ARMS), USDA's primary vehicle for collection of information on a broad range of issues about agricultural resource use and costs and farm sector financial conditions. The ARMS is a flexible data collection tool with several versions and uses. Information is collected via surveys, and it provides a measure of the annual changes in the financial conditions of production agriculture.

3.4 Literature Sources

EPA performed several Internet and literature searches to identify papers, presentations, and other applicable materials to use in developing the proposed rule. Literature sources were identified from library literature searches as well as through EPA contacts and industry experts. Literature collected by EPA covers such topics as housing equipment, fertilizer and manure application, general agricultural waste management, air emissions, pathogens, and construction cost data. EPA used literature sources to estimate the costs of design and expansion of waste management system components at AFOs. EPA also used publicly available information from several universities specializing in agricultural research for industry profile information, waste management and modeling information, and construction cost data, as well as existing computer models, such as the FarmWare Model that was developed by EPA's AgStar program.

3.5 References

ERG. 2000a. *Development of Frequency Factors for the Beef and Dairy Cost Model*. Memorandum from Eastern Research Group, Inc. to the Feedlots Rulemaking Record. December 11, 2000.

ERG. 2000b. *Facility Counts for Beef, Dairy, Veal, and Heifer Operations*. Memorandum from Eastern Research Group, Inc. to the Feedlots Rulemaking Record. December 15, 2000.

USDA ERS. 1997. *Financial Performance of U.S. Commercial Farms*, 1991-94. U.S. Department of Agriculture Economic Research Service. AER-751. June 1997.

USDA APHIS. 1999. *Re-aggregated Data from the National Animal Health Monitoring System's (NAHMS) Swine '95 Study*. Aggregated by Eric Bush of the U.S. Department of

Agriculture, Animal and Plant Health Inspection System, Centers for Epidemiology and Animal Health.

CHAPTER 4

INDUSTRY PROFILES

4.0 INTRODUCTION

This chapter describes the current organization, production processes, and facility and waste management practices of the Animal Feeding Operations (AFO) and Concentrated Animal Feeding Operations (CAFO) industries. Farm production methods, operation sizes, geographical distributions, pollution reduction activities, and waste treatment practices in use are described separately for the swine, poultry, beef, and dairy subcategories. Discussions of changes and trends over the past several decades are also provided.

Information on animal production was generally obtained from USDA's 1997 Census of Agriculture, USDA's National Agricultural Statistics Service (NASS), and information gathered from site visits and trade associations. For information obtained from the 1997 Census of Agriculture, EPA divided the U.S. into five production regions and designated them the South, Mid-Atlantic, Midwest, West, and Central regions. Originally, the USDA Economic Research Service (ERS) established ten regions so that it could group economic information. EPA condensed these regions into the five AFO regions because of similarities in animal production and manure handling techniques, and to allow for the aggregation of critical data on the number of facilities, production quantities, and financial conditions, which may otherwise not be possible due to concerns about disclosure.[1] The production regions are defined in Table 4-1.

[1] For example, USDA Census of Agriculture data are typically not released unless there is a sufficient number of observations to ensure confidentially. Consequently, if data were aggregated on a state basis (instead of a regional basis), many key data points needed to describe the industry segments would be unavailable.

Table 4-1. Animal Feeding Operation (AFO) Production Regions

Region	States Included
Central	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oklahoma, Texas, Utah, Wyoming
Midwest	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
Mid-Atlantic	Connecticut, Delaware, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, Tennessee, Vermont, Virginia, West Virginia
Pacific	Alaska, California, Hawaii, Oregon, Washington
South	Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, South Carolina

4.1 Swine Industry Description

Swine feeding operations include facilities that confine swine for feeding or maintenance for at least 45 days in any 12-month period. These facilities do not have significant vegetation in the confinement area during the normal growing season, thus swine pasture operations are generally not included. Facilities that have swine feeding operations may also include other animal and agricultural operations such as crop farming.

This section discusses the following aspects of the swine industry:

- 4.1.1: Distribution of the swine industry by size and region
- 4.1.2: Production cycles of swine
- 4.1.3: Swine facility types and management
- 4.1.4: Swine waste management practices
- 4.1.5: Pollution reduction
- 4.1.6: Waste disposal

The swine industry is a significant component of the domestic agricultural sector, generating farm receipts ranging from $9.2 billion to more than $11.5 billion annually during the past decade (USDA NASS, 1998a). Total annual receipts from the sale of hogs average approximately 12 percent of all livestock sales and 5 percent of all farm commodity sales. Annual swine output ranks fourth in livestock production value, after cattle, dairy products, and broilers. During 1997, more than 17 billion pounds of pork were processed from 93 million hogs. The retail value of pork sold to consumers exceeded $30 billion. The National Pork Producers Council estimates that the pork industry supports more than 600,000 jobs nationally (NPPC, 1999).

As described in the following sections, the swine industry has undergone a major transformation during the past several decades. Swine production has shifted from small, geographically dispersed family operations to large "factory farms" concentrated primarily in 10 states in the Midwest and the South. The number of hog operations, which approached 3 million in the 1950s, had declined to about 110,000 by 1997. The rate of consolidation has increased dramatically in the last decade, which has seen more than a 50 percent decline in the number of swine operations (USDA NASS, 1999a). All indications are that this trend toward consolidation is continuing.

Swine production has also changed dramatically in terms of the production process and the type of animal produced. The hog raised for today's consumer is markedly different from the one produced in the 1950s: Today hogs contain approximately 50 percent less fat and are the result of superior genetics and more efficient diets. The average whole-herd feed conversion ratio (pounds of feed per pound of live weight produced) used to be between 4 and 5 and has steadily decreased with current averages between 3.6 and 3.8. The most efficient herds have whole-herd feed conversion ratios under 3.0 (NPPC, 1999). Hence, a well-run swine operation can currently produce a 250-pound hog using only 750 pounds of animal feed during its lifetime.

The domestic hog industry is increasingly dominated by large, indoor, totally confined operations capable of handling 5,000 hogs or more at a time (USDA NASS, 1999b, and USDA NASS, 1999c). These operations typically produce no other livestock or crop commodities. In addition, there has been greater specialization as more swine operations serve only as nursery or finishing operations.

Another growing trend in the industry is that more hogs are being produced under contract arrangement whereby large hog producers, typically referred to as integrators or contractors, establish production contracts with smaller growers to feed hogs to market weight. The producer-integrator provides management services, feeder pigs, food, medicine, and other inputs, while the grower operations provide the labor and facilities. In return, each grower receives a fixed payment, adjusted for production efficiency. These arrangements allow integrators to grow rapidly by leveraging their capital. For example, instead of investing in all the buildings and equipment required for a farrow-to-finish operation, the integrator can invest in specialized facilities, such as farrowing units, while the growers pay for the remaining facilities, such as the nurseries and finishing facilities (Martinez, 1999). Occasionally other forms of contracts may be used.

According to a survey conducted for the USDA, 11 percent of the nation's hog inventory at the end of 1993 was produced under long-term contracts. This percentage was expected to increase to 29 percent by 1998 (Martinez, 1997). Regionally, the Mid-Atlantic region has the greatest proportion of contracted hogs, with more than 65 percent of the hogs grown at facilities where the grower does not own the hogs (USDA NASS 1999c).

These changes at both the industry and farm levels represent a significant departure from earlier eras, when hogs were produced primarily on relatively small but integrated farms where crop production and other livestock production activities occurred and where animals spent their complete life cycle. The following sections describe the current production and management practices of domestic swine producers.

4.1.1 Distribution of Swine Operations by Size and Region

EPA's 1974 CAFO Effluent Limitations Guidelines and Standards generally apply to swine feeding operations with more than 2,500 head, but counts only those swine weighing more than 55 pounds. (See Chapter 2 for the definition of a CAFO, and Chapter 5 for a discussion of the basis for revisions to the swine subcategory.) Most data sources cited in this section do not distinguish swine by weight, but may provide other information that distinguishes sows and other breeding pigs, feeder pigs, litters, and market pigs. Where numbers of head are presented in the following sections, feeder pigs were not included in the counts unless specified in the text.

4.1.1.1 *National Overview*

The estimated number of domestic swine operations has continuously declined since the 1950s. As recently as 1970, there were more than 870,000 producers of swine. By 1997, this number had decreased to about 110,000 (USDA NASS, 1999b).[2] The decline has been especially dramatic over the past decade. As shown in Table 4-2, the number of operations has steadily decreased over the years.

Table 4-2. Changes in the Number of U.S. Swine Operations and Inventory 1982-1997

Year	Operations	Inventory
1982	329,833	55,366,205
1987	243,398	52,271,120
1992	191,347	57,563,118
1997	109,754	61,206,236

Source: USDA NASS, 1999b

As the number of operations has decreased, however, hog inventories have actually risen due to the emerging market dominance by larger operations. Inventories increased from 55.4 million head in 1982 to 61.2 million head in 1997 (USDA NASS, 1999b).

4.1.1.2 *Operations by Size Class*

The general trend in the U.S. swine industry is toward a smaller number of large operations (Table 4-3). As the percentage of smaller producers decreases, there is a consistent increase in the percentage of herds with a total inventory of 2,000 or more head. The increase in the number

[2] USDA defines an operation as any place having one or more hogs or pigs on hand at any time during the year.

of large operations has predominantly occurred in conjunction with extended use of total confinement operations, which separate the three production phases described in 4.1.2.

Table 4-3. Percentage of U.S. Hog Operations and Inventory by Herd Size

Year	0-1,999 Head		2,000-4,999 Head		More Than 5,000 Head	
	Operations	Inventory	Operations	Inventory	Operations	Inventory
1982	99.3	85.7	0.6	9.5	0.1	4.8
1987	98.9	79.0	1.0	12.9	0.2	8.1
1992	97.9	68.7	1.6	15.2	0.4	17.0
1997	94.4	39.3	3.9	20.8	1.7	40.2

Source: USDA NASS, 1999b

In terms of farm numbers, small operations still dominate the industry; however, their contribution to total annual hog production has decreased dramatically in the past decade. For example, operations with up to 1,999 head, which produced 85.7 percent of the nation's hogs in 1982, raised only 39.3 percent of the total in 1997. In contrast, in 1982, the 0.1 percent of operations that reported more than 5,000 head produced approximately 5 percent of the swine; in 1997 these large operations (1.7 percent of all operations) produced over 40 percent of the nation's hogs.

4.1.1.3 *Regional Variation in Hog Operations*

Swine farming historically has been centered in the Midwest region of the U.S., with Iowa being the largest hog producer in the country. Although the Midwest continues to be the nation's leading hog producer (five of the top seven producers are still in the Midwest), significant growth has taken place in other areas. (See Table 4-4.) Perhaps the most dramatic growth has occurred in the Mid-Atlantic Region, in North Carolina. From 1987 to 1997, North Carolina advanced from being the 12th largest pork producer in the nation to second behind only Iowa. Climate and favorable regulatory policies played a major role in the growth of North Carolina's swine industry.

North Carolina's winters are mild and summers are tolerable, and this has allowed growers to use open-sided buildings. Such buildings are less expensive than the solid-sided buildings made necessary by the Midwest's cold winters. Midwestern growers must also insulate or heat their buildings in the winter. Tobacco farmers, who found hogs a means of diversifying their operations, also fueled North Carolina's pork boom. The idea of locating production phases at different sites was developed in North Carolina. The state also has a much higher average inventory per farm than any of the states in the Corn Belt. Whereas Iowa had an average of fewer than 850 head per farm, North Carolina had an average of more than 3,200 head per farm in 1997. In recent years, significant growth has occurred elsewhere as well: in the Central Region in the panhandle area of Texas and Oklahoma, Colorado, Utah, and Wyoming as well as in the Midwest Region in northern Iowa and southern Minnesota.

Tables 4-4 through 4-7 present the distribution of different types of swine operations for the key producing regions. For the purposes of these tables, breeder operations, also known as farrowing operations, have large numbers of sows and sell or transfer the pigs when they have been weaned or grown to approximately 55 pounds (feeder pigs); some farrowing operations may also keep boars. Nursery operations receive weaned pigs and grow them to approximately 55 pounds. Grow-finish operations are operations that receive feeder pigs and grow them out to marketable weight; these pigs are often labeled "swine for slaughter." Combined operations perform all phases of production, known in the industry as "farrow-to finish," or just the final two phases such as "wean-finish." Note that no large independent nurseries are depicted by the 1997 census data. EPA is aware that several large nurseries have recently begun operation or are under construction. The considerable amount of growth in the Central (Southwest) Region that has occurred in the past 3 years is not reflected in the 1997 statistics presented in this section.

Table 4-4 shows the number of operations for six different size classes of facilities. Table 4-5 presents the average herd size by operation type, region, and operation size. Table 4-6 presents the percentage of total swine animal counts at combined and slaughter operations by region and operation size. Table 4-7 presents the distribution of different animal types in combined swine operations by region and operation size.

Table 4-4. Total Number of Swine Operations by Region, Operation Type, and Size in 1997

<table>
<tr><th rowspan="2">Region [a]</th><th rowspan="2">Operation Type [b]</th><th colspan="7">Number of Swine Operations (Operation Size Presented by Number of Head)</th></tr>
<tr><th>>0-750</th><th>>750-1,875</th><th>>1,875-2,500</th><th>>2,500-5,000</th><th>>5,000-10,000</th><th>>10,000</th><th>Total</th></tr>
<tr><td rowspan="2">Mid Atlantic</td><td>combined</td><td>6,498</td><td>421</td><td>82</td><td>185</td><td>130</td><td>135</td><td>7,451</td></tr>
<tr><td>slaughter</td><td>8,120</td><td>344</td><td>150</td><td>413</td><td>281</td><td>119</td><td>9,427</td></tr>
<tr><td rowspan="2">Midwest</td><td>combined</td><td>35,263</td><td>5,212</td><td>782</td><td>1,106</td><td>410</td><td>213</td><td>42,986</td></tr>
<tr><td>slaughter</td><td>27,081</td><td>2,194</td><td>425</td><td>521</td><td>142</td><td>48</td><td>30,411</td></tr>
<tr><td rowspan="2">Other</td><td>combined</td><td>10,821</td><td>359</td><td>74</td><td>135</td><td>60</td><td>45</td><td>11,494</td></tr>
<tr><td>slaughter</td><td>13,502</td><td>83</td><td>50</td><td>91</td><td>45</td><td>10</td><td>13,781</td></tr>
<tr><td rowspan="4">National</td><td>combined</td><td>52,582</td><td>5,992</td><td>938</td><td>1,426</td><td>600</td><td>393</td><td>61,931</td></tr>
<tr><td>slaughter</td><td>48,703</td><td>2,621</td><td>625</td><td>1,025</td><td>468</td><td>177</td><td>53,619</td></tr>
<tr><td>breeder</td><td>2,227</td><td colspan="2">15</td><td colspan="3">3</td><td>2,245</td></tr>
<tr><td>nursery</td><td colspan="4">83</td><td colspan="2">0</td><td>83</td></tr>
</table>

[a] Mid Atlantic= ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest= ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other= ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK, WA, OR, WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL

[b] Operation type: combined=breeding inventory, finishing (average of inventory and sold/2.8), and feeders (sold/10); slaughter=finishing (average of inventory and sold/2.8); breeding (inventory); and nursery (feeders sold/10).

Table 4-5. Average Number of Swine at Various Operations by Region Operation Type, and Size in 1997

Region [a]	Operation Type [b]	Average Swine Animal Counts (Operation Size Presented by Number of Head)						
		>0-750	>750-1,875	>1,875-2,500	>2,500-5,000	>5,000-10,000	>10,000	All Operations
Mid-Atlantic	combined	74	1,182	2,165	3,509	5,021	28,766	851
	slaughter	32	1,242	2,184	3,554	6,877	13,653	641
Midwest	combined	209	1,137	2,152	3,444	6,761	27,403	637
	slaughter	135	1,161	2,124	3,417	6,791	19,607	355
Other	combined	51	1,255	2,150	3,455	7,052	59,172	410
	slaughter	13	1,291	2,215	3,626	6,830	14,901	85
National	combined	160	1,147	2,153	3,453	6,413	31,509	621
	slaughter	84	1,176	2,146	3,491	6,846	15,338	336

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC, WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL

[b] Operation type: combined=breeding inventory, finishing (average of inventory and sold/2.8), and feeders (sold/10); slaughter=finishing (average of inventory and sold/2.8).

Source: USDA NASS, 1999c

Table 4-6. Distribution of Swine Herd by Region, Operation Type, and Size in 1997

Region [a]	Operation Type [b]	Percentage of Total Swine Animal Counts by Size Group (Operation Size Presented by Number of Head)						
		>0-750	>750-1,875	>1,875-2,500	>2,500-5,000	>5,000-10,000	>10,000	Total
Mid Atlantic	combined	1.25	1.30	0.46	1.69	1.70	10.10	16.50
	slaughter	1.45	2.37	1.82	8.16	10.74	9.03	33.56
Midwest	combined	19.14	15.42	4.38	9.91	7.21	15.18	71.24
	slaughter	20.26	14.16	5.02	9.89	5.36	5.23	59.92
Other	combined	1.44	1.17	0.41	1.21	1.10	6.93	12.26
	slaughter	0.94	0.60	0.62	1.83	1.71	0.83	6.52
National	combined	21.83	17.88	5.25	12.81	10.01	32.21	100.00
	slaughter	22.65	17.13	7.45	19.88	17.80	15.09	100.00

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC, WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL

[b] Operation type: combined=breeding inventory, finishing (average of inventory and sold/2.8), and feeders (sold/10); slaughter=finishing (average of inventory and sold/2.8).

Source: USDA NASS, 1999c

Table 4-7. Distribution of Animal Type in Swine Herds at Combined Facilities by Region, Operation Type, and Size in 1997

Region [a]	Swine Type [b]	Percentage of Breeding, Finishing, and Feeder Hogs at Combined Facilities (Operation Size Presented by Number of Head)						
		>0-750	>750-1,875	>1,875-2,500	>2,500-5,000	>5,000-10,000	>10,000	All Operations
Mid Atlantic	Breeding	19.84	17.38	15.59	17.68	16.66	17.19	17.31
	Finishing	73.96	71.74	72.46	65.56	59.02	58.55	61.61
	Feeder	6.20	10.88	11.95	16.75	24.32	24.25	21.08
Midwest	Breeding	17.85	16.14	16.55	15.88	15.23	14.65	16.18
	Finishing	78.33	79.59	76.66	76.38	77.77	80.32	78.59
	Feeder	3.82	4.26	6.80	7.73	7.00	5.03	5.23
Other	Breeding	22.47	19.95	19.54	18.38	20.84	17.54	18.74
	Finishing	73.03	61.02	69.00	71.39	64.45	78.57	73.89
	Feeder	4.48	19.04	11.46	10.23	14.71	3.90	7.37
National	Breeding	18.27	16.50	16.70	16.36	16.16	16.10	16.66
	Finishing	77.73	77.70	75.66	74.44	71.78	72.63	74.91
	Feeder	4.00	5.79	7.63	9.21	12.05	11.27	8.40

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC, WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL
[b] Swine type: Breeding = inventory; finishing = average of inventory and sold/2.8; and feeder = sold/10.
Source: USDA NASS, 1999c

4.1.2 Production Cycles of Swine

Swine production falls into three phases. Pigs are farrowed, or born, in farrowing operations. Sows are usually bred for the first time when they are 180 to 200 days old. Farrowing facilities range from pasture systems to completely confined housing systems. A sow's gestation period is about 114 days. Farrowings are typically 9 to 11 pigs per litter, with a practical range of 6 to 13. The highest death losses in the pig-raising cycle occur within 3 to 4 days of birth. The average number of pigs weaned per litter in 1997 was 8.67. See Table 4-8. Producers incur significant expenses in keeping a sow, so the survival of each pig is critical to overall profitability. Sows usually resume sexual activity within a week after a litter is weaned. Growers are able to roughly synchronize production by weaning all their baby pigs on the same day. When they do this, all the sows in a farrowing group become sexually active again at roughly the same time and may be bred again at the same time. The sows will then farrow at about the same time, over a period of about a week. In this way, growers are able to keep groups of pigs together as they move from one phase of production to another. Sows normally produce five to six litters before they are culled and sold for slaughter at a weight of 400 to 460 pounds.

Table 4-8. Productivity Measures of Pigs

Year	Number of Pigs Weaned per Litter	Per Breeding Animal per Year		Average Live Weight per Pig (pounds)
		Litters	Head to Slaughter	
1992	8.08	1.69	13.08	252
1993	8.13	1.68	13.06	254
1994	8.19	1.73	13.36	255
1995	8.32	1.68	13.64	256
1996	8.50	1.64	13.51	257
1997	8.67	1.72	13.79	260
Average	8.32	1.69	13.41	256

Source: NPPC, 1999

Baby pigs are typically allowed to nurse from the sow, and then are relocated to a nursery, the second phase of swine production. In the nursery phase, pigs are weaned at 3-4 weeks of age and weigh 10 to 15 pounds. In the nursery, the pigs are raised to 8 to 10 weeks of age and 40 to 60 pounds. In practice, the weaning phase may take as few as 10 days, and may exceed 35 days.

During the third phase of production, growing pigs are raised to a market weight of 240 to 280 pounds. Finishing takes another 15 to 18 weeks, thus hogs are typically sent to market when they are about 26 weeks old (see Table 4-9). The growing and finishing phases were once separate production units, but are now combined in a single unit called grow-finish. In the growing–finishing unit, pigs are raised from 50 or 60 pounds to final market weight. The average grow-finish facility will produce approximately 2.8 turns (also called life cycles, herds, or groups) annually. Typically, finished pigs are from 166 to 212 days old, resulting in a range of 2.4 to 3.4 turns (or groups) of pigs produced from the grow-finish unit per year. Average farrow-to-finish operations will produce 2.1 groups per sow per year. The range of annual turnover frequency at farrow-to-finish farms is from 1.8 to 2.5.

Table 4-9. Age of Pigs Leaving Grow-Finish Unit in 1995

Age of Pig on Leaving Grow-Finish Unit (days)	Percentage of Operations and Pigs	
	Percentage of Operations	Percentage of Pigs
120 - 159	12.5	12.2
160 - 165	16.7	12.6
166 - 180	49.6	45.8
181 - 209	16.3	24.9
210 or more	4.9	4.5
Weighted Average	173 days	175 days

Source: USDA APHIS, 1995

In 1995, most operations had a farrowing facility, whereas slightly less than half of the facilities nationwide had a separate nursery facility. Most operations (85.6 percent) did have a finishing facility. Finishing operations get their pigs from on-site farrowing and nursery units (76.7 percent), off-site farrowing operations (10.2 percent), feeder pig producers under both contract and noncontract arrangements (13.8 percent), or livestock auctions or sales (5.9 percent). Large finishing operations (>10,000 head marketed) were more likely (56.3 percent) to get their pigs from off-site sources (USDA APHIS, 1995). Tables 4-10 and 4-11 present the frequency of the three major production phases by region and size. The sample profile of the Swine '95 survey indicates that 61.9 percent of respondents were farrow-to-finish operations and that 24.3 percent were grow-finish operations.

Table 4-10. Frequency of Production Phases in 1995 on Operations That Marketed Less Than 5,000 Hogs in a 6–Month Period

Production Phase	USDA APHIS Region[a]		
	Midwest	North	Southeast
Farrowing	76.6	68.6	69.3
Nursery	20.1	51	57.8
Finishing	78.8	79.7	93.4

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

Table 4-11. Frequency of Production Phases in 1995 on Operations That Marketed 5,000 or More Hogs in a 6–Month Period

Production Phase	USDA APHIS Region[a]		
	Midwest	North	Southeast
Farrowing	44.8	80.4	89
Nursery	75	67.1	97.4
Finishing	45.8	69.7	62.8

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

Although many large operations continue to have the full range of production phases at one facility, these operations are no longer the norm. More frequently, in new operations, several specialized farms are linked, or horizontally integrated, into a chain of production and marketing. Pigs begin in sowherds on one site, move to a nursery on another, and then move again to a finishing facility. Specialized operations can take advantage of skilled labor, expertise, advanced technology, streamlined management, and modern housing. However, the primary advantage of specialization is disease control. In a farrow-to-finish operation, a disease outbreak that begins in one phase of the operation can spread to the other phases. Physically separating the phases makes it easier to break this disease cycle. At the same time, separating phases spreads the cost of establishing swine operations, particularly if the different operations are owned by different persons.

Thus other categories of swine operations may comprise two or three of the three phrases described: combined farrow-nursery operations, which breed pigs and sell them at 40 to 60 pounds to finishing operations; wean-to-finish operations, which finish weaned pigs; and farrow-to-finish operations, which handle all phases of production from breeding through finishing. The emerging trend in the mid to late ‘90s was to produce pigs in two production phases rather than in three. In two-phase production, the weaned pigs may go straight into the grower building or finishing building, bypassing the nursery. The advantages of such practices are reduced transportation costs, lessened animal stress, and reduced animal mortality.

4.1.3 Swine Facility Types and Management

Table 4-12 summarizes the five major housing configurations used by domestic swine producers.

Although there are still many operations at which pigs are raised outdoors, the trend in the swine industry is toward larger confinement facilities where pigs are raised indoors. A typical confinement farrowing operation houses 3,000 sows, although some farrowing operations house as many as 10,000 sows at one location, and farms are being planned that will house as many as

15,000 sows at one location. Typical nursery operations are much smaller with a capacity of only about 1,500 head, but as stated earlier, separate nursery facilities are relatively uncommon.

Table 4-12. Summary of Major Swine Housing Facilities

Facility Type[a]	Description	Applicability
Total confinement	Pigs are raised in pens or stalls in an environmentally controlled building.	Most commonly used in nursery and farrowing operations and all phases of very large operations. Particularly common in the Southeast.
Open building with no outside access	Pigs are raised in pens or stalls but are exposed to natural climate conditions.	Relatively uncommon but used by operations of all sizes.
Open building with outside access	Pigs are raised in pens or stalls but may be moved to outdoors.	Relatively uncommon, but used by some small to mid-sized operations.
Lot with hut or no building	Pigs are raised on cement or soil lot and are not confined to pens or stalls.	Used by small to mid-sized operations.
Pasture with hut or no building	Pigs are raised on natural pasture land and are not confined to pens or stalls.	Traditional method of raising hogs currently used only at small operations.

[a] These are the main facility configurations contained in the *Swine '95* Survey conducted by USDA APHIS, 1995.

The economic advantages of confined facilities have been the primary driving factor (especially at large operations) for farmers to abandon dry lot or pasture raising of hogs. Although controlled-environment buildings require a greater initial capital investment than traditional farm operations, labor costs per unit output are significantly reduced. Furthermore, these facilities allow for far greater control of the production process, protect both animals and workers from weather, and usually result in faster growth-to-market weight and better feed efficiency. Most controlled-environment facilities employ "all in, all out" production, in which pigs are moved in groups and buildings are cleaned and disinfected between groups. It should be noted that the success of a controlled-environment operation is highly dependent on properly functioning ventilation, heating and cooling, and waste removal systems. A prolonged breakdown of any of these systems during extreme weather conditions can be catastrophic to the pig herd and economically devastating to the operator.

Facility requirements differ somewhat for each phase in a hog's life cycle, and hence farrowing, nursery, and growing/finishing facilities are configured differently. For example, farrowing operations require more intense management to ensure optimal production and reduce piglet mortality. A typical farrowing pen measures 5 by 7 feet, and the litter is provided with a protected area of approximately 8 square feet. The sow is relegated to a section of the pen and is separated from the piglets by low guard rails that reduce crushing but do not interfere with suckling. Floors are usually slatted under or to the rear of the sow area to facilitate waste removal (NPPC, 1996).

Newly born piglets require special care because of their vulnerability to injury and disease. Nursery systems are typically designed to provide a warm, dry, and draft-free environment in which animal stress is minimized to promote rapid growth and reduce injury and mortality. Nursery rooms are regularly cleaned and sanitized to reduce the piglets' exposure to pathogens. Nursery buildings are cleaned and disinfected thoroughly between groups of pigs to prevent the transmission of disease from one herd to another. Nursery pens usually hold 10 to 20 pigs. Pigs are held in the nursery from weaning until they are 8 to 12 weeks old (NPPC, 1996).

Finishing pigs at finishing facilities tend to require less intensive management than piglets and can tolerate greater variations in environmental conditions without incurring health problems. In an environmentally controlled building, growing and finishing pens hold 15 to 40 pigs and allow about 6 square feet per pig. Overcrowding leads to stress and aggressive behavior and can result in reduced growth rates and injury. Slatted concrete floors are the most common (NPPC, 1996).

As shown in Tables 4-13 through 4-18, smaller facilities tend to use open buildings, with or without access to the outside. Usually, hogs raised in these building are also confined to pens or stalls. Depending on the climate, the building might require ventilation and mist sprayer systems to prevent heat stress in the summer. Bedding might be needed during the winter months to protect the animals from the cold.

Hogs raised on dry lots or pasture require care and management similar to that for animals raised indoors, plus additional measures to protect the herds from extreme weather conditions. They must be provided with sufficient shade to reduce heat stress in the summer. Where natural shade is not available, facilities can be constructed to protect the herd from the sun in the summer and from wind and cold during the winter. Windbreaks are used under certain environmental conditions.

The most comprehensive information on swine facility and waste management systems currently in use by farm type, size, and state location was collected in conjunction with USDA's *Swine '95* study (USDA APHIS, 1995).   Included in the study were 16 major pork-producing states that accounted for almost 91 percent of the U.S. hog inventory and more than 70 percent of the pork producers. The samples for the major swine-raising operations were statistically designed to provide inferences to the nation's swine population. Although the survey was conducted by the Animal and Plant Health Inspection Service (APHIS) and focused on swine health issues, it contains much information on swine production and on facility and waste management. Tables 4-13 and 4-14 present information on the housing types used in the farrowing phase. Tables 4-15 and 4-16 present information on the housing types used in the nursery phase. Tables 4-17 and 4-18 present information on the housing types used in the finisher phase. These tables clearly demonstrate that the larger facilities tend to use total confinement in all regions.

Table 4-13. Housing Frequency (in percent) in 1995 of Farrowing Facilities at Operations That Marketed Fewer Than 5,000 Hogs in a 6–Month Period

Variable	USDA APHIS Region[a]		
	Midwest	North	Southeast
Total Confinement	22.6	53.1	56
Open Building; no outside access	13.1	8.0	8.8
Open Building; outside access	25.7	33.8	31.2
Lot	16.2	3.2	1.1
Pasture	22.4	1.9	2.8

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

Table 4-14. Housing Frequency (in percent) in 1995 of Farrowing Facilities at Operations That Marketed 5,000 or More Hogs in a 6–Month Period

Variable	USDA APHIS Region[a]		
	Midwest	North	Southeast
Total Confinement	98.3	100	100

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

Table 4-15. Housing Frequency (in percent) in 1995 of Nursery Facilities at Operations That Marketed Fewer Than 5,000 Hogs in a 6–Month Period

Variable	USDA APHIS Region[a]		
	Midwest	North	Southeast
Total Confinement	52.3	55.4	62
Open Building; no outside access	9.1	11.5	8.8
Open Building; outside access	27.7	33.8	31.2
Lot	7.0	not available	3.7

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

Table 4-16. Housing Frequency (in percent) in 1995 of Nursery Facilities at Operations That Marketed 5,000 or More Hogs in a 6–Month Period

Variable	USDA APHIS Region[a]		
	Midwest	North	Southeast
Total Confinement	99	100	96.4

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

Table 4-17. Housing Frequency (in percent) in 1995 of Finishing Facilities at Operations That Marketed Fewer Than 5,000 Hogs in a 6–Month Period

Variable	USDA APHIS Region[a]		
	Midwest	North	Southeast
Total Confinement	19.9	36.5	23.4
Open Building; no outside access	15.4	14.1	9.5
Open Building; outside access	24.5	42.1	55.9
Lot	17.1	4.6	9.3
Pasture	23.0	2.5	1.9

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

Table 4-18. Housing Frequency (in percent) in 1995 of Finishing Facilities at Operations That Marketed 5,000 or More Hogs in a 6–Month Period

Variable	Region[a]		
	Midwest	North	Southeast
Total Confinement	96.8	95.5	83.9

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA APHIS, 1995

4.1.4 Swine Waste Management Practices

Removal of manure from the animals' living space is critical for animal and farm worker well-being. Odor, gases, and dust carried by ventilation exhaust air are also affected by the waste management system used. Swine waste management systems can be separated into collection, storage, and treatment practices. An overview of the major practices in each of these areas is presented below; more detailed information on waste collection, storage, and treatment practices is provided in Section 8 of this document. Although the practices described below do not represent all of the waste management practices in use today, they are the predominant practices currently used at swine operations.

Swine Waste Collection Practices

Indoor raising of hogs requires that animals be physically separated from their waste products. Separation in larger facilities is usually accomplished through the use of concrete flooring with slots that allow the waste to drop below the living area and be transferred to a pit or trough beneath the pen. Smaller facilities hand clean pens to collect wastes.

The most frequently reported waste management system used in 1990 was hand cleaning (41.6 percent), which declined in use to 28.3 percent of operations in 1995 (USDA APHIS, 1995). This decrease in hand cleaning is highly correlated to the decrease in smaller facilities. Some facilities separate solid material from liquids before moving the material to storage. (A discussion of solid-liquid separation is presented in Section 8.) Slatted floors are now more commonly used to separate the manure from the animals at larger facilities. The waste is then deposited in an under floor pit or gutter where it is stored or moved to another type of storage. There are two main types of under-floor collection practices in which the waste is moved for storage elsewhere.

- *Pit recharge*. Pit recharge is the periodic draining of the pit contents by gravity to storage, followed by recharging the pit with new or recycled water. Regular pit draining removes much of the manure solids that would otherwise settle and remain in the bottom of the pit. The regular dissolution of settled solids increases the likelihood the solids will be removed at the next pit draining. Recharge systems use a 16- to 18-inch-deep in-house pit with 6 to 8 inches of water, which is emptied every 7 days to an anaerobic lagoon. Previously, 24-inch-deep pits were preferred, but now shallower pits are used with the hog slat system.

- *Flush*. Flush systems may use fresh water or recycled lagoon water for frequent removal of feces and urine from under-floor collection gutters or shallow pits. Like pit recharge systems, flush systems also improve animal health and performance as well as human working conditions in the swine houses by avoiding prolonged storage. Flush tanks with the capacity to release at least 1.5 gallons per 100 pounds of live animal weight per flush are placed at the end of the swine houses. Pit floors should be level from side to side, and wide pits should be divided into individual channels no wider than 4 to 5 feet. The floor slope for most flush systems is between 1 and 2 percent. Floors are flushed at least 1 to 12 times per day; the flush tanks are filled with new or recycled lagoon water before every flush. The flushed waste is collected and removed from the houses into storage through a system similar to that used in pit recharge systems.

Swine Waste Storage Practices

Waste storage is critical to the proper management of wastes from animal feeding operations because manure nutrients are best applied to farmland only at certain times of the year, as determined by crops, climate, and weather. Storage practices include deep pits, anaerobic and aerobic lagoons, aboveground and belowground slurry storage (tanks or pits), and dry storage. Most large hog farms (more than 80 percent) have from 90 to 365 days of waste storage capacity. (See Table 4-19.)

Table 4-19. Percentage of Swine Facilities With Manure Storage in 1998

Annual Marketed Head	0-3 months	3-6 months	6-9 months	9-12 months	None or NA
NA	3.2	3.7	3.2	7.4	82.5
0-1,000	31.9	27.2	12.3	17.4	11.3
1,000-2,000	14.9	38.0	20.7	19.4	7.1
2,000-3,000	10.1	35.4	21.9	28.1	4.4
3,000-5,000	5.8	33.5	22.8	32.6	5.3
5,000-10,000	6.1	29.2	22.1	35.6	7.0
10,000-20,000	4.7	26.4	21.1	40.9	6.8
20,000-50,000	6.0	23.5	22.8	39.2	8.6
50,000 +	4.0	19.5	28.7	28.0	19.8

Source: NPPC, 1998

An overview of common waste storage practices is provided below; More detailed information can be found in Section 8 of this document.

- *Deep pit manure storage.* Many operations use pits that are 6– to 8– feet deep and provide for up to 6 months' storage under the house. Commonly, slurry is removed from the pit twice a year. The slurry is disposed of through direct surface application or subsurface injection, transferred to an earthen storage facility, or pumped to an aboveground or belowground storage tank. This slurry system produces a waste stream with higher dry matter content (4 to 5 percent) and higher nutrient content than other liquid manure systems. The aboveground and belowground storage systems conserve more nitrogen than other systems (nitrogen loss of only 10 to 30 percent). Operations use this system to avoid problems associated with lagoons, such as odor, ammonia volatilization, and ground water impact resulting from leaking lagoons.

- *Lagoon Systems.* Lagoon systems can serve as both storage and treatment units. Anaerobic lagoons are the most common type of lagoon and are characterized by anaerobic decomposition of organic wastes. When properly designed an anaerobic lagoon will have a minimum total capacity that includes appropriate design treatment capacity, additional storage for sludge accumulation, and temporary storage for rainfall and wastewater inputs. A lagoon should also have sufficient freeboard and an indicator of the highest safe water level, to prevent the wastewater from overflowing the embankment.

  Lagoons usually fill to capacity within 2 to 3 years of startup due to the accumulated waste volume and, depending on the region, rainfall in excess of evaporation. When the lagoon is full, water overflow will occur unless the operator is in a position to apply the excess water to the land. Lagoon water drawdown by irrigation or other methods is usually begun before the water reaches the maximum wastewater storage level. Several states require that liquid level indicators be placed in the lagoon to be sure that the liquid stays below the level required to contain the 24-hour, 25-year storm.

  In addition to anaerobic lagoons, there are aerobic lagoons (which mix and aerate waste via mechanical aerators or ozone generators), two-stage lagoons (typically a constant volume covered treatment cell followed by a storage cell), and multi-stage cell lagoons. Technical information and a discussion of the advantages and disadvantages of these types of lagoons is presented in Section 8 of this document.

- *Settling and evaporation ponds.* Earthen ponds are used by some swine operations for solids separation. These ponds are designed to remove 40 percent of the total solids (in a 6 percent solids form) based on 3 months' storage. The material is then moved to another earthen pit, which serves as a drying bed, or flow is diverted to a parallel solids removal pond. The slurry dries to about 38 percent solids and 3-inch thickness within 6 months. The material is then moved with a front-end loader into a box-type spreader and applied to the land. Solids drying ponds and beds are not covered and therefore exposed to rainfall. A floating pump is located half the lagoon distance from the inlet, with a screen over the intake to protect sprinkler nozzles. The supernatant is pumped and used to irrigate fields. Another variation is to use a single lagoon followed by an evaporation pond that is 6 feet deep and as big as possible. Some evaporation ponds dry up during the summer. Because of odor problems, there is a trend away from the earthen pond for solids separation to either a single anaerobic lagoon or an anaerobic lagoon and an evaporation pond.

- *Waste runoff storage.* These systems described above can also be associated with operations that maintain hogs on an outside lot for at least part of the time. Such operations might also use housing similar to the systems described above, but allow outside access for the animals. Dry lot areas may be paved or dirt, and manure is stored in piles that are created by tractor or scraping system. Although controls might be in place to contain manure from enclosed areas through use of a deep pit or lagoon, they are not generally protective of the outside environment. Other typical runoff controls include surface diversions to prevent rainwater from running onto the lot and/or a crude settling basin with a slotted overflow.

- *Other*. Other types of waste management practices currently used include above-and belowground tanks (possibly covered and/or aerated), and hoop housing/deep bedding systems.

Swine Waste Treatment Practices

Many types of technology are used to treat swine wastes. These technologies work in a variety of ways to reduce the nitrogen, chemical oxygen demand, and the volatile solids content of waste or to change the form of the waste to make it more concentrated and thus easier to handle. The most common type of treatment practice is the anaerobic lagoon.

- *Lagoon treatment systems.* Lagoons designed to treat waste can reduce organic content and nitrogen by more than 50 percent (PADER, 1986). Anaerobic lagoons are generally preferred over aerobic lagoons because of their greater ability to handle high organic load. Nonetheless, incomplete anaerobic decomposition of organic material can result in offensive by-products, primarily hydrogen sulfide, ammonia, and intermediate organic acids, which can cause disagreeable odors. Therefore, proper design, size, and management are necessary to operate an anaerobic lagoon successfully.

  New lagoons are typically half filled with water before waste loading begins. Starting up during warm weather and seeding with bottom sludge from a working lagoon speeds establishment of a stable bacterial population. Proper lagoon maintenance and operation is absolutely necessary to ensure that lagoon liner integrity is not affected, that berms and embankments are stable, and the required freeboard and rainfall storage are provided.

  Even when bacterial digestion is efficient, significant amounts of sludge accumulate in anaerobic lagoons. Although lagoons can be designed with enough storage to minimize the frequency of bottom sludge removals, at some point sludge accumulation will greatly diminish the treatment capacity of most lagoons. Without the proper treatment volume, anaerobic decomposition will be incomplete, and odors will usually become more pronounced. Inadequate maintenance of treatment volume is the single most common reason for the failure of lagoon treatment systems. The method used most frequently to remove sludge entails vigorous mixing of sludge and lagoon water by means of an agitator/chopper pump or propeller agitator. The operation of the agitator/chopper must be continuously monitored to prevent damage to the liner berms, or embankments, which could result in contamination of surface or ground water. The sludge mixture is then pumped through an irrigation system onto cropland.

Some lagoons are covered with a synthetic material. There can be multiple advantages to covering a lagoon: A cover will prevent rainfall from entering the system, which can result in additional disposal costs. Nitrogen volatilization is minimized, making the waste a more balanced fertilizer and potentially saving expenses for the purchase of nitrogen fertilizers. The EPA AgSTAR Program has demonstrated that biogas production and subsequent electricity generation from covered lagoons and digesters can be cost effective, help control odor, and provide for more effective nutrient management.

- *Digesters*. Conventional aerobic digestion is frequently used to stabilize biosolids at small municipal and industrial facilities as well as at some animal feeding operations. Waste is aerated for relatively long periods of time to promote microbial growth. Substantial reductions in total and volatile solids, biochemical and chemical oxygen demand, and organic nitrogen as well as some reduction in pathogen densities can be realized. Autoheated aerobic digesters use the heat released during digestion to increase reaction rates and allow for more rapid reduction of pathogens. The biosolids created by digesters concentrate solids resulting in easier handling. Additional information on the operational considerations, performance, and advantages and disadvantages of digesters can be found in Section 8.

- *Sequencing batch reactors*. Manure is treated in sequence, typically in a vessel of metal construction. The vessel is filled, reacted (aeration cycled on and off), and then allowed to settle. Organic carbon and ammonia are reduced and phosphorus is removed through biosolids generation or chemical precipitation. The biosolids generated are in a concentrated form, allowing for ease in handling.

- *Other*. Many other practices are used separately or in combination with the practices listed above to treat swine wastes. Constructed wetland treatment cells, trickling filters, composting, oxidation ditches, are a few of the other ways to treat swine wastes. Systems being developed or under trial studies include Y- or V- shaped pits with scrapers for solid-liquid separation at the source, membrane filtration, chemical treatments, high-rise hog buildings, oligolysis, hydroponic cultivation, photosynthetic digesters, and closed loop water use systems using ultraviolet disinfection. Information on the operational considerations, performance, and advantages and disadvantages of these and other treatment practices can be found in Section 8.

4.1.4.1 *Waste Management Practices by Operation Size and Geographical Location*

The use of a particular waste management system is driven by the size of the operation and geographic considerations (e.g., climate). For example, operation of a confined facility with the use of a lagoon for treatment requires substantial capital investment. Below a certain number of head, such a system would be cost-prohibitive since the high start-up and maintenance costs of such a facility have to be spread over a large number of animals to ensure economic viability. Geographic considerations also play a role in waste management. Anaerobic lagoons are common in the Southeast, where factors such as land availability and climate conditions are favorable. Midwestern farms are more likely to use pit storage with slurry transport to aboveground or belowground tanks. The *Swine '95* Survey (USDA APHIS, 1995) provides a detailed picture of swine management practices by operation type, size, and location.

Waste Management Practice by Operation Size

As mentioned previously, large operations (greater than 2,000 head marketed in the past 12 months) are much more likely to use water for waste management than small operations. Smaller operations (less than 500 head) typically manage waste by hand cleaning or mechanical scraper/tractor. They also use pit-holding and flushing systems because of their relatively lower labor requirements. While larger operations also use pit storage and slurry storage in tanks, they are far more likely to move waste from the housing facility to a lagoon. Tables 4-20, 4-21, and 4-22 present the frequency of operations using the most common types of waste management systems for swine farrowing, nursery, and finishing phases, respectively. Table 4-23 presents the frequency of waste storage system use by size of operation. Table 4-24 presents the frequency of waste storage system use by region for operations that marketed 5,000 or more hogs in a 12-month period. It should be noted that the percentages do not add to 100 percent. This is because an operation may use more than one waste storage system. For example, many large facilities in the southeast have below floor slurry storage that is then moved to lagoon storage.

Table 4-20. Frequency (in percent) of Operations in 1995 by Type of Waste Management System Used Most in the Farrowing Phase

Variable	Number of Hogs Marketed in Past 12 Months		
	<2,000	2,000 - 10,000	>10,000
None	14.1	5.6	1.7
Pit-holding	24.4	53.9	49
Scraper / Tractor	12.3	3.6	6.0
Hand cleaned	39.7	0.6	0
Flush - under slats	4.6	20.8	39.3
Flush - gutter	3.0	2.7	2.6
Other	1.8	13	1.5

Source: USDA APHIS, 1995

Table 4-21. Frequency (in percent) of Operations in 1995 by Type of Waste Management System Used Most in the Nursery Phase

Variable	Number of Hogs Marketed in Past 12 Months		
	<2,000	2,000 - 10,000	>10,000
None	4.4	3.3	0
Pit-holding	32.3	55	48
Scraper / Tractor	18.5	3.9	1.7
Hand cleaned	31.7	1.6	0
Flush - under slats	8.7	19.6	10.2
Flush - gutter	2.1	1.7	3.4
Other	2.3	15	6.8

Source: USDA APHIS, 1995

Table 4-22. Frequency (in percent) of Operations in 1995 by Type of Waste Management System Used Most in the Finishing Phase

Variable	Number of Hogs Marketed in Past 12 Months		
	<2,000	2,000 - 10,000	>10,000
None	15.2	4.6	0
Pit-holding	22.1	53	45.3
Scraper / Tractor	25.5	8.6	11.4
Hand Cleaned	28.0	3.0	0
Flush - under slats	1.9	17.5	30.0
Flush - gutter	3.3	7.8	6.0
Other	4.0	5.5	7.4

Source: USDA APHIS, 1995

Table 4-23. Frequency (in percent) of Operations in 1995 That Used Any of the Following Waste Storage Systems by Size of Operation

Waste Storage System	Percentage of Operations by Number of Head Marketed for Slaughter		
	<2,000 Head	2,000 - 10,000 Head	>10,000 Head
Below-floor slurry	43.6	70.4	47.9
Aboveground slurry	4.1	10.3	8.3
Belowground slurry	17.3	25.6	26.8
Anaerobic lagoon with cover	2.2	0.5	2.0
Anaerobic lagoon without cover	17.4	29.2	81.8
Aerated lagoon	1.3	6.9	1.0
Oxidation ditch	2.9	0.1	0.0
Solids separated from liquids	4.1	5.9	4.7
Other	0.6	0.0	1.1

Source: USDA APHIS, 1995

With minor exceptions, there are consistent trends in operation management from one part of the country to another. The multi-site model that separates production phases is being adopted across the country; finishing age and number of litters per year already tend to be the same from one part of the nation to another. With the exception of the Midwest, producers tend to farrow small groups of sows weekly (USEPA, 1998). In the Midwest, some producers farrow only twice a year, usually in the spring and fall. This is usually done on smaller operations, where sows are maintained outdoors and then moved indoors for farrowing. The buildings in which pigs are housed in the Midwest tend to differ from those in more temperate parts of the country, and waste is managed differently in the Midwest than in other parts of the country. Confined, three-site operations predominate in the Southeast, south-central region, and West, although there are some smaller outdoor operations in the south-central region and the West.

Table 4-24. Frequency (in percent) of Operations in 1995 That Used Any of the Following Waste Storage Systems by Region for Operations That Marketed 5,000 or More Hogs in a 12–Month Period

Waste Storage System	USDA APHIS Region[a]		
	Midwest	North	Southeast
Below-floor slurry	21.5	28.5	85.7
Aboveground slurry	NA	NA	27.2
Belowground slurry	NA	NA	43.3
Anaerobic lagoon	91.2	4.8	33.3
Aerated lagoon	NA	X[b]	NA
Solids separated from liquids	NA	NA	14.4

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
[b] The standard error for the aerated lagoons in the northern region as evaluated by NAHMS exceeds 21 percent and was therefore determined by NAHMS not to be statistically valid. Note that the aerated lagoon is reportedly found in roughly 70 percent of the operations in the north region.

Source: USDA APHIS, 1995

Most types of waste management systems are also similar across most regions with only minor deviations. For example, the pit recharge systems with aboveground storage and land application are nearly identical among farms in the Midwest, the south-central region, and the Northeast. The primary waste management system that has the most variation among and within regions is known as the hand wash system. Hand wash systems are found predominantly on operations with fewer than 500 pigs; most of the operations using hand washing as their primary waste management system have fewer than 100 pigs. On these operations, it is in the farrowing house and/or nursery phases of production that hand washing is used to remove waste from the buildings. Either the wash water exits the building and enters the environment directly or a collection basin is located underneath or at one end of the building. In the case of collection, the wash water is stored and used for land application at a later time or is allowed to evaporate over time. Frequency of hand washing varies among operations from 3 times a day to once a week.

Another type of system identified as a primary waste management system on small operations in the Midwest and New England (USDA APHIS, 1995) uses a flat blade on the back of a tractor to scrape or remove manure from feeding floors. The popularity of this system apparently has waned, and the system no longer represents a major means for removing wastes from swine feeding operations (NCSU, 1998a).

Swine Waste Management Systems in the Pacific Region

Descriptive information about the waste management systems in this region is provided in Table 4-25. In general, the region is characterized by operations with fewer than 500 pigs that use hand washing and dry lots as their primary waste management system. In contrast, the majority of pigs are raised on operations with more than 1,000 animals that use either deep pit/aboveground storage or pit recharge/lagoon.

Table 4-25. Distribution of Predominant Waste Management Systems in the Pacific Region[a] in 1997

Farm Size (number of pigs)	Primary Waste Management System
Fewer than 500	1. Hand Wash/Dry Lots 2. Scraper/Aboveground Storage/Land Application
500 to 1,000	1. Hand Wash/Dry Lots 2. Deep Pit/Aboveground Storage/Land Application
More than 1,000	1. Deep Pit/Aboveground Storage/Land Application 2. Pit Recharge/Covered Anaerobic Lagoon/Irrigation

[a] Alaska, California, Hawaii, Oregon, and Washington
Source: Adapted from NCSU, 1998a

Swine Waste Management Systems in the Central Region

Table 4-26 presents information for the Central region. It is the fastest-growing area of swine production in the nation at the present time. As a result, large operations (>2,000 head) account for almost all of the swine in these states. As a group, these large operations appear to rely on evaporation from lagoons, aeration of anaerobic lagoons, or biogas production from lagoons as the main means for storing and treating swine waste.

Circle 4, one of the largest operations in the country, uses a pit-recharge system that is emptied about three times per week. Wastewater treatment is by a two-stage evaporative lagoon system. The primary stage is designed for treatment of volatile solids, with additional volume for 20 years of sludge storage. The exact treatment volume design is operation- (or complex-) specific and takes into consideration the diet, feed digestibility, and absorption and conversion efficiency of the animal for each group of confinement houses. The primary stage is sized on the basis of volume per input of volatile solids plus an additional volume for 20 years of sludge storage. The secondary stage lagoon volume and surface area are specified to allow evaporation of all excess water not required for pit recharge. Waste management plans call for sludge removal on the order of 20 years. Because the operation has not reached its design life at this time, this system cannot be evaluated.

Table 4-26. Distribution of Predominant Waste Management Systems in the Central Region[a] in 1997

Farm Size (number of pigs)	Primary Waste Management System
Fewer than 500	1. Hand Wash/Dry Lots
500 to 1,000	1. Flush or Pit Recharge/Anaerobic Lagoon/Irrigation 2. Deep Pit/Aboveground Storage/Land Application
More than 1,000	1. Flush or Pit Recharge/Aeration of Anaerobic Lagoon/Irrigation 2. Flush or Pit Recharge/Covered Anaerobic Lagoon/Land Application 3. Pit Recharge/Evaporation from Two-Stage System

[a] Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oklahoma, Texas, Utah, Wyoming
Source: NCSU 1998a

Swine Waste Management Systems in the Mid-Atlantic Region

Table 4-27 summarizes descriptive information for the region. Only North Carolina and Pennsylvania grow a significant number of swine. The medium and large operations rely on either anaerobic lagoons and wastewater irrigation or aboveground storage and land application as their primary means of waste management. Operations in the remaining states typically have fewer than 500 animals each, and they use hand washing in conjunction with dry lots as their primary waste management system.

The design and operation of the anaerobic lagoon and irrigation system are different in the two key states. In Pennsylvania, lagoon loading rates are lower to accommodate the lower temperatures, and storage requirements must be increased to accommodate the longer inactive period during winter. Average yearly rainfall is about the same in the two states, with rainfall in excess of evapotranspiration requiring increased storage requirements.

Table 4-27. Distribution of Predominant Waste Management Systems in the Mid-Atlantic Region[a] in 1997

Farm Size (number of pigs)	Primary Waste Management System
Fewer than 500	1. Hand Wash/Dry Lots 2. Gravity Drain/Collection Basin/Land Application
500 to 1,000	1. Deep Pit/Aboveground Storage/Land Application 2. Pit Recharge/Anaerobic Lagoons/Irrigation 3. Scraper/Aboveground Storage/Land Application
More Than 1,000	1. Deep Pit/Aboveground Storage/Land Application 2. Pit Recharge/Anaerobic Lagoons/Irrigation

[a] Connecticut, Delaware, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, Tennessee, Vermont, Virginia, and West Virginia
Source: Adapted from NCSU 1998a

Swine Waste Management Systems in the South Region

Table 4-28 summarizes descriptive information for the region. Large operations (more than 1,000 head) represent only a small fraction of the operations in the states of the region. The predominant waste management system is a flush or pit-recharge system for removal of waste from buildings, an anaerobic lagoon for treatment and storage of waste, and reincorporation of treated wastewater back into the environment by irrigation. In these states, housing is usually enclosed, with ventilation and a concrete floor surface.

Table 4-28. Distribution of Predominant Waste Management Systems in the South Region[a] in 1997

Farm Size (number of pigs)	Primary Waste Management System
Fewer than 500	1. Hand Wash/Dry Lots 2. Scraper System/ Aboveground Storage/Land Application
500 to 1,000	1. Flush or Pit Recharge/Anaerobic Lagoon/Irrigation
More Than 1,000	1. Flush or Pit Recharge/Anaerobic Lagoon/Irrigation

[a] Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, and South Carolina
Source: Adapted from NCSU 1998a

Swine Waste Management Systems in the Midwest Region

Table 4-29 summarizes descriptive information for this region. Small operations account for most of the operations in this region; however, recent construction of large units in Iowa, Minnesota, Missouri, and South Dakota indicate that the trend toward production in larger units seen in the southeastern U.S. is probably occurring in the Midwest Region as well. Primary waste management systems for operations with fewer than 500 pigs are hand wash coupled with dry lots with and without collection basins. In contrast, medium and large operations rely on storage of waste either under buildings with deep pits or in aboveground structures in conjunction with direct land application for crop production.

Table 4-29. Distribution of Predominant Waste Management Systems in the Midwest Region[a] in 1997

Farm Size (number of pigs)	Primary Waste Management System
Fewer than 500	1. Hand Wash/Dry Lots 2. Hand Wash/Dry Lots and Collection Basin/Land Application 3. Deep Pit/Land Application
500 to 1,000	1. Deep Pit/Aboveground Storage/Land Application 2. Pit Recharge/Aeration of Anaerobic Lagoons/Irrigation 3. Deep Pit/Land Application
More than 1,000	1. Deep Pit/Aboveground Storage/Land Application 2. Pit Recharge/Covered Anaerobic Lagoon/Irrigation

[a] Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin
Source: NCSU 1998a

4.1.5 Pollution Reduction

4.1.5.1 *Swine Feeding Strategies*

Swine producers use a variety of feed ingredients to achieve a balanced diet for a pig at each phase of the animal's development. Various grain products, including corn, barley, milo, and sometimes wheat form the foundation of the growing pig's diet and supply most of the carbohydrates and fat. Oilseed meals are the primary source of protein, and they foster muscle and organ development (NPPC, 1999). Producers also supplement the basic diet with minerals and vitamins as needed. A pig's diet changes as the animal grows. For example, finishing pigs typically receive a diet containing 13 to 15 percent crude protein versus the 20 to 22 percent protein diet received by young pigs. The *Swine '95* survey indicates that more than 96 percent of grower-finisher operations use multiple diets from time of entry to market weight. Almost 70 percent of the operations feed their pigs three or more diets during this phase.

Swine operations can use feeding strategies both to maximize growth rates and to reduce excretion of nutrients. The following feeding strategies can be used to reduce nitrogen and phosphorus manure content.

Grinding. Fine grinding and pelleting are simple but effective ways to improve feed utilization and decrease nitrogen and phosphorus excretion. By reducing the particle size, the surface area of the grain particles is increased, allowing for greater interaction with digestive enzymes. When particle size is reduced from 1,000 microns to 400 microns, nitrogen digestibility increases by approximately 5 to 6 percent. As particle size is reduced from 1,000 microns to 700 microns, excretion of nitrogen is reduced by 24 percent. The current average particle size is approximately 1,100 microns; the recommended size is between 650 and 750 microns. Reducing particle size below 650 to 750 microns greatly increases the energy costs of grinding and reduces the throughput of the mill. The use of so small a particle size will also increase the incidence of stomach ulcers in the hogs (NCSU, 1998b).

Amino Acid Supplemental Diets. Supplementing the diet with synthetic lysine to meet a portion of the dietary lysine requirement is an effective means of reducing nitrogen excretion by hogs. This process reduces nitrogen excretion because lower-protein diets can be fed when lysine is supplemented. Research studies have shown that protein levels can be reduced by 2 percentage points when the diet is supplemented with 0.15 percent lysine (3 pounds lysine-HC1/ton of feed) without negatively affecting the performance of grow-finish pigs. Greater reductions in protein are possible, but only if threonine, tryptophan, and methionine are also supplemented.

Table 4-30 shows the theoretical effect of feeding low-protein, amino acid-supplemented diets on nitrogen excretion of finishing pigs. Note that reducing the protein level from 14 percent to 12 percent and adding 0.15 percent lysine results in an estimated 22 percent reduction in nitrogen excretion. Reducing the protein further to 10 percent and adding 0.30 percent lysine, along with adequate threonine, tryptophan, and methionine, reduces the estimated nitrogen excretion by 41 percent.

Although it is currently cost-effective to use supplemental lysine and methionine, supplemental threonine and tryptophan are currently too expensive to use in widespread diets. However, because of rapid technological advances in fermentation procedures for synthesizing amino acids, the price of threonine and tryptophan will likely decrease in the next few years.

Table 4-30. Theoretical Effects of Reducing Dietary Protein and Supplementing With Amino Acids on Nitrogen Excretion by 200-lb Finishing Pig[a,b]

Diet Concentration	14 Percent CP	12 Percent CP + Lysine	10% CP + Lysine + Threonine + Tryptophan + Methionine
N balance			
N intake, g/d	67	58	50
N digested and absorbed, g/d	60	51	43
N excreted in feces, g/d	7	7	7
N retained, g/d	26	26	26
N excreted in urine, g/d	34	25	17
N excreted, total, g/d	41	32	24
Reduction in N excretion, %	----	22	41
Change in dietary costs, $/ton[b]	0	-0.35	+$14.50

[a] Assumes an intake of 6.6 lb/d and a growth rate of 1.98 lb/d. [b] Costs used L-Lysine HCl, $2.00/lb; corn, $2.50/bushel; SBM, $250/ton; L-Threonine, $3.50/lb; DL-Methionine, $1.65/lb; Tryptosine (70:15, Lys:Tryp) $4.70/lb.
Source: NCSU, 1998b

Phase Feeding and Split-Sex Feeding. Dividing the growth period into more phases with less spread in weight allows producers to more closely meet the pig's protein requirements. Also, since gilts (females) require more protein than barrows (males), penning barrows separately from gilts allows lower protein levels to be fed to barrows without compromising leanness and performance efficiency in gilts. Feeding three or four diets, compared with only two diets, during the grow-finish period would reduce nitrogen excretion by at least 5 to 8 percent (NCSU, 1998b).

Formulating Diets on an Available Phosphorus Basis. A high proportion (56 to 81 percent) of the phosphorus in cereal grains and oilseed meals occurs as phytate. Pigs do not use phosphorus in this form well because they lack significant amounts of intestinal phytase, the enzyme needed to remove the phosphate groups from the phytate molecule. Therefore, supplemental phosphorus is added to the diet to meet the pig's growth requirements.

Because some feedstuffs are high in phytate and because there is some endogenous phytase in certain small grains (wheat, rye, triticale, and barley), there is wide variation in the bioavailability of phosphorus in feed ingredients. For example, only 12 percent of the total phosphorus in corn is available, whereas 50 percent of the total phosphorus in wheat is available. The phosphorus in dehulled soybean meal is more available than the phosphorus in cottonseed meal (23 percent vs. 1 percent), but neither source of phosphorus is as highly available as the phosphorus in meat and bone meal (66 percent), fish meal (93 percent), or dicalcium phosphate (100 percent) (NCSU, 1998b).

Supplementing Diets with Phytase Enzyme. Supplementing the diet with the enzyme phytase is an effective means of increasing the breakdown of phytate phosphorus in the digestive tract and reducing the phosphorus excretion in the feces. Using phytase allows one to feed a lower phosphorus diet because the unavailable phytate phosphorus in the grain and soybean meal is made available by the phytase enzyme to help meet the pig's phosphorus needs. Studies at Purdue University, at the University of Kentucky, and in Denmark indicate that the inclusion of phytase increased the availability of phosphorus in a corn-soy diet threefold, from 15 percent up to 45 percent.

A theoretical example of using phytase is presented in Table 4-31. If a finishing pig is fed a diet with 0.4 percent phosphorus (the requirement estimated by NRC, 1988, cited in NCSU, 1998b), 12 grams of phosphorus would be consumed daily (3,000 grams times 0.4 percent), 4.5 grams of phosphorus would be retained, and 7.5 grams of phosphorus would be excreted. Feeding a higher level of phosphorus (0.5, 0.6, or 0.7 percent) results in a slight increase in phosphorus retention but causes considerably greater excretion of phosphorus (10.3, 13.2, and 16.2 g/d, respectively). Being able to reduce the phosphorus to 0.3 percent in a diet supplemented with phytase would reduce the intake to 9 grams of phosphorus per day and would potentially reduce the excreted phosphorus to 4.5 g/day (a 37 percent reduction in phosphorus excretion versus NRC's estimate). The percent reduction in excreted phosphorus is even more dramatic (56 percent) when one compares the 4.5 grams with the 10.3 grams of phosphorus excreted daily by finishing pigs fed at the 0.5 percent phosphorus level typically recommended by universities and feed companies. Bone strength can be completely recovered by supplementing a low-P diet with 1,000 phytase units per kilograms of feed, while most of the grain and feed efficiency is returned to NRC levels. In addition to returning bone strength and growth performance to control levels, there is a 32 percent reduction in phosphorus excretion. A summary of 11 experiments (Table 4-32) indicates that all the growth rate and feed efficiency can be recovered with the dietary supplementation of 500 phytase units and reduced-phosphorus diets. Some analyses have suggested that a 50 percent reduction in excreted phosphorus by pigs would mean that land requirements for manure applications based on phosphorus crop uptake would be comparable to manure applications based on nitrogen.

Table 4-31. Theoretical Effects of Dietary Phosphorus Level and Phytase Supplementation (200-lb Pig)

Dietary P (%)	Phosphorus (g/d)			Change From Industry Average (%)
	Intake	Retained	Excreted	
0.70	21.0	4.8	16.2	+57
0.60	18.0	4.8	13.2	+32
0.50	15.0	4.7	10.3	0
0.40 (NRC, 1988)	12.0	4.5	7.5	-27
0.30	9.0	2.5	6.5	-37
0.30 + Phytase	9.0	4.5	4.5	-56

Source: Cromwell and Coffey, 1995, cited in NCSU, 1998b.

Previously, phytase was too expensive to use as a feed additive. However, this enzyme can now be effectively produced by recombinant DNA techniques and the cost has decreased. A cost evaluation indicates that under certain conditions replacing dietary phosphorus of an inorganic phosphorus source (e.g., dicalcium phosphate) with the phytase enzyme would be cost neutral. Swine require that phytase supplements be fed at different levels based on the age of the pig (Table 4-33). The different levels are based on phase of production and are likely related to the digestive enzymes and cecum of the younger pig being less developed.

Table 4-32. Effect of Microbial Phytase on Relative Performance of Pigs[a]

Growth Response	Negative Control	Positive Control	Effect of 500+ Phytase Units/kg
ADG	100	115 (+/- 6.5)	116.7 (+/ -10.6)
ADFI	100	105 (+/- 5.2)	107.6 (+/- 7.8)
Feed Conversion Ratio	100	93 (+/- 4.9)	93.2 (+/- 5.0)

[a] Eleven experiments with the negative control diets set at 100 percent and the relative change in pig growth performance to the control diets.
Source: Jongbloed et al., 1996, cited in NCSU, 1998b

Table 4-33. Effect of Microbial Phytase on Increase in Phosphorus Digestibility by Age of Pigs and the Recommended Rates for Inclusion of Phytase in Each Phase

	Nursery	Grower	Finisher	Gestation	Lactation
Approximate Increase (%)	13	17	17	7	20
Inclusion Level (Phytase Unit/lb)	454-385	385-227	27-113	227	227

Source: Jonbloed et al., 1996, cited in NCSU, 1998b

4.1.5.2 *Waste and Waste Water Reductions*

Methods to reduce the quantity of waste water generated at swine operations include advanced swine watering systems to reduce water spillage and recycling water in waste flush systems. The feeding strategies discussed in the previous section will also reduce the quantity of waste generated by ensuring that animals do not receive more feed than required for optimal growth. Additional information on feeding strategies for swine can be found in Chapter 8. Advanced swine breeding has resulted in animals that produce less waste per pound of meat produced.

Nipple water delivery systems reduce the amount of waste water and are more healthy for the animals. Trough or cup waters are typically placed close to the floor of the pen. This allows the animal to spill water and add contaminates to the standing water. Nipple water delivery systems are placed higher in the pen and only deliver water to the animal when the animal is sucking on the nipple. Watering systems may also use water pressure sensors and automatic shutoff valves to reduce water spillage. The sensor will detect a sustained drop in water pressure resulting from a break in the water line. The sensor will then stop the water flow to the broken line and an alarm will sound. The operator can then fix the broken line and restore water to the animals with minimal water spillage. There is little information about the relative use of the various water delivery systems or the relative use of water pressure sensors and shutoff valves within the swine industry.

The use of recycled water in swine flush and pull plug waste management systems will also reduce the amount of waste water generated at an operation. To obtain recycled water of appropriate quality an operation can use a variety of methods to remove pollutants from the waste stream. Such methods include solid-liquid separation, digesters, and multiple-stage lagoon systems. Multiple-stage lagoon systems or the use of an initial settling basin will allow settling of solids and biological processes to occur that can result in high quality water. One large operation in Utah claims to have a completely closed system in which all waste water is treated in a multiple-stage lagoon system and them recycled back to the manure flush system.

4.1.6 Waste Disposal

Waste is disposed in either a liquid or solid form. Handling and disposal in a solid form has several advantages the more concentrated the waste. Hauling costs are reduced as the water content is reduced; however, most operations prefer to handle and dispose of waste in a liquid form because of the reduced labor cost of handling the waste in this manner. Table 4-34 shows the percentage of operations that use or dispose of manure and wastes as unseparated liquids and solids. Tables 4-35 and 4-36 show the percentage of operations that are using the most common disposal methods by USDA APHIS region.

Table 4-34. Percentage of Operations in 1995 That Used or Disposed of Manure and Wastes as Unseparated Liquids and Solids

Operation Size	USDA APHIS Region[a]		
	Midwest	North	Southeast
Operations marketing fewer than 5,000 hogs in 12 months	92.3	99.1	97.7
Operations marketing 5,000 or more hogs in 12 months	100	19.6[b]	98.5

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
[b] The standard error on this measurement is 16.0, resulting in questions of its accuracy
Source: USDA NAHMS, 1999

Table 4-35. Percentage of Operations in 1995 That Marketed Fewer Than 5,000 Hogs in a 12–Month Period and That Used the Following Methods of Use/Disposal by Region

Waste Disposal Method	USDA APHIS Region[a]		
	Midwest	North	Southeast
Placed on own land	97.9	98.5	96.8
Given away	NA	11.0	2.6

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA NAHMS, 1999

Table 4-36. Percentage of Operations in 1995 That Marketed 5,000 or More Hogs in a 12–Month Period and That used the Following Methods of Use/Disposal by Region

Waste Disposal Method	USDA APHIS Region[a]		
	Midwest	North	Southeast
Placed on own land	100	100	97.5
Sold	NA	NA	7.3
Given away	NA	NA	11.3

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA
Source: USDA NAHMS, 1999

Transport and land application of manure nutrients are necessary to realize the fertilizer benefit of such nutrients. Surface application and injection are common means of land application for slurry. Depending on the consistency of the manure, several types of equipment are available to apply the nutrients to the land. The common manure spreader is a low-maintenance, relatively inexpensive piece of equipment. The spreader is designed for solids and thick slurries; however, because of the characteristics of the equipment, the manure is hard to apply uniformly. This type of spreader requires loading equipment and usually takes longer to empty small loads. A flexible drag hose can be used on relatively flat landscapes. This system unloads the manure quickly, although it normally requires two tractors and a power unit on the pump. A flexible drag hose system is effective on regularly shaped fields, but the equipment is expensive. Tank wagon applications are used for liquid manure. The wagon is adaptable to either surface broadcast or injection, depending on the situation. Tank wagons apply liquid manure uniformly and are self-loading; however, the pump to discharge the manure requires a large amount of horsepower, which can be taxing on the tractor. Soil compaction is normally associated with tank wagons, and it usually takes longer to empty the storage facility. Tables 4-37 and 4-38 show the percentage of operations that disposed of manure and waste on owned or rented land using various methods. Operations may use more than one method, therefore columns do not add up to 100 percent.

Table 4-37. Method of Manure Application in 1995 on Land by Operations That Marketed Fewer Than 5,000 Hogs in a 12–Month Period

Variable	USDA APHIS Region[a]		
	Midwest	North	Southeast
Irrigation	47.6	11.2	2.9
Broadcast	18.4	57.8	69.0
Slurry–surface	33.0	55.7	46.6
Slurry–sSubsurface	X	26.6	22.9

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA
Source: USDA NAHMS, 1999

Table 4-38. Method of Manure Application in 1995 on Land by Operations That Marketed 5,000 or More Hogs in 12–Month Period

Variable	Region[a]		
	Midwest	North	Southeast
Irrigation	100	74.8	16.4
Broadcast	X[b]	X	39.4
Slurry–surface	X[b]	6.3	68.1
Slurry–subsurface	X	23.6	72.1

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA
[b] Operations in this region also use broadcast and slurry-surface methods, but NAHMS determined the standard error was too high to report statistically valid values.
Source: USDA NAHMS, 1999

Most manure and waste is disposed of on land owned or rented by the operator, thus the amount of land available for land application of wastes is critical. Applying too much manure and waste to the same land year after year can result in a steady increase in the soil phosphorus content. Tables 4-39 through 4-41 present the percentage of swine operations with and without adequate crop and pasture land for manure application on a nitrogen- and phosphorus-basis at plant removal rates and operations that own no land. The operations that have "no land" were determined by running queries of the USDA 1997 Census of Agriculture data to identify facilities that did not grow any of the 24 major crops grown in the U.S. Operations with no land available are assumed to haul their waste to land that can use the waste as a fertilizer resource.

Table 4-39. Percentage of Swine Grow-Finish Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Size (head)[a]	Sufficient Land		Insufficient Land		No Land
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	
1-749	76.4	67.38	7.2	14.54	18.7
750-1,874	84.4	68.19	8.98	23.55	15.5
1,875-2,499	80.2	56.56	13.81	34.66	16.46
2,500-4,999	73.8	44.15	19.45	49.27	17.79
> 5,000	48.31	15.53	42.04	69.48	21.97
Total	76.3	60.78	13.54	28.11	18.1

Source: USDA NASS, 1999c.
[a] Estimated by adding head sold in the last year to inventory and dividing the sum by 2.8 turns per year.

Table 4-40. Percentage of Swine Farrowing Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Size (head)	Sufficient Land		Insufficient Land		No Land
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	
1-749	70.7	57.77	8.44	21.33	20.9
750-2,499	13.33	0	33.33	46.7	53.33
> 2,500	20	0	60	80	20
Total	66.1	53.1	11	24.1	22.9

Source: USDA NASS, 1999c.

Table 4-41. Percentage of Swine Farrow-Finish Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Size (head)[a]	Sufficient Land		Insufficient Land		No Land
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	
1-749	0	67.4	6.6	15.6	17
750-1,874	84.4	68.2	6	22.2	9.6
1,875-2,499	80.2	56.6	7.9	31.5	12
2,500-4,999	73.8	44.2	12.4	42	13.9
> 5,000	48.3	15.5	23.1	55.8	28.6
Total	76.3	60.8	8.3	23.8	15.4

[a] Estimated by adding head sold in the last year to inventory and dividing the sum by 2.1 turns per year. Inventory includes the number of head in the breeding herd.
Source: USDA NASS, 1999c

Another waste product of swine farms is animal mortality. Mortalities are usually handled in an environmentally sound and responsible manner, but improper disposal may cause problems with odors, pathogens, biosecurity, and soil and water contamination. The 1995 USDA APHIS *Swine 95* study assessed the frequency of mortality disposal methods based on whether operations marketed more or fewer than 2,500 head in the prior 6-month period. (An operation that sold 2,500 head in the last 6–months corresponds roughly to an operation with 1,000 to 1,500 animal unit capacity.) Tables 4-42 and 4-43 show the percentage of operations by method of disposal for those operations which specified at least one pig had died in the 6–month period.

Table 4-42. Method of Mortality Disposal on Operations That Marketed Fewer Than 2,500 Hogs in a 6–Month Period in 1995

Method of disposal	USDA APHIS Region[a]		
	Midwest	North	Southeast
Burial on operation	73.2	71.6	46.6
Burn on operation	9.1	7.2	15.2
Renderer entering operation	2.1	14.1	38.7
Renderer at perimeter of operation	2.7	4.2	8.7
Composting	10.3	6.4	13.0
Other	7.0	9.8	6.8

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA NAHMS, 1999

Table 4-43. Method of Mortality Disposal on Operations That Marketed 2,500 or More Hogs in a 6–Month Period in 1995

Method of Disposal	USDA APHIS Region[a]		
	Midwest	North	Southeast
Burial on operation	23.0	21.0	20.8
Burn on operation	9.9	10.2	17.1
Renderer entering operation	39.9	50.1	37.5
Renderer at perimeter of operation	27.9	23.2	31.4
Composting	X	X	11.1
Other	3.4	X	1.8

[a] Midwest=SD, NE, MN, IA, IL; North=WI, MI, IN, OH, PA; Southeast=MO, KY, TN, NC, GA; Only the 16 major pork states that accounted for nearly 91 percent of U.S. hog inventory were surveyed.
Source: USDA NAHMS, 1999

4.2 Poultry Industry

Poultry feeding operations include facilities that confine chickens or turkeys for feeding or maintenance for at least 45 days in any 12-month period. These facilities do not have significant vegetation in the confinement area during the normal growing season, thus pasture and grazing operations are generally not included. Facilities at which poultry are raised may also include other animal and agricultural operations such as grazing, egg processing, and crop farming.

The specific poultry sectors are discussed in the following sections:

- 4.2.1: Broilers, roasters, and other meat-type chickens
- 4.2.2: Layers and pullets
- 4.2.3: Turkeys

Up until the 1950s most of the nation's poultry production was conducted on small family farms in the Midwest. Midwestern states provided favorable climatic conditions for seasonal production of poultry and close proximity to major sources of grain feed. Eventually, with the improvement of the transportation and distribution systems, the poultry industry expanded from the Midwest to other regions. With the advent of climate-controlled systems, poultry production evolved to a year-round production cycle. By 1997, the value of poultry production exceeded $21.6 billion, and much of the poultry output was generated by corporate producers on large facilities producing more than 100,000 birds (USDA NASS, 1998a).

The poultry industry encompasses several subsectors, including broilers, layers, turkeys, ducks, geese, and several other game fowl. This section focuses only on broilers, layers, and turkeys, which account for more than 99 percent of the annual farm receipts from the sale of poultry (USDA NASS, 1998a).

Together the annual sales of broilers, chicken eggs, and turkeys generate almost 10 percent of the value of all farm commodities. Although each of the poultry subsectors has experienced significant growth in output over the past two decades, broilers remain the dominant subsector, accounting for approximately 65 percent ($14.2 billion) of the $21.6 billion in poultry farm sales during 1997. Sales of eggs and turkeys accounted for 21 percent ($4.5 billion) and 13 percent ($2.9 billion), respectively. More than 15 million metric tons of poultry meat were produced in the U.S. during that year (USDA NASS, 1998c).

Poultry production (especially broiler production) is a highly integrated industry, and as a result, management strategies at the facility level tend to be more similar than in other sectors of animal feeding operations. Contract growing began in the South during the 1930s, and by the 1950s the contracts had evolved to their current form. Thus, the integrated structure seen today was in place by the 1960s (Sawyer, 1971, cited in Aust, 1997). For example, more than 90 percent of all chickens raised for human consumption in the U.S. are produced by independent farmers working under contract with integrated chicken production and processing companies. The company provides some inputs such as the birds themselves, feed, medication, and monitoring of flock health by company service personnel. The farmer provides the grow-out buildings, electricity, water, fuel, bedding material ("litter"), and his or her own labor and management skill. The company provides the newly hatched chicks that the farmer raises to market age and weight, giving them the feed provided by the company. The farmer is paid largely on the basis of weight gained by the flock as compared with other flocks produced during the same span of time. When the birds reach market weight, the company picks them up and takes them to processing plants, where they are processed into food products. Most integrated companies are stand-alone chicken operations, although some also produce turkeys.

The poultry industry has continued to evolve in terms of the type and number of birds it produces. Genetically designed birds have been developed with the ability to mature quickly and reach market weight or lay eggs more rapidly. This has resulted in increased efficiency and overall poultry production. Facilities that grow the birds have incorporated the latest automated technology for the feed and watering systems as well as ventilation systems. The technological advances have transformed poultry raising into a modern, mechanized industry.

4.2.1 Broiler Sector

This section describes the following aspect of the broiler industry:

- 4.2.1.1: Distribution of the broiler industry by size and region
- 4.2.1.2: Production cycles of broilers
- 4.2.1.3: Broiler facility types and management
- 4.2.1.4: Broiler waste management practices
- 4.2.1.5: Pollution reduction
- 4.2.1.6: Waste disposal

National Overview

Domestic broiler production has followed the same trend as swine and other livestock industries. Production has shifted from geographically diverse, small, family-run operations to large industrial production facilities concentrated in a few states. The number of broiler operations was quite stable between 1992 and 1997, with operations decreasing slightly from 23,949 broiler operations in 1992 to 23,937 operations in 1997, down less than 1 percent (USDA NASS, 1999b); however, between 1982 and 1992, more than 6,000 broiler operations, or 20 percent of the industry's producers, went out of business. As shown in Table 4-44, although the number of operations decreased over the past 20 years, total broiler production increased, with new large operations more than compensating for the small producers who have left the industry.

Table 4-44. Broiler Operations and Production in the United States 1982-1997[a]

Year	Operations	Production
1982	30,100	3,516,095,408
1987	27,645	4,361,198,301
1992	23,949	5,427,532,921
1997	23,937	6,741,476,153

[a] Broilers are young chickens of the meat-type breeds, raised for the purpose of meat production. Estimates cover a 12-month period (Dec. 1 through Nov. 30) and exclude states with fewer than 500,000 broilers.
Source: USDA NASS, 1998a, 1998b

4.2.1.1 *Distribution of Broiler Operations by Size and Region*

EPA's 1974 CAFO Effluent Limitations Guidelines and Standards generally apply to broiler operations with more than 100,000 birds and with continuous overflow watering systems, and to broiler operations with 30,000 birds and with a liquid manure system. (See Chapter 2 for the definition of a CAFO, and Chapter 5 for a discussion of the basis for revisions to the poultry subcategories.) Where numbers of birds are presented, all birds regardless of age (e.g., poult, laying age, or pullet) or function (i.e., breeder, layer, meat-type chicken) are included unless otherwise indicated in the text.

Large operations dominate broiler production. Although large production operations are characteristic of other livestock industries, such as the swine sector, the consolidation of the broiler industry began earlier and was well entrenched by the 1970s. By 1982, farms that produced fewer than 2,000 birds per flock numbered only 2,811, or about 5 percent of the total. This number decreased by two-thirds to about 1,000 farms a decade later (Abt, 1998). Compared with other livestock industries, such as swine, the broiler industry has the smallest proportion of small operators. For example, the smallest hog operations still accounted for more than 60 percent of all hog producers in 1992.

Regional Variation in Broiler Operations

Table 4-45 presents the 1997 distribution of broiler operations by region and operation size, and Table 4-46 presents the average flock size for these operations. In addition to being dominated by large producers, the broiler industry is concentrated in several states. Georgia, Arkansas, and Alabama, all in the South Region are some of the largest broiler-producing states. Table 4-47 presents the distribution of total chickens by region and operation size. It is important to note that operations with more than 90,000 birds accounted for more than 48 percent of the broilers even though they represented only 11.3 percent of the broiler operations. Operations with fewer than 30,000 birds represented almost 60 percent of the operations but accounted for less than 7 percent of the total birds.

Table 4-45. Total Number of Broiler Operations by Region and Operation Size in 1997

Region [a]	Number of Chicken Broiler Operations by Size Group [b] (Operation Size Presented by Number of Birds Spot Capacity)					
	>0-30,000	>30,000-60,000	>60,000-90,000	>90,000-180,000	>180,000	Total
Central	3,046	412	325	274	78	4,135
Mid Atlantic	5,113	2,105	1,055	842	100	9,215
Midwest	7,910	207	96	141	43	8,397
Pacific	1,244	41	38	42	63	1,428
South	3,403	3,597	2,327	1,980	377	11,684
National	20,716	6,362	3,841	3,279	661	34,859

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL

[b] Broilers are young chickens of the meat-type breeds, raised for the purpose of meat production. Estimates cover a 12-month period (Dec. 1 through Nov. 30) and exclude states with fewer than 500,000 broilers.

Source: USDA NASS, 1999c

Table 4-46. Average Number of Chickens at Broiler Operations by Region and Operation Size in 1997

Region [a]	Average Chicken Broiler Animal Counts [b] (Operation Size Presented by Number of Birds Spot Capacity)					
	>0-30,000	>30,000-60,000	>60,000-90,000	>90,000-180,000	>180,000	All Operators
Central	1,494	44,224	73,084	119,026	332,030	25,402
Mid Atlantic	6,178	44,193	73,590	115,281	303,155	35,771
Midwest	830	47,357	75,821	118,611	414,945	6,933
Pacific	608	44,041	73,695	132,560	624,380	35,200
South	12,538	43,998	73,776	117,581	281,453	60,897
National	4,158	44,187	73,717	117,347	332,073	35,993

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
[b] Broilers are young chickens of the meat-type breeds, raised for the purpose of meat production. Estimates cover a 12-month period (Dec. 1 through Nov. 30) and exclude states with fewer than 500,000 broilers.
Source: USDA NASS, 1999c

Table 4-47. Distribution of Chickens by Region and Operation Size in 1997

Region [a]	Percentage of Total Chicken Broiler Counts [b] (Operation Size Presented by Number of Birds Spot Capacity)					
	>0-30,000	>30,000-60,000	>60,000-90,000	>90,000-180,000	>180,000	Total
Central	0.36	1.45	1.89	2.60	2.06	8.37
Mid Atlantic	2.52	7.41	6.19	7.74	2.42	26.27
Midwest	0.52	0.78	0.58	1.33	1.42	4.64
Pacific	0.06	0.14	0.22	0.44	3.14	4.01
South	3.40	12.61	13.68	18.56	8.46	56.71
National	6.86	22.41	22.57	30.67	17.49	100.00

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
[b] Broilers are young chickens of the meat-type breeds, raised for the purpose of meat production. Estimates cover a 12-month period (Dec. 1 through Nov. 30) and exclude states with fewer than 500,000 broilers.
Source: USDA NASS, 1999c

4.2.1.2 *Production Cycles of Broilers*

Broilers are usually grown for 42 to 56 days depending on the market weight desired. Female broilers can also be grown to lay eggs for replacement stock, and these females are called broiler breeders. Roasters are usually grown separated by sex, with the females being harvested at 42 days of age and the males given the space in the entire house until they are sent to market several weeks later (USEPA, 1998). Other meat-type chickens (capons, game hens) comprise less than 1 percent of chickens raised for meat. Since they are raised in a similar manner to broilers, albeit with different market weights and ages, they are not usually differentiated in the data.

Chickens are produced to meet specific requirements of the customer which can be a retail outlet, fast-food chain, or institutional buyer, among others. A broiler is considered any chicken raised for meat products, though the industry further classifies chickens primarily by the size, weight, and age of the bird when processed.

- **Poussin** - Less than 24 days of age and about 1 pound or less.
- **Cornish Game Hens** - Less than 30 days of age and about 2 pounds.
- **Fast-food Broiler** - 2 pounds 4 ounces to 3 pounds 2 ounces (mostly 2 pounds 6 ounces to 2 pounds 14 ounces) and less than 42 days of age.
- **3's and Up** - 3 to 4 3/4 pounds and 40 to 45 days of age.
- **Broiler Roaster** - 5 to 6 pounds, hens usually 55 days.
- **Broiler for De-boning** - 5 to 6 pounds, males usually 47 to 56 days.
- **Heavy Young Broiler Roaster** - The typical “roaster,” 6 to 8 pounds, less than 10 weeks.
- **Capon** - 7 to 9 pounds, surgically de-sexed male broiler, 14 to 16 weeks.
- **Heavy Hens** - spent breeder hens, 5 to 5 ½ pounds, 15 months of age.

4.2.1.3 *Broiler Facility Types and Management*

The most common type of housing for broilers, roasters, pullets, and breeding stock is some type of enclosed housing with bedding derived from wood shavings, rice hulls, chopped straw, peanut hulls, or other products, depending on availability. The bedding absorbs moisture and dilutes the manure produced by the birds. Modern houses have an automatic feeding system to distribute the feed, a closed water system (automatic) to deliver the water for the birds, and a ventilation system to provide clean air. Some houses have side curtains that can be retracted to allow diffusion of air. Ventilation is typically provided using a negative-pressure system, with exhaust fans drawing air out of the house, and fresh air returning through ducts around the perimeter of the roof. The ventilation system uses exhaust fans to remove moisture and noxious gases during the winter season and excess heat during the summer. Advanced systems use thermostats and timers to control exhaust fans. These houses are also commonly integrated with an alarm signal to notify the operator of malfunctions and a back-up electric generator during power outages.

Broilers and Roasters. Houses for broilers and roasters are usually 40 feet wide and 400 to 500 feet long and typically designed for 25,000 to 30,000 broilers per flock. Older houses may be somewhat smaller, holding 20,000 to 25,000 birds. The houses contain an impermeable surface for the floor, typically clay. Wood shavings are initially added to the houses to a depth of approximately 4 inches. Between flocks, a small amount of litter referred to as cake (compacted and concentrated manure/litter mix) is removed and the remaining litter may be "top dressed" with an inch or so of new bedding material.

Pullets. Pullets are young chickens, usually less than 20 weeks of age, often raised for the purpose of egg production. Pullet houses are similar in construction to broiler houses. The houses are usually 40 to 45 feet in width and 300 to 500 feet in length. Most pullet houses are equipped with nipple, trough, or bell drinkers and often use mechanical feeders (drag chain, trough, or pan) to distribute feed to the birds. Pullets are usually raised on a floor covered with a bedding source, 1 to 4 inches deep. This litter mixture is either removed after each flock (20 to 21 weeks) or used for a second flock. If the litter is used for a second flock, a small amount of litter as cake is removed and the remaining litter is top dressed with an inch or so of new bedding material. When the house is totally cleaned out, the litter is pushed to the center of the house and a front loader places it in a litter spreader for land application or disposal. Regular and thorough house cleaning is required to minimize disease transmission.

Breeders. Houses are usually 40 to 45 feet in width and 300 to 600 feet in length. Most of the breeder houses contain two rows of slats for the birds to roost. The slats are panels of wood elevated 18 to 24 inches and laid across supports. The slats are spaced 1 inch apart to allow the feces material to fall to the floor. Equipment can access the center section of the house to aid in the clean-out between flocks. These slats cover two-thirds of the entire length of the house along the outside walls, with the center one-third of the building containing bedding litter.

The center third of the house is covered with 2 to 6 inches of a bedding source before young breeder layers are placed in the breeder house. Drinkers, mechanical feeders, and nests are placed over the slat section of the house, which allows most of the manure produced by the birds to fall beneath the slat area, keeping the area accessible to the birds cleaner.

4.2.1.4 *Broiler Waste Management Practices*

This section summarizes waste management practices for broiler, breeding stock, pullets, and roaster production facilities. Manure as excreted by the birds has a high water content, most of which evaporates. A typical broiler house with capacity for 22,000 birds at a time will produce 120 tons of litter per year. The litter consists mainly of wood chips or other organic plant matter even after it has been in place for a year (NCC, 1999).

Litter Clean-out Schedules. The litter (bedding and manure) of broiler, pullet, and roaster houses is typically cleaned out completely once a year, although there is a trend toward less frequent complete clean-outs. Between flocks, the feeders, waterers, and brooding equipment are winched to the ceiling. A machine is often used to clean out any clumps of litter (termed caking out) that may build up around waterers and feeders. When the broiler or roaster house is completely cleaned out, the litter is typically removed with a front-end loader or bobcat to a spreader truck or flail-type spreader. Spreader trucks are similar to lime-spreading trucks, with a moving bed that empties onto large, round metal plates that distribute the litter for use as fertilizer nutrients for pasture and crops. The rate of application is controlled by the rate at which the moving bed empties and the speed of the truck (NCSU, 1998).

The common clean-out frequency in broiler breeder houses is once a year. When the house is cleaned, all the equipment (including slats) is removed from the house to allow a front-end loader to push all of the manure to the center litter section of the house. Then a front-end loader places the mixture of manure and litter into a spreader for land application. A thorough cleaning after each flock (essentially once a year) removes pathogens that could be transferred to the next flock. After removal of all organic matter, the house is disinfected.

Litter Storage. Litter is removed from houses in large quantities during annual clean-out. Thus, operators that have land try to time the annual clean-out to coincide with the time land is available for litter application. If this approach is successful, the facility will need only enough storage for cake out during the rest of the year. Traditionally, operators stack litter outside, near the poultry houses or at the edge of fields for spreading in the spring.

However, an increasing number of states are imposing restrictions on the outdoor storage of waste, although the stringency of these requirements vary from state to state. For example, under Virginia's Poultry Waste Management Program, stockpiled poultry litter must be (1) covered, (2) located to prevent storm water runoff, and (3) separated a minimum of 3 feet from the seasonally high water table or by the use an impermeable barrier. Maryland's requirements for outdoor storage are less restrictive and require only that storage be conducted in manner to be protective from rainfall and runoff. The State of Delaware, which is also an important producer of poultry, is less restrictive than Maryland and allows for uncovered storage of poultry litter (Hansen, 2000).

There are several methods for storing poultry litter ranging from open stock piles to roofed-storage structures. The size and type of method employed varies with location and size of the operation as well as applicable regulations. Open stockpiles are the least expensive alternative, but pose the greatest risk of contaminating the surrounding environment. Contamination risk is reduced if these stockpiles are put on top of ground liners. Other storage structures include bunker-type storage structures, which are permanent aboveground concrete slabs with two parallel walls of concrete identical to those used for storing silage on livestock farms (Brodie et al., 2000). Storage structures with permanent roofs offer both advantages and disadvantages. These structures eliminate the need for plastic covers and reduce the risk of runoff contamination; however, they require a higher level of investment and higher maintenance costs than the other types of structures. Also if these roof structures are not high enough, compacting becomes more difficult and reduces the operator's ability to use the full capacity of the structure (Goan, 2000).

4.2.1.5 *Pollution Reduction*

New technologies in drinking water systems result in less spillage and are equipped with automatic shutoff valves that help ensure that broiler litter stays drier. Feeding strategies reduce the quantity of waste generated by ensuring that broilers do not receive more feed than required for optimal growth. State regulations have also driven many broiler operations to handle mortalities in ways other than burials such as rendering and composting, which are increasing (see Section 4.2.1.6).

Nipple water delivery systems reduce the amount of wasted water and are healthier for the animals. Trough or bell type watering devices allow the animal to spill water and add contaminants to the standing water. Nipple water systems deliver water only when the animal is sucking on the nipple. Watering systems may also use water pressure sensors with automatic shutoff valves to reduce water spillage. The sensor will detect a sustained drop in water pressure resulting from a break in the water line. The sensor will then stop the water flow to the broken line and an alarm will sound. The operator can then fix the broken line and restore water to the animals with minimal water spillage.

Feeding strategies that reduce nitrogen and phosphorus can reduce the quantity of nutrients in the excreta. Dietary strategies designed to reduce nitrogen and phosphorus include enhancing the digestibility of feed ingredients, genetic enhancement of cereal grains and other ingredients resulting in increased feed digestibility, more precise diet formulation, and improved quality control. Although nitrogen and phosphorus are currently the focus of attention, these strategies also have the potential to decrease other nutrients. Phytase is commonly added to broiler feed. Phytase additions are expected to achieve a reduction in phosphorus excretion of 20 to 60 percent depending on the phosphorus form and concentration in the diet (NCSU, 1998b). Protein content, calcium, other mineral content, vitamin B, as well as other factors identified in the literature influence the effectiveness of phytase use in feed. Additional information on feeding strategies for broilers can be found in Chapter 8.

Feeding Strategies. Phosphorus excretion can be reduced by improving the utilization of feed nutrients through genetic improvements in poultry or by improving the availability of nutrients in the feed ingredients through processing or genetics. Absorption of some minerals is relatively poor and is dependent on the chemical form in the feed or supplement.

4.2.1.6 *Waste Disposal*

This section summarizes waste disposal practices for poultry production facilities. The two major categories of poultry waste are manure or litter (manure mixed with bedding) and dead animals. There is little variation in manure characteristics, but the litter composition varies by storage, composting management, and other practices. Poultry litter can be disposed of in several ways including land application, animal feed, and incineration. Waste may be pelletized before its applied to the land. Pelletizing produces a more uniform product that is lighter, easily transported in bulk, and spread more uniformly. Additional information on pelletizing poultry wastes and other waste disposal methods can be found in Chapter 8.

Land Application of Poultry Litter. Land application of poultry litter recovers nutrients that otherwise would be lost and improves crop yields. Poultry manure slowly releases its nutrients, so annual applications are possible. Composting and bagging a pelleted poultry manure fertilizer produces a marketable product for the commercial horticulture industry. One main obstacle to greater commercialization of poultry manure as a fertilizer product has been the inconsistency in product quality from one facility to another.

Where land application is employed, operators commonly use broadcast spreaders and flail-type spreaders for litter. Recommended application rates are based on the nutrient content of the litter, crop type and yield goals, and current soil conditions.

Many producers with cropland apply their litter to their own crops. However, as operations have increased in size and have become more specialized, this option is becoming more limited. In some cases, poultry production provides supplemental income to an otherwise small or non-agricultural household with little or no land. Further exacerbating the problem of poultry litter disposal is the fact that many areas of chicken production have a surplus of nutrient supply over crop needs (USDA NRCS, 1998). In these areas, the poultry producers face difficulties in selling litter, giving litter away, or even paying local farmers to take the litter. The percentage of broiler operations with enough land and without enough land for application of manure on a nitrogen- and phosphorus-basis and operations with no land are shown in Table 4-48. The facilities that have "no land" were determined by running queries of the USDA 1997 Census of Agriculture data to identify facilities that did not grow any of the 24 major crops grown in the U.S. More details on the national and county level nutrient balance are found in Chapter 6.

Table 4-48. Percentage of Broiler Dominated Poultry Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Capacity (Number of Birds)	Sufficient Land		Insufficient Land		No Land
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	
1-29,999	11.92	9.6	37.7	40.07	50.37
30,000-59,999	6.38	2.9	53.52	56.99	40.09
60,000-89,999	4.78	2.1	57.39	6.008	37.82
90000-179,999	4.42	1	64.16	67.62	31.41
> 180,000	3.63	0.7	68.93	7.19	27.43
Total	5.39	2.3	59.97	62.69	35.02

Source: USDA NASS, 1999c

Use of Poultry Litter as Animal Feed. Data on the use of poultry litter as animal feed is inadequate to determine how prevalent it is as a waste disposal method. Anecdotal information indicates that use of poultry litter as a food supplement for beef herds may be common in the Mid-Atlantic and Southeast regions.

Incineration of Poultry Wastes. Incineration of poultry wastes is not done on a large scale in the U.S. The practice is being successfully implemented in the United Kingdom and is actively being investigated in the U.S. Additional information on centralized incineration of poultry wastes is presented in Chapter 8.

Disposal of Dead Animals. Concerns about possible ground water pollution from the burial of dead birds have caused the poultry industry to search for alternatives for dealing safely with dead stock. The most common methods of disposal of dead birds are composting, incineration, burial in deep pits, rendering, and disposal in landfills. Anecdotal information indicates that some broiler integrators have begun to distribute freezers to grower operations to store dead birds prior to pick up for rendering. Technical information on practices for the disposal of dead animals is presented in Chapter 8. However, there is little information available on the relative use of these practices within the broiler industry.

4.2.2 Layer Sector

This section describes the following aspect of the layer industry:

- 4.2.2.1: Distribution of the layer industry by size and region
- 4.2.2.2: Production cycles of layers and pullets
- 4.2.2.3: Layer facility types and management
- 4.2.2.4: Layer waste management practices
- 4.2.2.5: Egg processing and wash water
- 4.2.2.6: Pollution reduction
- 4.2.2.7: Waste disposal

National Overview. Trends in the egg production subsector have paralleled those in other livestock industries—increasing overall production on fewer and larger farms. At the end of 1997, there were 69,761 operations with hens and pullets of laying age in the U.S. (layers 20 weeks and older). This number represents a 19 percent decrease from the estimated 86,245 operations with egg-producing birds in 1992 (USDA NASS, 1999c). In the ten–year period from 1982 to 1992, the number of operations with hens and pullets declined from more than 212,000, a 60 percent decrease (Abt, 1998). Table 4-49 shows the number of operations and bird inventory for 1982, 1987, 1992, and 1997. The number of operations in each category of operation has decreased substantially while total production has increased. Table 4-49 also provides data on operations and inventory with birds below laying age. As with other sectors, specialization of production has gained a foothold, with a small but increasing number of operations producing only pullets.

One major difference between the layer and egg production sector and the broiler production sector is geographical distribution. Layer production, although primarily performed in 10 states, is much less geographically concentrated than the broiler industry. Hence, the key regions identified for the broiler industry in the previous section are not applicable to the layer and egg production sector. Overall, layer production has not increased as rapidly as has broiler production has.

Table 4-49. Operations With Inventory of Layers or Pullets 1982-1997.

Total Number of Farms with	1997		1992		1987		1982	
	Ops	Production	Ops	Production	Ops	Production	Ops	Production
Layers 20 weeks and older	69,761	313,851,480	86,245	301,467,288	141,880	316,503,065	212,608	310,515,367
Layer and pullets 13 weeks and older	72,616	366,989,851	88,235	351,310,317	144,438	373,577,186	215,812	362,464,997
Pullets between 13 and 20 weeks old	13,180	53,138,371	14,818	49,843,029	19,639	57,074,121	28,109	51,949,630
Pullets less than 13 weeks	5,122	51,755,985	4,938	44,567,993	6,753	47,409,798	8,726	40,705,085

Source: USDA NASS, 1999b

4.2.2.1 *Distribution of Layer Operations by Size and Region*

Layers are defined as chickens maintained for the production of table eggs. Eggs may be produced for human consumption in the shell form (sold in cartons) or may be used in the production of liquid, frozen, or dehydrated eggs. Laying hen operations include facilities that confine chickens for feeding or maintenance for at least 45 days in any 12-month period. These facilities do not have significant vegetation in the confinement area during the normal growing season. Facilities that raise pullets are generally included. Egg washing and egg processing facilities located at the same site as the birds are generally included. Facilities that have laying hen or pullet feeding operations may also include animal and agricultural operations such as grazing and crop farming.

EPA's 1974 CAFO Effluent Limitations Guidelines and Standards generally apply to laying hen operations with more than 100,000 birds and with continuous overflow watering systems, and to laying hen operations with 30,000 birds and with a liquid manure system. (See Chapter 2 for the definition of a CAFO, and Chapter 5 for a discussion of the basis for revisions to the poultry subcategories.) Where numbers of birds are presented, all birds regardless of age (e.g., poult, laying age, or pullet) or function (i.e., breeder, layer, meat-type chicken) are included unless otherwise indicated in the text.

Table 4-50 presents the number of layer, pullet, and combined operations by size class as well as the average bird count at each type of operation. Table 4-51 presents the number of operations with laying hens by operation size and region, and Table 4-52 presents the average number of birds at these operations. Data on the three types of operations were obtained through special queries of the 1997 Census of Agriculture (USDA NASS, 1999c). Each operation is uniquely characterized, thus the sum of all three provides the total number of operations with layers or pullets or both (75,172 total operations). Pullet operations were assumed to be evenly distributed so as to support layer operations. Thus the percentage of operations in a region from Table 4-51 is used to estimate the percentages of all layer and pullet operations in that region. Table 4-53 presents the distribution of egg laying chickens by facility size and region. It is important to note that in 1997 the 326 largest operations with laying hens were less than one half of a percent of the total operations (70,857) but had over 55 percent of the laying hens.

Table 4-50. Number of Operations in 1997 and Average Number of Birds at Operations with Layers or Pullets or Both Layers and Pullets in 1997

National Item	Number of Layer, Pullet, and combined Layer and Pullet Operations and Average Bird Counts (Operation Size Presented by Number of Birds Spot Capacity)					
	>0-30,000	>30,000-62,500	>62,500-180,000	>180,000-600,000	>600,000	Total
Layer Ops	57,413	528	419	146	25	58,531
Layer Count	926	43,621	103,048	311,189	1,013,318	
Pullet Ops [a]	3,694	516	61	44		4,315
Pullet Count	5,010	51,162	133,303	305,679		
Layer and Pullet Ops	12,011	67	93	91	64	12,326
Layer and Pullet Count	218	45,963	112,377	358,580	1,367,476	

[a] Pullet size ranges vary from the others: >0-30,000; >30,000-100,000; >100,000-180,000; and >180,000.
Source: USDA NASS, 1999c

Table 4-51. Number of Operations in 1997 With Laying Hens by Region and Operation Size in 1997

Region [a]	Number of Chicken Egg Laying Operations (Operation Size Presented by Number of Layers in Inventory)					
	>0-30,000	>30,000-62,500	>62,500-180,000	>180,000-600,000	>600,000	Total
Central	15,067	76	41	28	9	15,221
Mid Atlantic	17,445	150	133	48	15	17,791
Midwest	23,069	123	182	78	39	23,491
Pacific	6,509	38	66	39	17	6,669
South	7,334	208	90	44	9	7,685
National	69,424	595	512	237	89	70,857

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS, 1999c

Table 4-52. Average Number of Chickens at Operations in 1997 With Laying Hens by Region and Facility Size

Region [a]	Average Chicken Egg Layer Counts (Operation Size Presented by Number of Layers in Inventory)					
	>0-30,000	>30,000-62,500	>62,500-180,000	>180,000-600,000	>600,000	All Operations
Central	311	42,360	89,688	317,725	733,354	1,779
Mid Atlantic	911	42,588	95,585	286,946	1,007,755	3,590
Midwest	281	45,244	97,848	279,202	1,229,095	4,236
Pacific	115	43,613	99,354	277,755	813,356	5,041
South	3,654	38,642	97,413	293,512	884,291	8,390
National	787	41,786	96,595	287,740	1,027,318	4,072

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS, 1999c

Table 4-53. Distribution of Chickens at Operations in 1997 With Laying Hens by Region and Facility Size

Region [a]	Percentage of Total Chicken Egg Layer Counts (Operation Size Presented by Number of Layers in Inventory)					
	>0-30,000	>30,000-62,500	>62,500-180,000	>180,000-600,000	>600,000	Total
Central	1.62	1.12	1.27	3.08	2.29	9.38
Mid Atlantic	5.51	2.21	4.41	4.77	5.24	22.14
Midwest	2.25	1.93	6.15	7.55	16.61	34.49
Pacific	0.26	0.57	2.27	3.75	4.79	11.65
South	9.29	2.79	3.04	4.48	2.79	22.34
National	18.92	8.62	17.14	23.63	31.69	100.00

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS, 1999c

4.2.2.2 *Production Cycles of Layers and Pullets*

A layer is a sexually mature female chicken capable of producing eggs. Egg production can be divided into two types, table and hatching. Table eggs are used for consumption, and hatching eggs are used to supply broiler or layer production operations.

Traditionally, layers are kept through 1 year of egg production and sold for meat at 18 to 20 months of age. Depending on market conditions (relative price of eggs to hens), it has become increasingly common to recycle layers through more than 1 year of production (Bradley et al., 1998). Producers will recycle their flocks into a second or even a third cycle of lay. Flock recycling involves stopping the flock's egg production, allowing a suitable rest period, and then bringing the flock back into production. The entire process (called "force molting") of recycling layers takes approximately 4 to 5 weeks. Producers stop egg production by reducing the length of day (lighting) and feed supply. This period typically takes 2 to 4 weeks and involves a 7–day fast followed by a period during which the flock is fed a low calcium diet. After this "rest period," the flock is returned to normal lighting conditions and a nutritionally balanced diet to support egg production (UCD, 1998). Once the flock is brought back into production, most layers will meet or exceed original levels of egg production. Under this regime, the flock's life is extended for 6 to 12 additional months.

4.2.2.3 *Layer Facility Types and Management*

Litter-based Housing. A few litter and slat/litter houses are used to produce table eggs. These same housing systems are used for the breeders that produce fertile eggs for the production of hatching eggs, which eventually replace the current flock of egg layers.

Non-litter Based Housing. Layers are often raised in cages arranged in two or four decks. Cages have been the preferred way of housing table egg layers since the mid-1940s (Bradley et al., 1998). They are popular because they provide good sanitation. When the birds are caged, flock nutrition can be better managed and products (eggs) kept cleaner. Cages are designed to separate the layers from their own feces and thereby eliminate many of the feces-related parasite and health problems. Most commercial layer facilities employ one of the following designs.

High-rise Cage Systems. Cage systems are two-story poultry houses with cages for the laying hens in the top story suspended over the bottom story, where the manure is deposited and stored. The house structure itself is usually 40 to 60 feet wide and from 400 to 500 feet long. The watering system is a closed (noncontinuous flow) nipple or cup system. The ventilation system is designed so that the external air is brought into the top story, through the cages where the birds are located, and then over the manure in the bottom story, exiting through fans in the bottom story side wall. The ventilation system is designed to dry manure as it is stored. With proper management of waterers to prevent water leaking to the bottom story, layer waste commonly has a moisture content of 30 to 50 percent.

Scrape-out and Belt Systems. Housing facilities for scrape-out and belt manure removal cage systems are the same dimensions as high-rise units except they have only one story. Watering systems in these operations are also closed, using nipple or cup waterers. Ventilation varies from fan-controlled to adjustable curtains in the side wall.

Cages in the scrape-out system are suspended over a shallow pit, which is scraped out to the end of the house by a small tractor or a pit scraper. Belt systems have a continuous belt under the different tiers of cages that moves the manure to the end of the house, where it is placed into a field spreader or some other suitable storage device. Some of the newer belt systems move air over the manure on the belt in an attempt to dry the manure before it is removed.

The manure from scrape-out and belt systems usually has a moisture content of between 70 and 85 percent. Therefore, the manure can be handled as a slurry, which is either injected or land applied to the land with a spreader that can handle the high-moisture manure.

Flush-Cage Housing. Housing, equipment, and ventilation in flush-cage housing are similar to the scrape-out system with the exception of how the manure is handled. Cages are suspended over a shallow pit as in the scrape-out system, but water is used to move the manure from under the cages to the end of the house, where the water and manure mixture is placed in an anaerobic lagoon. The water used to flush the manure pits is recycled from the lagoon. A variation of this system consists of solids separation by means of a primary lagoon and a secondary lagoon. (NCSU, 1998a).

Although storage, management, and disposal practices are quite similar for broiler and layer operations, with the exception of layer operations using lagoon systems, there are regional differences in how operations manage waste. A survey conducted by the United Egg Producers during 1998 indicated significant regional differences in the way layer wastes are managed. These differences are shown in Table 4-54. This data was used with the data in Table 4-51 to estimate that the total number of layer operations that use water to move the wastes to a lagoon (referred to as wet layer systems) was approximately 3,100 operations.

Table 4-54. Summary of Manure Storage, Management, and Disposal

Practice	**Percentage of Region With Practice**				
	Pacific	**Central**	**Midwest**	**Mid-Atlantic**	**South**
Storage sheds in addition to high-rise housing	0	0	10	0	0
Housing with 6-month or longer storage of dry manure	75	40	90	90	40
Export or sale of some or all of litter	100	40	100	75	50
Litter use other than land application (incineration, pelletization)	0	0	5	5	0
Farms with wet storage systems, such as lagoon	0	60	2	5	60

Source: UEP, 1998

4.2.2.4 *Layer Waste Management Practices*

Manure handling systems vary by region. In 1999 the USDA's Animal and Plant Health Inspection Service completed the Layers '99 Study (USDA APHIS, 2000b), which looked at a 15-state target population to develop information on the nation's table egg layer population. The 15 states accounted for over 75 percent of the table egg layers in the U.S. on December 1, 1998. The information collected was summarized by four regions. The data collected on the manure handling methods of layer facilities are presented in Table 4-55.

Table 4-55. Frequency of Primary Manure Handling Method by Region

Primary Manure Handling Method	Great Lakes		Southeast		Central		West		All Farms	
	%	SE	%	SE	%	SE	%	SE	%	SE
High-rise (pit at ground level with house above	63.0	12.3	31.4	6.0	48.1	6.0	7.8	2.1	39.7	4.4
Deep pit below ground	0.0	--	0.0	--	6.4	3.9	7.3	2.5	2.9	1.0
Shallow pit (pit at ground level with raised cages)	23.4	9.6	19.9	7.3	1.6	1.2	24.1	7.2	18.9	4.4
Flush system to lagoon	0.0	--	41.0	5.9	0.0	--	12.0	3.6	12.5	2.5
Manure belt	13.6	6.7	4.3	2.1	20.2	4.9	5.2	1.5	10.6	2.7
Scraper system (not flush)	0.0	--	2.5	2.1	23.7	8.7	43.6	6.4	15.4	2.6
Total	100		100		100		100		100	

Regions: Great Lakes: IN, OH, and PA; Southeast: AL, FL, GA, and NC; Central: AR, IA, MN, MO, and NE; West: CA, TX, WA.
SE = Standard Error
Source: USDA APHIS, 2000b

4.2.2.5 *Layer Egg Wash Water*

The majority of eggs marketed commercially in the U.S. are washed using automatic washers. Cleaning compounds such as sodium carbonate, sodium metasilicate, or trisodium phosphate, together with small amounts of other additives, are commonly used in these systems. In addition, plants operating under the Federal Grading Service are required to rinse eggs with a sanitizer following washing (Moats, 1981). Wash water is contaminated with shell, egg solids, dirt, manure, and bacteria washed from the egg surface into the recycled water.

A study by Hamm et al. (1974), performed to characterize the wastewater from shell egg washers, calculated the pollutant load from 11 egg grading and egg breaking plants. Median waste concentrations in the wash waters at the grading plants were found to be 7,300 mg/L for chemical oxygen demand, 9,300 mg/L for total solids, and 4,600 mg/L for volatile solids; median concentrations at the breaking plants were found to be 22,500 mg/L for chemical oxygen demand, 27,000 mg/L for total solids, and 16,600 mg/L for volatile soilds.

Eggs may be washed either on farm or off farm. Operations that wash their eggs on farm may do so in-line or off-line. The frequency of the egg processing location is presented in Table 4-56. The frequency of egg processing location by operation size is presented in Table 4-57. The eggs from over 80 percent of the operations are processed off site. Operations with fewer than 100,000 layers are more likely to have their eggs processed off site. Smaller poultry operations primarily haul their wash water to treatment centers or sell their eggs to larger operations for washing and processing (Thorne, 1999). On the other hand, larger egg production operations collect and store egg wash water on site in large tanks or lagoons for treatment and storage. This lagoon water may then be applied to fields using spray irrigation. These anaerobic lagoons are earthen structures designed to provide biological treatment and long-term storage of poultry layer waste. Treatment of waste occurs anaerobically, a process in which organic material is decomposed to carbon dioxide and water, while stabilized products, primarily humic substances, are synthesized. Where space is available, two-stage lagoons may be constructed for better wastewater treatment and greater management flexibility. The first stage thus contains only the treatment (permanent) volume and sludge volume while the second stage lagoon stores treated wastewater for irrigation and provides additional treatment that produces a higher quality effluent for recycling as flush water (Tyson, 1996).

Table 4-56. Percentage of Operations by Egg Processing Location and Region

Primary Egg Processing Location	Great Lakes		Southeast		Central		West		All	
	%	SE	%	SE	%	SE	%	SE	%	SE
On farm in-line	17.8	8.4	13.1	4.3	9.0	3.2	10.9	2.4	13.5	3.0
On farm off-line	6.7	5.4	0.6	0.6	3.3	3.3	9.3	2.4	5.3	2.1
Off farm	75.5	8.1	86.3	4.4	87.7	4.5	79.8	3.6	81.2	3.2
Total	100	--	100	--	100	--	100	--	100	--

Regions: Great Lakes: IN, OH, and PA; Southeast: AL, FL, GA, and NC; Central: AR, IA, MN, MO, and NE; West: CA, TX, WA.
SE = Standard Error
Source: USDA APHIS, 2000b

Table 4-57. Percentage of Operations by Egg Processing Location and Operation Size

Primary Egg Processing Location	Egg Laying Operations with <100,000 Layers		Egg Laying Operations with 100,000+ Layers	
	%	SE	%	SE
On farm in-line	4.3	2.8	28.9	5.6
On farm off-line	5.2	3.1	5.5	1.9
Off farm	90.5	4.1	65.6	6.0
Total	100	--	100	--

Regions: Great Lakes: IN, OH, and PA; Southeast: AL, FL, GA, and NC; Central: AR, IO, MN, MO, and NE; West: CA, TX, WA.
SE = Standard Error
Source: USDA NAHMS, 2000

4.2.2.6 *Waste and Wastewater Reductions*

Methods to reduce the quantity of wastewater generated at layer operations include advanced watering systems to reduce water spillage and feeding strategies. The use of feeding strategies will reduce the quantity of waste generated by ensuring that animals do not receive more feed than required for optimal growth. Dietary strategies to reduce nitrogen and phosphorus content include developing more precise diets and improving the digestibility of feed ingredients through the use of enzyme additives and genetic enhancement of cereal grains. Information on feeding strategies for layer operations can be found in Chapter 8.

There are several types of water delivery systems used in layer operations. Nipple water delivery systems reduce the amount of wastewater and result in healthier birds. Trough or cup drinkers allow the bird to spill water and add contaminates to the standing water. Continual overflow watering systems reduce the health risk to the birds but produce a greater quantity of wastewater.

Nipple water delivery systems are placed in the cage and deliver water only when the bird is sucking on the nipple. Approximately 62 percent of all layer operations use nipple drinker systems (USDA APHIS, 2000b). However, for layer operations with more than 100,000 birds this number increases to approximately 81.5 percent (USDA NAHMS, 2000). Watering systems may also use water pressure sensors and automatic shutoff valves to reduce water spillage. The sensor will detect a sustained drop in water pressure resulting from a break in the water line. The sensor will then stop the water flow to the broken line and an alarm will sound. The operator can then fix the broken line and restore water to the animals with minimal water spillage. There is little information about the relative use of water pressure sensors within the layer industry.

4.2.2.7 *Waste Disposal*

Practices for the disposal of layer wastes are similar to those for other poultry litter. After removal from the housing facilities, waste can be directly applied to the land (if available), stored prior to final disposal, or pelletized and bagged for use as commercial fertilizer. Waste storage, application of litter, and other poultry waste disposal practices are discussed in detail in Section 4.2.1.6. The percentage of layer and pullet operations with and without enough land for application of manure on a nitrogen- and phosphorus-basis and operations with no land are shown in Tables 4-58 and 4-59. The facilities that have "no land" were determined by running queries of the USDA 1997 Census of Agriculture data to identify facilities that did not grow any of the 24 major crops grown in the U.S.

Table 4-58. Percentage of Layer Dominated Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Capacity (Number of Birds)	Sufficient Land		Insufficient Land		No Land
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	
1-29,999	12.2	9.2	49.1	53	41.1
30,000-59,999	6.8	1	60.3	65	33.2
60,000-179,999	6.2	0	52	62.2	36.8
> 180,000	1.1	0	46.6	47.1	52.9
Total	10.5	6.9	49.5	57.5	38.8

Source: USDA NASS, 1999c

Table 4-59. Percentage of Pullet Dominated Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Capacity (Number of Birds)	Sufficient Land		Insufficient Land		No Land
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	
1-29,999	11.6	5.9	47.3	53	41.1
30,000-59,999	11.9	1.7	54.9	65	33.2
60,000-179,999	14.1	1.1	49.2	62.2	36.8
> 180,000	2	0	45.1	47.1	52.9
Total	11.6	3.7	49.5	57.5	38.8

Source: USDA NASS, 1999c

Mortality and the disposal of dead hens is a potentially significant source of contamination at laying operations. A total of 6.5 percent of hens placed in the last completed flock (one flock per farm site) died by 60 weeks of age and overall the average cumulative mortality was 14.6 percent (USDA APHIS, 2000b). The common methods of disposing of dead hens and frequency of use are presented in Table 4-60. Tables 4-61 and 4-62 present this information for operations with fewer than and more than 100,000 laying hens. Larger facilities are much more likely than smaller facilities to send dead birds to rendering plants (50.2 percent versus 21.1 percent). While smaller facilities are more likely than larger facilities to bury their dead birds (45.6 percent versus 9.1 percent).

Table 4-60. Frequency of Disposal Methods for Dead Layers for All Facilities

Method of Disposal	Farm Sites		Dead Hens	
	Percent	Std Error	Percent	Std Error
Composting	15.0	(3.5)	11.7	(4.1)
Incineration	9.0	(2.9)	10.4	(4.5)
Covered deep pit	32.0	(5.8)	17.9	(4.3)
Rendering	32.0	(4.9)	41.4	(8.6)
Other	16.1	(3.6)	18.6	(5.4)
Total	--		100.0	

Source: USDA APHIS, 2000b

Table 4-61. Frequency of Disposal Methods for Dead Layers for Facilities With <100,000 Birds

Method of Disposal	Farm Sites		Dead Hens	
	Percent	Std Error	Percent	Std Error
Composting	13.9	4.7	13.4	7.5
Incineration	9.3	4.2	19.8	9.8
Covered deep pit	45.6	7.2	36.4	8.3
Rendering	21.1	4.5	19.7	6.0
Other	14.0	4.7	10.7	3.8
Total	--	--	100.0	--

Source: USDA NAHMS, 2000

Table 4-62. Frequency of Disposal Methods for Dead Layers for Facilities With >100,000 Birds

Method of Disposal	Farm Sites		Dead Hens	
	Percent	Std Error	Percent	Std Error
Composting	16.8	4.6	10.6	4.4
Incineration	8.7	3.3	4.6	2.5
Covered deep pit	9.1	2.2	6.5	2.5
Rendering	50.2	7.2	54.8	10.9
Other	19.7	5.8	23.5	8.7
Total	--	--	100.0	--

Source: USDA NAHMS, 2000

4.2.3 Turkey Sector

This section describes the following aspects of the turkey industry:

- 4.2.3.1: Distribution of the turkey industry by size and region
- 4.2.3.2: Production cycles of turkeys
- 4.2.3.3: Turkey facility types and management
- 4.2.3.4: Turkey waste management practices
- 4.2.3.5: Pollution reduction
- 4.2.3.6: Waste disposal

National Overview

Turkey production has increased steadily over the past 2 decades, and as in the other poultry sectors, there has been a shift in production to fewer but larger operations. Between 1982 and 1997, almost 21 percent of the turkey operations went out of business (USDA NASS, 1998b). As shown in Table 4-63, the number of turkey operations decreased from 12,708 operations in 1992 to 12,207 operations in 1997, a 4 percent decrease. The number of turkeys produced rose approximately 10 percent between 1992 and 1997. The number of hens held for breeding, however, decreased by almost 6 percent during the same period.

As in the broiler industry, most turkeys are produced under contract production arrangements. For each contract arrangement, an integrator company provides the birds, feed, medicines, bird transport, and technical help. The contract producer provides the production facilities and labor to grow the birds from hatchlings to market-age birds. In return, the contract producer receives a guaranteed price, which may be adjusted up or down based on the performance of the birds compared with that of other flocks produced or processed by the company during the same span of time. Some turkeys are raised by independent turkey producers. Even under this type of production, however, the independent producer may arrange for feed, poults, medical care, and possibly processing, through contracts. Finally, some turkeys are produced on farms owned by the integrator company. The integrator company may also be the company that processes the birds; however, some turkey integrators provide all services except the processing, which the integrator arranges with a processing company.

Table 4-63. Turkey Operations (Ops) in 1997, 1992, 1987, and 1982 With Inventories of Turkeys for Slaughter and Hens for Breeding

Total Farms With	1997		1992		1987		1982	
	Ops	Production	Ops	Production	Ops	Production	Ops	Production
Turkeys	6,031	307,586,680	6,257	279,230,136	7,347	243,336,202	7,498	172,034,935
Turkeys sold for slaughter	5,429	299,488,350	5,658	272,831,801	6,813	238,176,199	6,838	167,540,306
Turkey hens kept for breeding	747	8,098,330	793	6,398,335	761	5,160,003	1,040	4,494,629

Source: USDA NASS, 1998b

4.2.3.1 *Distribution of Turkey Operations by Size and Region*

EPA's 1974 CAFO Effluent Limitations Guidelines and Standards generally apply to turkey operations with more than 55,000 birds. (See Chapter 2 for the definition of a CAFO, and Chapter 5 for a discussion of the basis for revisions to the poultry subcategories.) Where numbers of birds are presented, all birds regardless of age (e.g., poult, laying age, or pullet) or function (i.e. breeder, layer, meat-type birds) are included unless otherwise indicated in the text.

The consolidation of the turkey industry has mirrored that of other livestock industries. The number of turkey farms with fewer than 30,000 birds decreased from 5,113 in 1987 to only 3,378 in 1997 (USDA NASS, 1999b). Concurrently, the number of operations with more than 60,000 birds increased 26 percent from 1232 in 1987 to 1671 in 1997. Although these changes are not as dramatic as those for the swine or broiler industry, they are indicative of an industry that is undergoing a steady transformation into one dominated by large integrated operations.

Table 4-64 presents the number of turkey operations in 1997 by size and region. Table 4-65 presents the average number of birds at these operations, and Table 4-66 presents the distribution of turkey production by size of operation and region. It is important to note that the 369 largest operations (2.7 percent) had 43.6 percent of the total turkey count. These tables reflect the use of 2.5 turns (flocks) per year. USDA NASS performed an analysis for EPA to estimate how variations in the estimated of number of turns per year would change the number of potential CAFOs (operations with more than 55,000 birds). This analysis showed that there would be only minor changes to the estimated number of CAFOs if the estimated number of turns was adjusted to two or three turns.

State-level data from the 1997 Census of Agriculture (USDA NASS, 1999b) indicate that states in the Midwest and Mid-Atlantic regions account for more than 70 percent of all turkeys produced. Key production states (determined by number of turkeys produced) are North Carolina, Minnesota, Virginia, Arkansas, California, and Missouri. Other states with significant production include Indiana, South Carolina, Texas, Pennsylvania, and Iowa.

Table 4-64. Number of Turkey Operations in 1997 by Region and Operation Size

Region [a]	Number of Turkey Operations by Size (Operation Size Presented by Number of Birds Spot Capacity)				
	>0-16,500	>16,500-38,500	>38,500-55,000	>55,000	Total
Central	2,301	54	19	34	2,408
Mid-Atlantic	3,265	597	143	83	4,088
Midwest	4,016	493	121	142	4,772
Other	2,035	222	83	110	2,450
National	11,617	1,366	366	369	13,718

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other=WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS, 1999c

Table 4-65. Average Number of Birds at Turkey Operations in 1997 by Region and Operation Size

Region [a]	Average Turkey Counts by Operation Size (Operation Size Presented by Number of Birds Spot Capacity)				
	>0-16,500	>16,500-38,500	>38,500-55,000	>55,000	All Operations
Central	311	25,420	47,310	172,416	3,675
Mid-Atlantic	1,705	24,903	45,193	97,111	8,551
Midwest	1,231	24,303	45,469	158,365	9,413
Other	818	26,310	45,520	116,295	9,827
National	1,110	24,936	45,486	133,340	8,223

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other=WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS, 1999c

Table 4-66. Distribution of Turkeys in 1997 by Region and Operation Size

Region [a]	Percentage of Total Turkey Counts by Operation Size (Operation Size Presented by Number of Birds Spot Capacity)				
	>0-16,500	>16,500-38,500	>38,500-55,000	>55,000	Total
Central	0.64	1.22	0.80	5.20	7.85
Mid-Atlantic	4.93	13.18	5.73	7.15	30.99
Midwest	4.38	10.62	4.88	19.94	39.82
Other	1.48	5.18	3.35	11.34	21.34
National	11.43	30.20	14.75	43.62	100.00

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other=WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS 1999c

4.2.3.2 *Production Cycles of Turkeys*

The growth of a turkey is commonly divided into two phases: brooding and grow out. The brooding phase is the period of the poult's life extending from 1 day to about 6-8 weeks. During this time, the poults are unable to maintain a constant body temperature and need supplemental heat. Brooder stoves are used to keep the ambient temperature at 90 to 95 °F when the poults arrive; thereafter, the producer decreases the temperature by 5 °F for the next 3 weeks until the temperature reaches 75 °F. Poults are extremely susceptible to disease and are typically administered special starter feeds containing antibiotics and a high percentage of protein. A difference between turkeys and broilers is that feeding strategies such as the use of phytase to reduce phosphorus content in waste is not employed with turkeys through the entire life cycle because phytase is thought be some to inhibit bone development in poults. As with the broiler industry, further research in diet, nutrition, and the complex relationships between calcium, vitamins, and phosphorus may overcome this limitation.

The grow-out phase is the period in a turkey's life between the brooding phase and the market or breeding phase. Depending on the sex of the birds, the grow-out phase typically lasts up to 14 weeks. Modern turkeys grow rapidly. A tom (male turkey) poult weighs about ¼ pound at birth; at 22 weeks it weighs almost 37 pounds. Hens (female turkey) are usually grown for 14 to 16 weeks and toms from 17 to 21 weeks before being marketed. Most operators start fewer toms than hens in a given house to allow more space for the larger birds.

4.2.3.3 *Turkey Facility Types and Management*

Market and breeder turkeys are raised in similar housing systems. Typically, young turkey poults are delivered to the operation on the day of or the day after hatching. The poults are placed in barns called brooder houses. The brooder houses for turkeys are usually as wide as broiler and pullet houses but are usually only 300 to 400 feet long. The houses have an impermeable floor surface made of either clay or cement. The floors are then covered with 3 to 4 inches of bedding.

As with broilers, ventilation is usually provided by a negative-pressure system, with exhaust fans drawing air out of the house and fresh air returning through ventilation ducts around the perimeter of the roof. Some turkey houses have side curtains that can be retracted to allow diffusion of air. More advanced ventilation systems use exhaust fans controlled by a thermostat and timer. Brooding heaters are normally present in one-third to one-half of the house, for the early stages of development. As the poults get older, they are usually released into the other two-thirds or half of the house and remain there until they are of market age. In some operations the poults are moved to a specially designed grower house, where they stay until they are of market age. Some operations will move poults to range.

The construction of the housing facilities varies by region and depends on climatic conditions and production practices. Generally, in the southern and southeastern U.S. the houses are more open. The side walls of the houses are 6 to 8 feet high, with a 4- to 5- foot-wide opening covered by wires and curtains. Since moderate winters are normal in the South and Southeast, the curtains can contain the heat necessary to maintain a reasonable temperature within the commercial poultry houses. In the northern and central states, most houses have solid side walls and contain considerable insulation to combat the colder temperatures. These houses rely on exhaust fans or moveable solid side walls during the hot summer days to diminish the effects of heat stress on the birds.

These traditional systems are called two-age farms because two ages of birds can be on the farm at one time. Once the poults have been moved to the grower barn, the brooder house is totally cleaned out for another group of poults. This cleanup includes removal of all litter used during the brooding phase. The second group of poults occupies the brooder house while the first group of birds is still in the grower barn. Operations in the Shenandoah Valley area of Virginia and

West Virginia are known to use a modification of the typical two-age management system. Under this system the houses are longer. Poults may occupy one end of the house, while an older group is being grown out at the other end. The birds do not have to be moved as often under this system.

The two-age farm system has served the turkey industry for more than 20 years. Currently, however, there are efforts to modify this system because of morbidity and mortality. The modifications are directed at raising older birds in facilities removed from the poults. This approach provides an opportunity to break any disease cycle that might put the birds, especially the younger ones, at increased risk for disease (USEPA, 1998).

4.2.3.4 *Turkey Waste Management Practices*

For brooder facilities, the litter is removed after every flock of brooded poults. This practice is necessary to provide the next group of poults with clean bedding to achieve the lowest possible risk of disease exposure. Poult litter many be composted between flocks to control pathogens and then reused in the grow out houses. For grower systems, the litter is removed once a year. In between flocks, cake is removed and the old litter may be top-dressed with a thin layer of new bedding. For single-age farms, the bedding in the brooding section is moved to the grower section. New bedding is put in the brooder section, and the facilities are prepared for the next group of poults.

4.2.3.5 *Pollution Reduction*

New technologies in drinking water systems result in less spillage and ensure that turkey litter stays drier. Feeding strategies will also reduce the quantity of waste generated by ensuring that turkeys do not receive more feed than required for optimal growth. State regulations have also driven many turkey operations to handle mortalities in ways other than burial such as rendering and composting, which are on the rise (see Section 4.2.3.6).

Nipple water delivery systems reduce the amount of wasted water and are healthier for the animals. Trough or bell type watering devices allow the animal to spill water and add contaminants to the standing water. Nipple water systems deliver water only when the animal is sucking on the nipple. Watering systems may also use water pressure sensors and automatic shutoff valves to reduce water spillage. The sensor will detect a sustained drop in water pressure resulting from a break in the water line. The sensor will then stop the water flow to the broken line and an alarm will sound. The operator can then fix the broken line and restore water to the animals with minimal water spillage.

Feeding strategies can be used to reduce the quantity of nutrients in the excreta. Dietary strategies designed to reduce nitrogen and phosphorus include enhancing the digestibility of feed ingredients, genetic enhancement of cereal grains and other ingredients resulting in increased feed digestibility, more precise diet formulation, and improved quality control. Although nitrogen and phosphorus are currently the focus of attention, these strategies also have the potential to decrease other nutrients. There is debate on the impacts of phytase feed supplements for turkey poults concerning bone growth and bone development. Phytase additions are expected to achieve a reduction in phosphorus excretion of 20 to 60 percent depending on the phosphorus form and concentration in the diet (NCSU, 1999b). Protein content, calcium, other mineral content, vitamin B, as well as other factors identified in the literature influence the effectiveness of phytase use in feed. Additional information on feeding strategies for turkeys can be found in Chapter 8.

4.2.3.6 *Waste Disposal*

Practices for the disposal of turkey litter are similar to those for other poultry litter. After removal from the housing facilities, waste can be directly applied to the land (if available), stored prior to final disposal, or pelletized and bagged for use as commercial fertilizer. Waste storage, application of litter, and other poultry waste management practices are discussed in detail in Section 4.2.1.4. The percentage of turkey operations with and without enough land for application of manure on a nitrogen- and phosphorus-basis and operations with no land are shown in Table 4-67. The facilities that have no land were determined by running queries of the USDA 1997 Census of Agriculture data to identify facilities that did not grow any of the 24 major crops grown in the U.S.

Table 4-67. Percentage of Turkey Dominated Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Capacity (Number of Birds)	Sufficient Land:		Insufficient Land:		No Land
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	
1-16,499	15.6	5.9	52.5	62.2	31.8
16,500-38,499	6.8	0.3	65.4	71.9	27.9
38,500-54,999	4.1	0	65.5	69.9	30.4
> 55,000	3	0	58.1	61.1	38.9
Total	9.4	2.4	59.5	66.5	31.1

Source: USDA NASS, 1999c

Disposal of dead birds can be handled through composting, incineration, burial in deep pits, rendering, and disposal in landfills. Technical information on practices for the disposal of dead animals is presented in Chapter 8; however, there is little information available on the relative use of these practices within the turkey industry.

4.3 Dairy Industry

Dairy animal feeding operations include facilities that confine dairy cattle for feeding or maintenance for at least 45 days in any 12-month period, and do not have significant vegetation in the area of confinement. Dairies may also perform other animal and agricultural operations that are not covered by the existing dairy effluent guidelines, including grazing, milk processing, and crop farming.

This section discusses the following about dairy operations:

- Section 4.3.1: The distribution of dairy operations by size of operation and region in 1997
- Section 4.3.2: Dairy production cycles
- Section 4.3.3: Stand-alone heifer raising operations
- Section 4.3.4: Dairy facility management practices
- Section 4.3.5: Dairy waste management practices
- Section 4.3.6 lists the references used in this section

4.3.1 Distribution of Dairy Operations by Size and Region

Current effluent limitations guidelines and standards apply to dairy operations with a capacity of 700 or more mature dairy cattle (both lactating and dry cows), where the animals are fed at the place of confinement and crop or forage growth or production is not sustained in the confinement area.

Information presented in this section comes from USDA's National Agricultural Statistics Service (NASS), 1997 Census of Agriculture data, and from site visits and trade associations. The 1993 to 1997 NASS reports on dairy operations present the number of dairies by size class; however, dairy operations with more than 200 mature dairy cattle are grouped in one size class; therefore, an analysis of dairy operations that fall under the current effluent guidelines regulations (i.e., those with more than 700 milking cows) cannot be completed with NASS data alone. Data from the 1997 Census of Agriculture provide some additional information on medium and large (more than 200 milking cows) dairy operations. Although the NASS and Census data do not match exactly, EPA has found that there is generally a good correlation between the two data sets. EPA used the Census data to estimate farm counts.

From 1988 to 1997, the number of dairies and milking cows in the U.S. decreased while total milk production increased. Improved feeding, animal health, and dairy management practices have allowed the dairy industry to continue to produce more milk year with fewer milking cattle. Since 1988, the total number of milking cows has decreased by 10 percent and the total number of dairy operations has decreased by 43 percent, indicating a general trend toward consolidation (USDA NASS, 1995b; 1999d).

Between 1993 and 1997, the number of operations with fewer than 200 milking cows decreased, while the number of operations with 200 milking cows or more increased. Both NASS and the 1997 Census of Agriculture have collected data that quantify the changes by size class. Based on the NASS data, the number of operations with 200 milking cows or more increased by almost 7 percent between 1993 and 1997, while all smaller size classes decreased in numbers of operations. Table 4-68 shows the estimated distribution of dairy operations by size and region in 1997, and Table 4-69 shows the total number of milk cows and average cow herd size by size class in 1997. EPA derived the data in these tables from the Census data (ERG, 2000b).

According to Census of Agriculture data, of the 116,874 dairy operations across all size groups in 1997, Wisconsin had the most with 22,576 (19 percent), followed by Pennsylvania with 10,920 (9 percent), Minnesota with 9,603 (8 percent), and New York with 8,732 (7 percent). Table 4-70 presents the number of dairies by top-producing states for the following size groups:

- 1 to 199 milk cows;
- 200 to 349 milk cows;
- 350 to 700 milk cows; and
- more than 700 milk cows.

Of the large dairies (more than 700 milking cows), California has the most operations (46 percent), and of the medium dairies (200 to 700 milking cows), California, New York, Wisconsin, and Texas have the most operations.

Table 4-71 shows the annual milk production in 1997 for the top-producing states. Although California has only 2,650 dairy farms in all, it is the largest milk-producing state in the U.S., according to NASS data and data received from the National Milk Producers Federation (National Milk Producers, 1999; USDA NASS, 1999d).

Table 4-68. Distribution of Dairy Operations by Region and Operation Size in 1997

	Number of Operations				
Region[a]	**0-199 Milk Cows**	**200-349 Milk Cows**	**350-700 Milk Cows**	**> 700 Milk Cows**	**Total**
Central	9,685	593	433	404	11,115
Mid-Atlantic	32,490	870	487	81	33,928
Midwest	59,685	943	497	90	61,215
Pacific	2,875	722	725	786	5,108
South	5,001	253	170	84	5,508
National	109,736	3,381	2,312	1,445	116,874

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL

Table 4-69. Total Milk Cows by Size of Operation in 1997

Size Class	Number of Operations	Total Number of Milk Cows	Average Milk Cow Herd Size
0-199 Milk Cows	109,736	5,186,000	47
200-349 Milk Cows	3,381[a]	795,000	235
350-700 Milk Cows	2,312[a,b]	1,064,000	460
> 700 Milk Cows	1,445[b]	2,050,455	1,419
Total United States	116,874	9,095,455	78

[a] Estimated value. Published Census of Agriculture data show 4,881 dairies with 200-499 milk cows. Assumes approximately 70 percent have 200-349 milk cows and 30 percent have 350-500 milk cows.
[b] Estimated value. Published Census of Agriculture data show 1,379 dairies with 500-999 milk cows. Assumes approximately 60 percent have 500-699 milk cows and the remainder have 700-1,000 milk cows.

Table 4-70. Number of Dairies by Size and State in 1997

Location	Size Class				Total
	1-199 Milk Cows	200-349 Milk Cows	350-700 Milk Cows	>700 Milk Cows	
California	969	471	547	663	2,650
Florida	495	51	58	62	666
Idaho	1,105	119	90	90	1,404
Michigan	3,743	144	81	22	3,990
Minnesota	9,379	135	75	14	9,603
New York	8,162	319	194	57	8,732
Pennsylvania	10,693	148	71	8	10,920
Texas	3,562	266	188	97	4,113
Washington	925	175	130	72	1,302
Wisconsin	22,041	333	171	31	22,576
Total United States	109,736	3,381	2,312	1,445	116,874

Table Table 4-71. Milk Production by State in 1997

Location	Total Milk Production (million pounds)	Milk Produced Per Cow (pounds)
California	27,582	19,829
Florida	2,476	15,475
Idaho	5,193	19,092
Michigan	5,410	17,680
Minnesota	9,210	16,186
New York	11,530	16,495
Pennsylvania	10,662	16,951
Texas	5,768	15,259
Washington	5,305	20,968
Wisconsin	22,368	16,057
Total United States	156,091	16,871

4.3.2 Dairy Production Cycles

The primary function of a dairy is the production of milk, which requires a herd of mature dairy cows that are lactating. In order to produce milk, the cows must be bred and give birth. Therefore, a dairy operation may have several types of animal groups present, including:

- Calves (0 to 5 months)
- Heifers (6 to 24 months)
- Cows that are close to calving (close-up cows)
- Lactating dairy cows
- Dry cows
- Bulls

Most dairies operate by physically separating and handling their animals in groups according to age, size, milking status, or special management needs. This separation allows each group to be treated according to its needs. Section 4.3.2.1 presents a description of the typical mature dairy herd, and Section 4.3.2.2 discusses the immature animal groups that may also be present at the dairy.

4.3.2.1 *Milk Herd*

The dairy milk herd is made up of mature dairy cows that have calved at least once. These mature cows are either lactating or "dry" (not currently producing milk). After a cow has calved, the milk she initially produces (called "colostrum") contains higher amounts of protein, fat, minerals, and vitamins than normal milk. The colostrum is usually collected and fed to the calves. After about 4 days, the milk returns to normal and the cow rejoins the lactating cow herd.

After being milked for about 10 to 12 months after calving, the cows go through a dry period. These dry periods allow the cow to regain body condition and the milk secretory tissue in the udder to regenerate. The dairy industry has reported an average of 60.5 days of dry period per cow (USDA APHIS, 1996a).

Periodically, all dairies must cull certain cows that are no longer producing enough milk for that dairy. Cows are most often culled for the following reasons: reproductive problems; udder or mastitis problems; poor production for other reasons; lameness or injury; disease; or aggressiveness or belligerence. In 1995, an average of 24 percent of the herd was culled from all size operations (USDA APHIS, 1996a). Dairies in high milk-producing regions (e.g., California) have reported during site visits cull rates of up to 40 percent.

Some dairies decide when a cow is to be culled by determining a milk break-even level (pounds of milk per cow per day). Approximately 28 percent of dairies use this practice and reported an average milk break-even level of approximately 33 pounds per cow per day. The milk break-even levels ranged from 32.5 pounds per cow per day at small dairies (less than 100 head) up to 36.5 pounds per cow per day at larger dairies (200 or more head) (USDA APHIS, 1996a).

Nearly all culled cows (approximately 96 percent) are sent away for slaughter. Approximately 74 percent are sent to a market, auction, or the stockyards. Others (21 percent) are sold directly to a packer or slaughter plant, and the remaining 1 percent are sent elsewhere. Cows that are not sold for slaughter (approximately 4 percent) are usually sent to another dairy operation (USDA APHIS, 1996a).

4.3.2.2 *Calves, Heifers, and Bulls*

The immature animals at a dairy are heifers and calves. Typically, according to Census of Agriculture data, for dairies greater than 200 milking cows, the number of calves and heifers on site equals approximately 60 percent of the mature dairy (milking) cows. EPA assumes that there are an equal number of calves and heifers on site (30 percent each). Calves are considered to be heifers between the age of six months and the time of their first calving (between 25 and 28 months of age) (USDA APHIS, 1996a). Heifers tend to be handled in larger groups, and often they are divided for management purposes into a breeding group and a bred heifer group (Bickert et al., 1997). Heifers and cows are often bred artificially. They may be placed daily in stanchions for estrus (heat) detection with the aid of tail chalk or heatmount detectors. Heifers and cows in pastures or in pens without stanchions may be heat detected by observation and then bred in a restraining chute. Heifers that do not conceive after attempts with artificial insemination are often placed in groups with a breeding-age bull to allow natural service of those animals. Approximately 45 percent of dairy operations do not keep bulls on site, and approximately 35 percent of dairy operations keep one bull on site for breeding (USDA APHIS, 1996a).

Cows and heifers that are at the end of their pregnancy are considered to be “periparturient” or “close-up cows.” About 2 weeks before she is due, the heifer or cow is moved from her regular herd into a smaller pen or area where she can be observed and managed more closely. When the cow is very near to calving, she is often moved to an isolated maternity pen. Shortly after birth, the calves are separated from their mothers and are generally kept isolated from other calves or in small groups until they are about 2 months old. After the calves are weaned from milk (at about 3 months of age), they are usually moved from their individual pen or small group into larger groups of calves of similar age. Female calves are raised (as replacements) to be dairy cows at the dairy or sent to an off-site calf operation. Female calves (heifers) may also be raised as beef cattle. Male calves that are not used for breeding are either raised as beef cattle (see Section 4.4) or as veal calves (see Section 4.4.5).

4.3.3 Stand-Alone Heifer Raising Operations

Stand-alone heifer raising operations provide replacement heifer services to dairies. It has been estimated that 10 percent to 15 percent of all dairy heifers are raised by stand-alone heifer raisers (Personal communication: Larry Jordan and Dr. Don Gardner). These heifer raising operations often contract with specific dairies to raise those dairies' heifers for a specified period of time, and many also provide replacement heifers to any dairy needing additional cows. The age at which dairies send their animals to heifer raising operations varies significantly (USDA APHIS, 1996a). Table 4-72 shows the percentage of dairies that use heifer raising operations, the median age at which heifers are received by these facilities, and the amount of time that the heifers remain at these facilities.

Table 4-72. Characteristics of Heifer Raising Operations

Age of Heifer	Percentage of Dairies Using Heifer Raisers	Median Age of Heifer	Time That Heifers Remain on Site
0 - 4 months	41.2	1 week	12 months
4 months - breeding	47.1	6 months	15 months
Breeding - first calving	11.8	Breeding age	9 months

There are a number of advantages for dairies to use heifer raising operations. Specifically, dairies using heifer raising operations could expand their herd size by 25 percent or more within existing facilities, specialize in milking cows or raising crops, and obtain healthier and better producing milking cows. In addition, raising calves off the farm may reduce risks of transmission of diseases for which older cows are the main source of infection. Some disadvantages include an increased risk of introducing disease into the herd and a shortage of replacement heifers if the raiser's breeding results are less than adequate. Also, the costs associated with raising the heifers could run higher than what the dairies are paying if labor, feed, and other resources are not allocated profitably (USDA APHIS, 1993).

Custom raising of dairy heifers is becoming more common as dairy herds increase in size and dairy farmers do not have facilities to raise all their heifers (Noyes, 1999). Throughout the U.S., the level of specialization is increasing for dairy farms; in fact, some large dairy farms raise no crops, purchase all of their feedstuffs, or do not raise replacement heifers for the milking herd.

Herd owners for these dairies must use other strategies to obtain herd replacements. As a result, enterprises that specialize in raising dairy calves and heifers are found in many western U.S. states (Faust, 2000). It is also believed that the poor beef market in the last few years has caused some beef feedlots to add pens of dairy heifers or switch to heifers entirely (Personal Communication: Dr. Roger Cady).

Stand-alone heifer operations use two primary methods for raising their animals. One method is to raise heifers on pasture, usually in moderate to warm climates where grazing land is available. The second method is to raise heifers in confinement (on drylots, as for beef cattle). Confinement is commonly used at operations in colder climates or areas without sufficient grazing land (Personal Communication: Larry Jordan).

The actual number of stand-alone heifer raising operations, as well as the number of confined operations, is unknown. However, based on information supplied by industry representatives (e.g., Professional Dairy Heifer Growers Association), EPA estimates that there may be 5,000 heifer raising operations in the U.S.: 300 to 400 operations with more than 1,000 head; 750 to 1,000 operations with more than 500 head; and 4,000 heifer operations with fewer than 500 head (most of them with around 50 head) (Personal Communication: Dr. Roger Cady). Most large dairy heifer raising operations (those with more than 1,000 head) are confinement-based while smaller operations are often pasture-based (Personal Communication: Dr. Roger Cady). Table 4-73 shows EPA's estimate of confined heifer raising operations by size and region (ERG, 2000a; 2000b).

Table 4-73. Distribution of Confined Heifer Raising Operations by Size and Region in 1997

	Number of Operations			
Region[a]	**300-499 Heifers**	**500-1,000 Heifers**	**> 1,000 Heifers**	**Total**
Central	25	250	180	455
Mid-Atlantic	0	0	0	0
Midwest	200	100	0	300
Pacific	25	150	120	295
South	0	0	0	0
National	250	500	300	1,050

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL

The sizes of heifer raising operations range from 50 head (typical "mom and pop" operations) to 25,000 head and tend to vary geographically. The average size of a heifer operation located west of the Mississippi River is 1,000 to 5,000 head, while the average size in the upper Midwest, Northeast, and South is 50 to 200 head. Nationally, the median size of a dairy heifer raising operation is approximately 200 head (Personal Communication: Dr. Roger Cady).

Stand-alone heifer raising operations are found nationwide with more heifer raisers located where cows are concentrated and in areas where the dairy industry is evolving toward more specialization (Bocher, 2000). EPA estimates that, of the number of heifers raised at stand-alone heifer operations, approximately 70 percent are managed in the West, 20 percent are managed in the South/Southeast, 7 percent are managed in the Northeast, and approximately 3 percent are managed in the upper Midwest. The upper Midwest is also believed to be the single largest growing region with respect to small heifer operations (Personal Communication: Dr. Roger Cady).

4.3.4 Dairy Facility Management

This section describes factors that affect the facility management of a dairy operation, including housing by type of animal, as well as use of housing in the industry, flooring and bedding type, feeding and watering practices, milking operations, and rotational grazing.

4.3.4.1 *Housing Practices*

The purpose of dairy housing is to provide the animals with a dry and comfortable shelter, while providing the workers with a safe and efficient working environment. Optimal housing facilities accommodate flexibility in management styles and routines, enhance the quality of milk production, and allow for the protection of the environment, yet remain cost-effective (Adams, 1995). The following subsections describes housing for each type of animal group according to age, from milking cows to calves.

Milking Cows

The primary goal in housing lactating dairy cows is to provide an optimum environment for the comfort, proper nutrition, and health of the lactating cow for maximum milk productivity. It is also designed to allow for efficient milking processes. The most common types of lactating cow housing include freestalls, drylots, tie stalls/stanchions, pastures, and combinations of these. The types of housing used for dry cows include loose housing and freestalls (Stull et al., 1998). These housing types are described in detail below.

- <u>Freestalls</u> - This type of housing provides individual resting areas for cows in freestalls or cubicles, which helps to orient the cow for manure handling. Freestalls provide the cows with a dry and comfortable place to rest and feed. The cows are not restrained in the freestalls and are allowed to roam on concrete alleys to feeding and watering areas. Manure collects in the travel alleys and is typically removed with a tractor or mechanical alley-scraper, by flushing with water, or through slotted openings in the floor (refer to Section 4.3.5 for a more detailed description of waste handling) (Adams, 1995). Recently, there has been a trend toward using freestalls to house dairy cows and many loose housing units have been converted to freestalls (Bickert, 1997).

- <u>Drylots</u> - Drylots are outside pens that allow the animals some exercise, but do not generally allow them to graze. The use of drylots depends upon the farm layout, availability of land, and weather conditions. Also, milking cows are not likely to spend their entire time on a drylot, as they need to be milked at least twice a day at a tiestall or in a milking parlor.

- <u>Tie Stalls/Stanchions</u> - Tie stalls or stanchions confine the cow to a single stall where she rests, feeds, and is often milked. The tie stall prevents the cow from moving out of her stall with a chained collar, but allows her enough freedom to get up and lie down without interfering with her neighbors. Tie stalls are also designed to allow the cows access to feed and fresh water in a natural grazing position (Adams, 1995). Cows that are housed in tie stalls may be let out at certain times each day (e.g., between milkings) to graze in a pasture. Tie stalls are the most predominant type of dairy cow housing for lactating cows (USDA APHIS, 1996a); however, this is true of older, smaller dairies. The current preference, particularly for medium and large dairies, is freestalls.

- <u>Loose Housing</u> - Barns, shades, and corrals are considered loose housing. The design of these facilities depends upon the number of cows, climate, and waste-handling techniques. Overcrowding in this type of housing can lead to health problems and may reduce access to feed, water, or resting areas for some subordinate animals. Loose housing that is hard-surfaced typically has at least a 4 percent slope, depending on soil type and rainfall (Stull et al., 1998).

- <u>Pastures</u> - Depending on the farm layout, availability of pastureland, and weather conditions, heifers or cows may spend part or most of their day in a pasture. Milking cows do not spend all of their day outside, since they are milked at least twice per day in a parlor or from a tie stall. On some farms, the cows may be contained outdoors during the day, but are housed in a tie stall or freestall overnight.

Close-Up Cows

The primary objective in housing for cows that are close to calving is to minimize disease and stress to both the cow and calf. Sod pastures are often used in warmer climates or during the summer; however, the pastures can become too muddy in the winter in some climates, requiring additional worker time to keep watch over the cows. Alternatively, the cows may be housed in multiple-animal or individual pens prior to calving. About 2 weeks before the cow is due (i.e., 2 weeks prior to freshening), she is moved to a "close-up" pen. The cow density in close-up pens is about one-half the density in lactating cow pens to allow the calving cows some space to segregate themselves from other cows if they go into labor, although calving in close-up pens is usually avoided.

When birth is very near, cows are moved to a maternity area for calving. If the climate is sufficiently mild, pastures can be used for a maternity area; otherwise, small individual pens are used. Pens are usually designed to allow at least 100 square feet per cow and to provide a well-ventilated area that is not drafty (Stull et al., 1998).

Approximately 45 percent of all dairy farms have maternity housing apart from the housing used for the lactating cows. This feature is more prevalent in larger farms than in smaller farms. Approximately 87 percent of farms with 200 or more cows have separate maternity housing (USDA APHIS, 1996a).

Bulls

When bulls are housed on site at a dairy operation, they are typically kept in a pen or on pasture. If possible, bulls are penned individually with sufficient space for special care and to reduce fighting. When a bull is grazed on pasture, an electric fence is typically used to prevent the bull from escaping and causing danger (Bodman et al., 1987).

Heifers

According to information collected during site visits, the majority of heifers are kept on drylots either on or off site. Heifers may also be kept in a pasture, in which the herd is allowed to move about freely and to graze. Pastures may be provided with an appropriate shelter. Heifer housing is typically designed for ease in:

- Animal handling for treatment (e.g., vaccinations, dehorning, pregnancy checks)
- Animal breeding
- Animal observation
- Convenient feeding, bedding, and manure handling (Bickert et al., 1997)

Weaned Calves (Transition Housing)

After calves are weaned, they are usually moved from individual pens or small group pens into housing for a larger numbers of calves. This change causes a number of stresses due to the new social interactions with other calves, competition for feed and water, and the new housing. Therefore, the housing is designed such that the workers can monitor each calf's adjustment into the social group. Transition housing is used for calves from weaning to about 5 months of age. The most common types of housing used for weaned calves are calf shelters or superhutches, transition barns, and calf barns (Bickert et al., 1997). These types of housing are described below.

- Superhutches - Superhutches are open-front, portable pens that provide a feeder, water trough, and shelter for 5 to 12 calves. Superhutches typically provide 25 to 30 square feet per calf and can be moved in a field, drylot, or pasture as needed to provide calves with a clean surface.

- Transition Barns - A transition barn is composed of a series of pens for groups of six to eight calves of up to 6 months old. Some transition barns are designed such that the back and end walls may be open or covered, depending on the weather conditions.

- Calf Barns - A calf barn combines both individual calf pens and transition barns within one building. The pens can be designed to be easily dismantled for waste removal, to minimize calf contact, or to provide draft protection (Bickert et al., 1997).

Calves

Sickness and mortality rates are highest among calves under 2 months of age; therefore, the housing for this group typically minimizes environmental stress by protecting the calves against heat, wind, and rain. Common calf housing types include individual animal pens and hutches, which are described below.

- Individual Pens - Pens are sized to house animals individually and separate them from others. Individual pens make it easier to observe changes in behavior, feed consumption, and waste production, which can indicate sickness. Calves may be raised in 2-foot by 4-foot expanded metal or slatted wood, elevated pens; however, these pens provide little shelter from drafts and cold in the winter (Stull, et al., 1998). Individual pens can be used inside a barn to provide isolation for each calf. Pens are typically 4-feet by 7-feet and removable. Solid partitions between pens and beyond the front of the pen prevent nose-to-nose contact between the calves. A cover over the back half of the pen gives the calf additional protection, especially in drafty locations. Pens can be placed on a crushed rock base or a concrete floor to provide a base for bedding (Bickert et al., 1997).

- Hutches - Hutches are portable shelters typically made of wood, fiberglass, or polyethylene and are placed in outdoor areas. Hutches allow for complete separation of unweaned calves since one calf occupies each hutch. One end of the hutch is open and a wire fence may be provided around the hutch to allow the calf to move outside. Lightweight construction materials improve hutch mobility and also allow for easier cleaning. Hutches are typically 4 feet by 8 feet by 4 feet and may be placed inside a shed or structure to provide protection from cold weather and direct sunlight (Bickert et al., 1997).

Use of Housing in Industry

Table 4-74 summarizes the relative percentages of U.S. dairies reporting various types of housing for their animals (USDA APHIS, 1996a). These data were collected in 1996 for activities in 1995 by USDA's NAHMS. Note that some operations may have reported more than one type of housing being used for a particular group. The NAHMS data did not include housing type for dry cows. It is expected that dry cows are typically housed similarly to lactating cows (Stull et al., 1998).

Multiple age groups may be housed within a single building that allows for each group to be managed separately. Larger farms tend to place their animals in more than one building (Bickert et al., 1997). Superhutches, transition barns, calf barns, and loose housing were not specifically addressed in the NAHMS study, but may be considered specific types of multiple animal pens. Dairies predominantly use some sort of multiple animal area for unweaned calves, weaned calves, and heifers.

Table 4-74. Percentage of U.S. Dairies by Housing Type and Animal Group in 1995

Housing Type	Unweaned Calves	Weaned Calves and Heifers	Lactating Cows	Periparturient Cows
Drylot	9.1	38.1	47.2	28.9
Freestall	2.5	9.7	24.4	5.6
Hutch	32.5	NA	NA	NA
Individual animal area	29.7	6.6	2.3	38.3
Multiple animal area	40.0	73.9	17.9	26.3
Pasture	7.4	51.4	59.6	41.9
Tie stall/stanchion	10.5	11.5	61.4	26.3

NA - Not applicable.

4.3.4.2 *Flooring and Bedding*

The flooring and bedding used in housing provide physical comfort for the cow, as well as a clean, dry surface to reduce the incidence of mastitis and other diseases. Tables 4-75 and 4-76 summarize the various types of flooring and bedding, respectively, that are used for lactating cows, as reported by U.S. dairies in the NAHMS study (USDA APHIS, 1996b).

The most predominantly used flooring is smooth concrete, reported by over 40 percent of the dairies. Other fairly common flooring types include grooved and textured concrete. The less common flooring types that were reported include slatted concrete, dirt, and pastures (USDA APHIS, 1996b). The flooring design is important in loose housing to maintain secure footing for the animals, as well as facilitate waste removal. The surfaces typically contain scarified concrete areas around water troughs, feed bunks, and entrances. Both hard-surface and dirt lots are sloped to allow proper drainage of waste and rainfall (Stull et al., 1998).

Table 4-75. Types of Flooring for Lactating Cows

Type of Flooring	Percentage of Dairies Reporting
Smooth concrete	41.6
Grooved concrete	27.2
Textured concrete	16.2
Pasture	6.9
Dirt	5.8
Other	1.5
Slatted concrete	0.8

Table 4-76. Types of Bedding for Lactating Cows

Type of Bedding	Percentage of Dairies Reporting
Straw and/or hay	66.9
Wood products	27.9
Rubber mats	27.0
Corn cobs or stalks	12.8
Sand	11.2
Shredded newspaper	6.7
Mattresses	4.7
Other	3.7
Composted manure	2.4
Rubber tires	1.0

More than one bedding type may be reported by a single dairy. The most commonly used bedding is straw or hay, or a combination of the two, while other common bedding includes wood products and rubber mats. Less frequently used are rubber tires, composted manure, mattresses, shredded newspaper, sand, and corn cobs and stalks (each reported by less than 13 percent of the dairies) (USDA APHIS, 1996b).

4.3.4.3 *Feeding and Watering Practices*

Feeding and watering practices vary for each type of animal group at the dairy. Most dairies deliver feed several times each day to the cows, and provide a continuous water supply. The type of feed provided varies with the age of the animal and the level of milk production to be achieved.

Milking cows - At dairies, mature cows are fed several times a day. Lactating cows are provided a balanced ration of nutrients, including energy, protein, fiber, vitamins, and minerals (NRC, 1989). Dairies with greater than 200 milking cows typically feed a total mixed ration. In addition, most dairies in the U.S. feed grains and/or roughages (e.g., hay) that were grown and raised on the farm. Over half of all U.S. dairies reported that they pastured their dairy cows for at least 3 months in the year. Almost half of these dairies reported that grazing provided at least 90 percent of the total roughage for the cows while they were pastured (USDA APHIS, 1996a).

A lactating dairy cow consumes about 5 gallons of water per gallon of milk produced daily (Stull et al., 1998). Temperature can affect water consumption; therefore, actual consumption may vary. The predominant method for providing water to cows is from a water trough where more than one cow can drink at a time. Other watering methods frequently reported by small dairies (less than 200 cows) include automatic waterers for use by either individual cows or by a group of cows, at which only one cow drinks at a time (USDA APHIS, 1996b).

Heifers - Rations are balanced so heifers raised on site reach a breeding weight of 750 to 800 pounds by 13 to 15 months of age. Heifers are fed high-forage rations between breeding and calving, and usually are given enough manger space for all heifers to eat simultaneously (Stull et al., 1998).

Cows within 10 to 16 days of calving are normally fed as a separate group. They may be fed a few pounds of a grain concentrate mix in addition to forages. This practice avoids a sudden shift from an all-forage ration to a ration with a high proportion of concentrates, which is typical of that fed to cows in early lactation. If a postpartum cow is fed a total mixed ration, she may be fed about 5 pounds of long-stemmed hay in the ration for at least 10 days after calving to stimulate feed intake.

Calves - Calves are initially fed colostrum, the milk that is produced by the cow just prior to and during the first few days after calving. Colostrum contains more protein (especially immunoglobulins), fat, minerals, and vitamins than the milk normally produced, and less lactose (USDA BAMN, 1997). When calves are about 5 days old, their feed is switched to fresh whole milk or a milk replacer. Milk replacers are powdered products that contain predominantly dry milk ingredients. These are mixed with water to provide the optimum nutrition for the calf (Stull et al., 1998).

Calves are then weaned from a milk replacer or milk-based diet to a forage and/or concentrate diet. Calves are offered a starter ration in addition to milk or milk replacer when they are approximately 1 week old. Calves will consume 1 to 1.5 pounds of starter ration per day at weaning time, usually when they are 2 to 3 months old (Stull et al., 1998).

Because calves require more water than they receive from milk or milk replacer, water is typically available to them at all times.

4.3.4.4 *Milking Operations*

Lactating cows require milking at least twice a day and are either milked in their tie stalls or are led into a separate milking parlor. The milking parlors are often used in the freestall type of housing. The milking center typically includes other types of auxiliary facilities, such as a holding area, milk room, and treatment area (Bickert, 1997).

Milking Parlor - Milking parlors are separate facilities, apart from the lactating cow housing, where the cows are milked. Usually, groups of cows at similar stages of lactation are milked at a time. The parlor is designed to facilitate changing the groups of cows milked and the workers' access to the cows during milking. Often, the milking parlors are designed with a worker "pit" in the center of a room with the cows to be milked arranged around the pit at a height that allows the workers convenient access to the cows' udders.

The milking parlor is most often equipped with a pipeline system. The milk is collected from the cow through a device called a "milking claw" that attaches to each of her four teats. Each milking claw is connected to the pipeline and the milk is drawn from the cow, through the claw, and into the pipeline by a common vacuum pump. The pipeline is usually constructed of glass or steel and flows into a milk receiver. From the receiver, the milk is pumped through a filter and into a bulk tank where it is stored until collection.

The milking parlor is typically cleaned several times each day to remove manure and dirt. Large dairies tend to use automatic flush systems, while smaller dairies simply hose down the area. Water use can vary from 1 to 3 gallons per day per cow milked (for scrape systems) to 30 to 50 gallons per day per cow milked (for flush systems) in the dairy parlor and holding area (Loudon et al., 1985).

Milking at Tie Stalls - Cows that are kept in tie stalls may be milked from their stalls. The housing is equipped with a pipeline system that flows around the barn and contains ports where the milking claws may be "plugged in" at each stall. The workers carry the necessary udder and teat cleaning equipment as well as the milking claws from one cow to the next.

Approximately 70 percent of dairy operations reported that they milk the cows from their tie stalls, while only 29 percent reported that they used a milking parlor; however, more than half of the lactating cow population (approximately 55 percent) is milked in a milking parlor (USDA APHIS, 1996a; 1996b). Therefore, it can be interpreted that many of the large dairies are using milking parlors, while the smaller dairies are typically using tie stalls.

Holding Area - The holding area confines cows that are ready for milking. Usually, the area is enclosed and is part of the milking center, which in turn, may be connected to the barn or located in the immediate vicinity of the cow housing. The holding area is typically sized such that each cow is provided 15 square feet and is not held for more than 1 hour prior to milking (Bickert et al., 1997). The cows' udders may sometimes be washed in this area using ground-level sprinklers.

Milk Room - The milk room often contains the milk bulk tank, a milk receiver group, a filtration device, in-line cooling equipment, and a place to wash and store the milking equipment (Bickert et al., 1997). To enhance and maintain milk quality and to meet federal milk quality standards, it is cooled from the first milking to 40°F or less within 30 minutes. Some commonly used milk cooling devices include precoolers, heat exchangers, bulk tank coolers, and combinations of these. The cooling fluid used is typically fresh or chilled service water. This water is still clean and may then be used to water the animals (Bickert et al., 1997), or more commonly as milk parlor flush water.

Milking equipment cleaning and sterilizing processes are often controlled from the milk room. Typically, the milking equipment is washed in hot water (95 to 160 °F) in a prerinse, detergent wash, and acid rinse cycles. The amount of water used by an automatic washing system, including milking parlor floor washes, can vary from 450 to 850 gallons per day (Bickert et al., 1997).

Treatment Area - Treatment areas are used on farms to confine cows for artificial insemination, postpartum examination, pregnancy diagnosis, sick cow examination, and surgery. A single stall or a separate barn can be used as a treatment area.

Other Areas of the Milking Center - Milking and processing equipment is typically stored in a utility room. This equipment may include:

- Milk vacuum pump
- Compressor
- Water heater
- Furnace
- Storage

A separate room may also be used to store cleaning compounds, medical supplies, bulk materials, replacement milking system rubber components, and similar products. The storage room is often separated from the utility room to reduce the deterioration of rubber products, and is typically designed to minimize high temperatures, light, and ozone associated with motor operation (Bickert et al., 1997).

4.3.4.5 *Rotational Grazing*

Intensive rotational grazing is known by many terms, including intensive grazing management, short duration grazing, savory grazing, controlled grazing management, and voisin grazing management (Murphy, 1988). This practice involves rotating grazing cows among several pasture subunits or paddocks to obtain maximum efficiency of the pastureland. Dairy cows managed under this system spend all of their time, except time spent milking, out on the paddocks during the grazing season.

During intensive rotational grazing, each paddock is grazed quickly (1 or 2 days) and then allowed to regrow, ungrazed, until ready for another grazing. The recovery period depends on the forage type, the forage growth rate, and the climate, and may vary from 10 to 60 days (USDA, 1997). This practice is labor- and land-intensive as cows must be moved daily to new paddocks. All paddocks used in this system require fencing and a sufficient water supply. Many operations using intensive rotational grazing move their fencing from one paddock to another and have a water system (i.e., pump and tank) installed in each predefined paddock area.

The number of required paddocks is determined by the grazing and recovery periods for the forage. For example, if a pasture-type paddock is grazed for 1 day and recovers for 21 days, 22 paddocks are needed (USDA, 1997). The total amount of required land depends on a number of factors including the dry matter content of the pasture forage, use of supplemental feed, and the number of head requiring grazing. Generally, this averages out to one or two head per acre of pastureland (Personal Communication: Jim Hannawald). Successful intensive rotational grazing, however, requires thorough planning and constant monitoring. All paddocks are typically monitored once a week. High-producing milk cows (e.g., more than 80 pounds of milk per day) need a large forage allowance to maintain a high level of intake. Therefore, they need to graze in pastures that have sufficient available forage or be fed stored feed (USDA, 1997).

Due to the labor, fencing, water, and land requirements for intensive rotational grazing, typically only small dairy operations (those with less than 100 head) use this practice (Personal Communication: Jim Hannawald; USDA NRCS, 1996; CIAS, 2000a). Climate and associated growing seasons, however, make it very difficult for operations to use an intensive rotational grazing system throughout the entire year. These operations, therefore, must maintain barns and/or drylots for the cows when they are not being grazed or outwinter their milk cows. Outwintering is the practice of managing cows outside during the winter months. This is not a common practice as it requires farmers to provide additional feed (as cows expend more energy outside in the winter), provide windbreaks for cattle, conduct more frequent and diligent health checks on the cows, and keep the cows clean and dry so that they can stay warm (CIAS, 2000b).

There are two basic management approaches to outwintering: rotation through paddocks and "sacrifice paddocks." Some farms use a combination of these practices to manage their cows during the winter. During winter months, farmers may rotate cattle, hay, and round bale feeders throughout the paddocks. The main differences between this approach and standard rotational grazing practices are that the cows are not rotated as often and supplemental feed is provided to the animals. Deep snow, however, can cause problems for farmers rotating their animals in the winter because it limits the mobility of round bale feeders. The outwintering practice of sacrifice paddocks consists of managing animals in one pasture during the entire winter. There are several disadvantages and advantages associated with this practice. If the paddock surface is not frozen during the entire winter, compaction, plugging (tearing up of the soil), and puddling can occur. Due to the large amounts of manure deposited in these paddocks during the winter, the sacrifical paddocks must be renovated in the spring. This spring renovation may consist of dragging or scraping the paddocks to remove excess manure and then seeding to reestablish a vegetative cover. Some farmers place sacrifice paddocks strategically in areas where an undesirable plant grows or where they plan to reseed the pasture or cultivate for a crop (CIAS, 2000c).

Advantages of rotational grazing compared to conventional grazing include:

- Higher live weight gain per acre. Intensive rotational grazing systems result in high stocking density, which increases competition for feed between animals, forcing them to spend more time eating and less time wandering (AAFC, 1999).

- Higher net economic return. Dairy farmers using pasture as a feed source will produce more feed value with intensive rotational grazing than with continuous grazing (USDA NRCS 1996). Competition also forces animals to be less selective when grazing. They will eat species of plants that they would ignore in other grazing systems. This reduces less desirable plant species in the pasture and produces a better economic return (AAFC, 1999).

- Better land. Pastureland used in rotational grazing is often better maintained than typical pastureland. Intensive rotational grazing encourages grass growth and development of healthy sod, which in turn reduces erosion. Intensive rotational grazing in shoreline areas may help stabilize stream banks and could be used to maintain and improve riparian habitats (PPRC, 1996).

- Less manure handling. In continuous grazing systems, pastures require frequent maintenance to break up large clumps of manure. In a good rotational system, however, manure is more evenly distributed and will break up and disappear faster. Rotational grazing systems may still require manure maintenance near watering areas and paths to and from the paddock areas (Emmicx, 2000).

Grazing systems are not directly comparable to confined feeding operations, as one system can not readily switch to the other; however, assuming all things are equal, intensive rotational grazing systems have a number of advantages over confined feeding operations:

- Reduced cost. Pasture stocking systems are typically less expensive to invest in than livestock facilities and farm equipment required to harvest crops. Feeding costs may also be lowered.

- Improved cow health. Farmers practicing intensive rotational grazing typically have a lower cull rate than confined dairy farmers, because the cows have less hoof damage, and they are more closely observed as they are moved from one paddock to another (USDA, 1997).

- Less manure handling. Intensive rotational grazing operations have less recoverable solid manure to manage than confined operations.

- Better rate of return. Research indicates that grazing systems are more economically flexible than the confinement systems. For example, farmers investing in a well-planned grazing operation will likely be able to recover most of their investment in assets if they leave farming in a few years. But farmers investing from scratch in a confinement operation would at best recover half their investments if they decide to leave farming (CIAS, 2000d).

There are a number of disadvantages associated with intensive rotational grazing compared with either conventional grazing or confined dairy operations. The major disadvantages are:

- Limited applicability. Implementation of intensive rotational grazing systems depends upon available acreage, herd size, land resources (i.e., tillable versus steep or rocky), water availability, proximity of pasture area to milking center, and feed storage capabilities. Several sources indicate that this system is used by dairy farms with less than 100 cows. Typical confined dairy systems are often not designed to allow cows easy access to the available cropland or pastureland. Large distances between the milking center and pastureland will increase the cows expended energy and, therefore, increase forage demands.

  In most of the country, limited growing seasons prevent many operations from implementing a year-round intensive rotational grazing system. Southern states, such as Florida, can place cows on pasture 12 months of the year, but the extreme heat presents other problems for cows exposed to the elements. Grazing operations in southern states typically install shade structures and increase water availability to cows, which in turn increases the costs and labor associated with intensive rotational grazing systems. Because most dairy operations cannot provide year-round grazing, they still must maintain barns and drylot areas for their cows when they are not grazing, and dairy operations often prefer not to have to maintain two management systems.

- Reduced milk production levels. Studies indicate that dairy farmers using intensive rotational grazing have a lower milk production average than confined dairy farms (USDA NRCS, 1996). Lower milk production can offset the benefit of lower feed costs, especially if rations are not properly balanced once pasture becomes the primary feed source during warm months.

- Limited manure handling options. Dairies using intensive rotational grazing systems may not be able to apply the wastewater and solid manure collected during the non-grazing seasons to their available pastureland as crops may not be growing.

- Increased likelihood of infectious diseases. Some infectious diseases are more likely to occur in pastured animals by direct or indirect transmission from wild animals or presence of an infective organism in pasture soil or water (Hutchinson, 1988).

- Limited flexibility. Intensive rotational grazing systems have limited flexibility for planning how many animals can be pastured in any one paddock. Available forage in a paddock can vary from one cycle to another, because of weather and other conditions that affect forage growth rates. As a result, a paddock that was sized for a certain number of cows under adequate rainfall conditions will not be able to accommodate the same number of cows under drought conditions (USDA, 1997).

4.3.5 Dairy Waste Management Practices

Dairy waste management systems are generally designed based on the physical state of the waste being handled (e.g., solids, slurries, or liquids). Most dairies have both wet and dry waste management systems. Waste with 20 percent to 25 percent solids content can usually be handled as a solid while waste with less than 10 percent solids can be handled as a liquid (Loudon, 1985).

In a dry system, the manure is collected on a regular basis and stored where an appreciable amount of rainfall or runoff does not come in contact with it. Handling manure as a solid minimizes the volume of manure that is handled.

In a slurry or liquid system, manure is often diluted with water that typically comes from flushing system water, effluent from the solids separation system, and/or supernatant from lagoons. When dairy manure is handled and stored as a slurry or liquid, the milking center wastewater can be mixed in with the animal manure, serving as dilution water to ease pumping. If a gravity system is used to transfer manure to storage, milking center wastewater may be added at the collection point in the barn. Liquid systems are usually favored by large dairies for their lower labor cost and because the larger dairies tend to use automatic flushing systems.

4.3.5.1 *Waste Collection*

The collection methods for dairy manure vary depending on the management of the dairy operation. Dairy cows may be partially, totally, or seasonally confined. As previously mentioned, manure accumulates in confinement areas such as barns, drylots, and milking parlors and in other areas where the herd is fed and watered. In wet climates, it is difficult to collect and store manure from unroofed areas as a solid, but it can be done if the manure is collected daily, stored in a roofed structure, and mixed with bedding. In arid climates, manure from unroofed areas can be handled as a solid if collection time can be flexible.

The following methods are used at dairy operations to collect waste:

- <u>Mechanical/Tractor Scraper</u> - Manure and bedding from barns and shade structures are collected normally by tractor or mechanical chain-pulled scrapers. Eighty-five percent of operations with more than 200 milking cows use a mechanical or tractor scraper (USDA APHIS 1996b). Tractor scraping is more common since the same equipment can be used to clean outside lots as well as freestalls and loose housing. A mechanical alley scraper consists of one or more blades that are wide enough to scrape the entire alley in one pass. The blades are pulled by a cable or chain drive that is set into a groove in the center of the alley. A timer can be set so that the scraper runs two to four times a day, or continuously in colder conditions to prevent the blade from freezing to the floor. Scrapers reduce daily labor requirements, but have a higher maintenance cost due to corrosion and deterioration.

- <u>Flushing System</u> - Manure can be collected from areas with concrete flooring by using a flushing system. A large volume of water is introduced at the head of a paved area, and the cascading water removes the manure. Flush water can be introduced from storage tanks or high-volume pumps. The required volume of flush water varies with the size of the area to be flushed and slope of the area. The total amount of flush water introduced can be minimized by recycling; however, only fresh water can be used to clean the milking parlor area. Flushing systems are predominantly used by large dairies with 200 or more head (approximately 27 percent) that tend to house the animals in a freestall-designed barn. These systems are much less common in dairies with fewer than 200 head (fewer than 5 percent reported using this system) (USDA APHIS, 1996b). These systems are also more common at dairies located in warmer climates.

- <u>Gutter Cleaner/Gravity Gutters</u> - Gutter cleaners or gravity gutters are frequently used in confined stall dairy barns. The gutters are usually 16 to 24 inches wide, 12 to 16 inches deep, and flat on the bottom. Either shuttle-stroke or chain and flight gutter cleaners are typically used to clean the gutters. About three-fourths (74 percent) of U.S. dairy operations with fewer than 100 milking cows and approximately one-third of U.S. dairy operations with 100 to 199 milking cows use a gutter cleaner (USDA APHIS, 1996b).

- Slotted Floor - Concrete slotted floors allow manure to be quickly removed from the animal environment with minimal labor cost. Manure falls through the slotted floor or is worked though by animal traffic. The waste is then stored in a pit beneath the floor or removed with gravity flow channels, flushing systems, or mechanical scrapers. The storage of animal and milking center waste in a pit beneath slotted floors combines manure collection, transfer, and storage.

4.3.5.2 *Transport*

The method used to transport manure depends largely on the consistency of the manure. Liquids and slurries can be transferred through open channels, pipes, and in liquid tank wagons. Pumps can be used to transfer liquid and slurry wastes as needed; however, the greater the solids content of the manure, the more difficult it will be to pump.

Solid and semisolid manure can be transferred by mechanical conveyance or in solid manure spreaders. Slurries can be transferred in large pipes by using gravity, piston pumps, or air pressure. Gravity systems are preferred because of their low operating cost.

4.3.5.3 *Storage, Treatment, and Disposal*

Waste collected from the dairy operation is transported within the site to storage, treatment, and use or disposal areas. Typical storage areas for dairy waste include above- and belowground storage tanks and storage ponds. Handling and storage methods used at dairy operations are discussed in detail in Section 8.2.

One common practice for the treatment of waste at dairies is solids separation. Mechanical or gravity solids separators are used to remove bulk solids from a liquid waste stream; this separation reduces the volume of solids entering a storage facility, which increases its storage capacity. Separation facilitates reuse of liquid in a flushing system reduces clogging of irrigation sprinklers and reduces waste volume going to treatment or to land application sites. Manure slurry is often separated using mechanical separators, such as stationary screens, vibrating screens, presses, or centrifuges, all of which recover a relatively dry byproduct (Dougherty, 1998). Sedimentation by gravity settling is also used for solid/liquid separation.

Another common technology for the treatment of waste at dairies is an anaerobic lagoon. Anaerobic lagoons are biological treatment systems used to degrade animal wastes into stable end products. The advantage of anaerobic lagoons is their long storage times, which allow bacteria to break down solids. Disadvantages include odors produced during environmental or management changes and sensitivity to sudden changes in temperature and loading rates. Anaerobic lagoons are designed to hold the following volumes: a minimum treatment volume (based on volatile solids loading), the volume of accumulated sludge for the period between sludge removal events, the volume of manure and wastewater accumulated during the treatment period, the depth of normal precipitation minus evaporation, the depth of the 25-year, 24-hour storm event, and an additional 1 foot of freeboard.

Typical manure and waste treatment technologies used at dairy operations are discussed in detail in Section 8.2.

The majority (approximately 99 percent) of small and large dairy operations (fewer than and more than 200 milking cows) dispose of their waste through land application (USDA APHIS, 1996b). The amount of cropland and pastureland that is available for manure application varies at each dairy operation. Generally, dairy operations can be categorized into three groups with respect to available cropland and pastureland: (1) those with sufficient land so that all manure can be applied without exceeding agronomic application rates, (2) those without sufficient land to apply all of their manure at agronomic rates, and (3) those without any available cropland and pastureland. Operations without sufficient land, or any land, often have agreements with other farmers allowing them to apply manure on their land. Depending on the size of the dairy operation, 1997 Census of Agriculture data indicate that the average acres of cropland at dairies with at least 300 milking cows is approximately 350 acres and the average acres of pastureland is approximately 75 acres (Kellogg, 2000).

USDA conducted an analysis of the 1997 Census of Agriculture data to estimate the manure production at livestock farms (Kellogg, 2000). As part of this analysis, USDA estimated the number of confined livestock operations that produce more manure than they can apply on their available cropland and pastureland at agronomic rates for nitrogen and phosphorus and the number of confined livestock operations that do not have any available cropland or pastureland. The analysis assumed land application of manure would occur on one of 24 typical crops or pastureland. Using the percentage of these facilities estimated by USDA against the total number of livestock facilities, one can also estimate the number of facilities that have sufficient cropland and pastureland for agronomic manure application. Table 4-77 summarizes the percentage of dairy operations that have sufficient, insufficient, and no land for manure application at agronomic application rates for nitrogen and phosphorus. EPA assumes that confined heifer operations have similar percentages.

Table 4-77. Percentage of Dairy Operations With Sufficient, Insufficient, and No Land for Agronomic Application of Generated Manure

Size Class	Sufficient Land		Insufficient Land		No Land[a]
	Nitrogen Application	Phosphorus Application	Nitrogen Application	Phosphorus Application	
200-700 milking cows	50	25	36	61	14
> 700 milking cows	27	10	51	68	22

[a] No acres of cropland (24 crops) or pastureland.
Source: Kellogg, 2000

4.4 Beef Industry

Beef feeding operations include facilities that confine beef cattle for feeding or maintenance for at least 45 days in any 12-month period. These facilities do not have significant vegetation on the beef feedlot during the normal growing season (i.e., the feedlot area does not include grazing operations). Facilities that have beef feedlot operations may also include other animal and agricultural operations not considered part of the feedlots, such as grazing and crop farming.

This section discusses the following aspects of the beef industry:

- Section 4.4.1: Distribution of the beef industry by size of operation and region in 1997;
- Section 4.4.2: Beef production cycles
- Section 4.4.3: Beef feedlot facility management
- Section 4.4.4: Backgrounding operations
- Section 4.4.5: Veal operations
- Section 4.4.6: Cow-calf operations
- Section 4.4.7: Beef waste management practices

4.4.1 Distribution of the Beef Industry by Size and Region

EPA's current Effluent Limitations Guidelines and Standards apply to beef feedlot operations with a capacity of 1,000 or more slaughter steers and heifers, where the animals are fed at the place of confinement and crop or forage growth or production is not sustained in the confinement area.

Information presented in this section comes from USDA's National Agricultural Statistics Service (NASS), 1997 Census of Agriculture data, and from site visits and trade associations. The 1994 to 1998 NASS reports on beef feedlots present annual estimates of beef operations that have a capacity of 1,000 head of cattle or more grouped in the following categories:

- Cattle inventory and calf crop
- Number of operations
- Inventory by class and size groups
- Monthly cattle on feed numbers
- Annual estimates of cattle on feed

NASS publishes only limited data for operations that have a capacity of fewer than 1,000 head of cattle (USDA NASS, 1999e). The 1997 Census of Agriculture collects information on cattle inventory and the number of cattle fattened for slaughter.

The capacity of a beef feedlot is the maximum number of cattle that can be held on site at any one time and can usually be determined by the amount of feedbunk space available for the cattle. On average, most beef feedlots operate at 80 percent to 85 percent of capacity over the course of a year, depending on market conditions (NCBA, 1999). In addition, most feedlots have cattle on site for 150 to 270 days (see Section 4.4.2); therefore, on average, the feedlot can run one and one half to two and one half "turns" of cattle each year. However, a feedlot may have anywhere from one to three and one half turnovers of its herd per year. For example, some feedlots only have cattle on site during the winter months (one turnover) when crops cannot be grown, while other feedlots move cattle through the feedyard more quickly (three and one half turnovers).

EPA estimated the maximum capacity of beef feedlots reported in the 1997 Census of Agriculture using the reported sales of cattle combined with estimated turnovers and average feedlot capacity (ERG, 2000b).

Maximum Feedlot Capacity (Head) = Cattle Sales (Head) * Average Feedlot Capacity (%) / Turnovers

For example, a feedlot that sold 1,500 cattle in 1997 and is estimated to operate at 80 percent capacity with one and one half turnovers has an estimated maximum capacity of 800 head.

In 1997, there were approximately 2,075 beef feedlots with a capacity of more than 1,000 head in the U.S. (USDA NASS, 1999e). These operations represent only about 2 percent of all beef feedlots. EPA estimates that there were approximately 1,000 additional beef feedlots with a capacity of between 500 and 1,000 head (another 1 percent of beef feedlots), 1,000 beef feedlots with a capacity of between 300 and 500 head, and another 102,000 beef feedlots with a capacity of fewer than 300 head. Table 4-78 shows the estimated distribution of these operations by size and region. Table 4-79 shows the estimated number of cattle sold during 1997 by size class. EPA derived these data from the 1997 Census of Agriculture data and NASS data (ERG, 2000b).

Table 4-80 presents the number of beef feedlots by top producing states and nationally for the following eight size categories:

- up to 299 head
- 300 to 999 head
- 1,000 to 1,999 head
- 2,000 to 3,999 head
- 4,000 to 7,999 head
- 8,000 to 15,999 head
- 16,000 to 31,999 head
- 32,000 head and greater

The data in this table were obtained from NASS and were also derived from the 1997 Census of Agriculture data. Note that in some cases the feedlots from several size groups have been aggregated to avoid disclosing details on individual operations for some states.

As one would expect, the number of feedlots decreases as the capacity increases. For example, there are 842 feedlots in the 1,000 to 1,999 size category but only 93 in the greater than 32,000 size category. Of the 106,075 beef feedlots across all size groups in 1997, the Midwest region has the most with 71,183 (67 percent). Nebraska and Iowa have the most large beef feedlots (more than 1,000 head). Texas has the largest number of feedlots with a capacity of more than 32,000 head in the U.S. (41 percent).

Table 4-78. Distribution of Beef Feedlots by Size and Region in 1997

	Feedlot Capacity					
Region[a]	< 300 Head	300-500 Head	500-1,000 Head	1,000-8,000 Head	> 8000 Head	Total
Central	9,990	87	130	332	182	10,721
Mid-Atlantic	15,441	150	34	25	0	15,650
Midwest	68,235	685	810	1,236	217	71,183
Pacific	3,953	35	19	55	22	4,085
South	4,381	43	7	6	0	4,436
National	102,000[b]	1,000[b]	1,000	1,654	421	106,075

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
[b] Estimated value. Assumes 98 percent of feedlots with fewer than 1,000 head have a capacity of fewer than 300 head, and 99 percent of all feedlots with fewer than 1,000 head have a capacity of fewer than 500 head.

Table 4-79. Cattle Sold in 1997

Size Class	Number of Facilities	Cattle Sold	Average Cattle Sold
< 300 Head Capacity	102,000	2,362,000[a]	23
300-500 Head Capacity	1,000	600,000[b]	600
500-1,000 Head Capacity	1,000	1,088,000[b]	1,088
> 1,000 Head Capacity	2,075	22,789,000	10,983
All Operations	106,075	26,839,000	253

[a] Estimated value. Value presented is the difference between total sales for all feedlots with fewer than 1,000-head capacity, and the estimated sales for feedlots with 300-1,000 head capacity.
[b] Estimated value. Calculated from using the midpoint of the size range (e.g., 400 head for the 300-500 size class) and an average turnover rate of one and one half herds a year.

Table 4-80. Number of Beef Feedlots by Size of Feedlot and State in 1997[a]

Location	Feedlot Capacity							
	1 - 299 Head	300 - 999 Head	1,000-1,999 Head	2,000-3,999 Head	4,000-7,999 Head	8,000-15,999 Head	16,000-31,999 Head	32,000 + Head
Arizona	151	4	-	3[b]	-	-	3	3
California	885	25	4[b]	-	4	4	5	7
Colorado	1,374	70	54	46	32	23	11	8
Idaho	894	13	19	15	9	17[b]	-	-
Iowa	11,839	435	200	110[b]	-	-	-	-
Kansas	2,563	160	45	28	30	34	41	17
Nebraska	4,700	359	270	181	118	64	25	7
New Mexico	318	6	-	-	6[b]	-	4[b]	-
Oklahoma	1,840	21	3[b]	-	9	5	3	6
South Dakota	2,652	124	50	41	17	6[b]	-	-
Texas	3,556	49	8	13	28	25	35	38
Washington	1,166	8	7[b]	-	-	4	5[b]	-
Other States	70,062	726	191	85	36	8	5	-
United States	102,000	2,000	842	504	308	191	137	93

[a] The number of feedlots is the number of lots operating at any time during the year. The U.S. totals show the actual number of feedlots in each size group. The sum of the numbers shown by states under a specified size group may or may not add to the U.S. total for that size group because some states size groups are combined to avoid disclosing individual operations.
[b] Lots from other size groups are included to avoid disclosing individual operations.

Also included in the beef industry are veal operations, which are discussed in detail in Section 4.4.5. Veal operations are not specifically reported in the 1997 Census of Agriculture or NASS data. Therefore, EPA conducted site visits to veal operations and requested distribution data from the industry to ultimately estimate the number of veal operations in the U.S., as shown in Table 4-81 (ERG, 2000b).

Table 4-81. Distribution of Veal Operations by Size and Region in 1997

Region[a]	Capacity		Total
	300-500 Calves	> 500 Calves	
Central	5	3	8
Mid-Atlantic	1	1	2
Midwest	119	81	200
Pacific	0	0	0
South	0	0	0
Total United States	125	85	210

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL

4.4.2 Beef Production Cycles

Beef feedlots conduct feeding operations in confined areas to increase beef weight gain, control feed rations, increase feeding efficiency, reduce feed costs, and manage animal health. Calves are often brought in from backgrounding operations to the feedlot (Section 4.4.4). Calves usually begin the “finishing” phase when they reach 6 months of age or a weight of at least 400 pounds. Cattle are typically held on the feedlot for 150 to 180 days. As stated previously in this section, a beef feedlot may run anywhere from one to three and one half turnovers of its herd per year. The annual average steer weight at slaughter ranges from 1,150 to 1,250 pounds, while the annual average heifer slaughter weight ranges from 1,050 to 1,150 pounds.

Some feedlots may bring in young calves at around 275 pounds and feed them on site for approximately 270 days. As a result, these feedlot operations have fewer turnovers of the herd per year. Based on site visits, this type of operation is typical at feedlots in southern California. Some operations may only bring in cattle during the winter months when no crops are being grown, also resulting in fewer turnovers of the herd per year. Other operations, the true “final finishing” operations, may bring cattle in at a heavier weight and require only approximately 100 days to feed cattle, resulting in more turnovers of the herd per year. These variations in turnovers often make it difficult to estimate farm counts if data only show cattle inventory.

4.4.3 Beef Feedlot Facility Management

This section describes factors that affect the facility management at a feedlot operation, including the layout of feedlot systems, feeding and watering practices, water use and wastewater generation, and climate.

4.4.3.1 *Feedlot Systems*

Cattle traffic flow is an important factor in the design of a feedlot. These operations use separate vehicle and cattle traffic lanes when possible to minimize congestion, reduce the spread of parasites and disease, and promote drainage to make pen cleaning easier and to promote animal comfort and welfare. Outdoor feedlot systems comprise the following units which can be organized in various ways.

- Office - This is usually located on or near the main access road and has truck scales and facilities for sampling incoming feed. All bulk feed delivered to the lot enters at this point. Cattle trucks also use these scales for in and out weights (Thompson et al., 1983).

- Feed Mill - Truck traffic around the feed mill is typically heavy. A good design allows feed ingredients to be received while finished rations are trucked to the pens without traffic conflict. Feeding pens are often near the feed mill to reduce travel (Thompson et al., 1983).

- Pens - Pens are designed for efficient movement of cattle, optimum drainage conditions, and easy feed truck access. A typical pen holds 150 to 300 head but the size can vary substantially. Required pen space may range from 75 to 300 square feet of pen space per head, depending on climate (see Section 4.4.3.4). Space needs vary with the amount of paved space, soil type, drainage, annual rainfall, and freezing and thawing cycles.

  Large feedlots use cattle alleys behind the pens to keep the flow of cattle separate from the feed trucks. Smaller feedlots often use feeding alleys to move the cattle. The pens should allow for proper drainage of runoff to provide comfortable conditions. A grade of at least 3 percent is necessary to allow proper drainage in most areas (Thompson et al., 1983).

- Cattle Loading and Unloading Facilities - Feedlots locate these facilities to ensure the smooth flow of trucks to bring cattle in and out of the lot. Larger feedlots typically use two shipping areas, with the receiving area having hospital or separate processing facilities where cattle can receive various identification markers, vaccinations, and treatment for internal and external parasites, and are held until they are healthy enough to go to regular feeding pens (Thompson et al., 1983).

- Hospital Areas - These are facilities where cattle can be medically treated. Each facility normally has a squeeze chute, refrigerator, water, and medicine and equipment storage (Thompson et al., 1983). Approximately 10 percent of the cattle in a feedlot will be treated in hospital areas during the feeding period (NCBA, 1999).

The majority of beef feedlots are open feedlots, which are usually unpaved. These types of operations may use mounds in the pens to improve drainage and provide areas that dry quickly, because dry resting areas improve cattle comfort, health, and feed utilization. In open feedlots, protection from the weather is often limited to a windbreak near the fence in the winter and sunshade in the summer; however, treatment facilities for the cattle and the hospital area are usually covered. A concrete apron is typically located along feedbunks and around waterers, because these are heavy traffic areas (Bodman et al., 1987).

Open-front barns and lots with mechanical conveyors or fenceline bunks are common for feedlots of up to 1,000 head, especially in areas with severe winter weather and high rainfall. Confinement feeding barns with concrete floors are also sometimes used at feedlots in cold or high rainfall areas. These barns require less land and solve feedlot problems caused by drifting snow, severe wind, mud, lot runoff, and mound maintenance. Feeding is typically mechanical bunk feeding or fenceline bunks. Manure is usually scraped and piled in a containment area. If the barn has slotted floors, the manure is collected beneath slotted floors, and is scraped and stored or flushed to the end of the barn where it is pumped to a storage area for later application (Bodman et al., 1987).

4.4.3.2 *Feeding and Watering Practices*

At feedyards, all cattle are fed two or three times a day and are normally fed for 120 to 180 days, depending on their initial weight and type. Some operations may feed as long as 270 days if they receive young calves. Feedlots consider the following factors when determining feeding methods: the number of animals being fed; the type and size of grain and roughage storage; the equipment necessary to unload, meter, mix, and process feed; and the location and condition of existing feed storage (Bodman et al., 1987).

Beef feedlots use the following types of feeding methods:

- <u>Fenceline feeding</u> - Bunks are located along the side of a lot or pen. This method requires twice as much bunk length as bunks that feed from both sides, but the advantage is that feed trucks do not have to enter the pens with the cattle. Fenceline feedbunks have 6 to 14 inches of bunk space per head, and are typically used for feedlots with more than 100 head. Feedbunks are cleaned routinely to remove uneaten feed, manure, and other foreign objects.

- <u>Mechanical bunk feeding</u> - Bunks typically allow cattle to eat from both sides and are also used as pen dividers. This feeding method is common with continuous feed processing systems and small operations. Mechanical feedbunks are useful for feedlots of up to 500 head.

- <u>Self-feeding</u> - Feedlots use haystacks, feed from horizontal silos or plastic bags, and grain and mixed rations in bunks or self feeders with this feeding method. Portable silage and grain bunks are useful for up to 200 head (Bodman et al., 1987).

Twenty-four hour access to the water trough is required for the health of the animals and maximum production efficiency. Cattle water consumption varies, depending on such factors as animal size and season, and may range from 9 gallons per day per 1,000 pounds during winter to 18 gallons per day per 1,000 pounds during hot weather (Bodman et al., 1987). Typically, one watering space for each 200 head and a minimum of one watering location per pen of animals is provided (USDA NASS, 1999e). Some water may be required to add to the feed processing or to clean equipment.

4.4.3.3 *Water Use and Wastewater Generation*

The main source of wastewater to be managed is the runoff from rainfall events and snow melt. Surface runoff from rain and snow melt can transport manure, soil, nutrients, other chemicals (e.g., pesticides), and debris off the feedlot; therefore, it is important to divert clean water away from contact with manure, animals, feed processing and storage, and manure storage areas to reduce the total volume of contaminated wastewater. Runoff is affected by rainfall amount and intensity, feedlot maintenance practices, and soil type and slope. Runoff can be controlled by using diversions, sediment basins, and storage ponds or lagoons. Feedlots can also reduce the volume of runoff by limiting the size of confinement areas.

Typically, pens are constructed such that runoff is removed as quickly as possible, transported from the lot through a settling basin, and diverted into storage ponds designed to retain, at a minimum, the 24-hour, 25-year storm. Feedlots can reduce the runoff volume by preventing all runon water from entering clean areas and by diverting all roof runoff.

Only specially constructed barns use water to flush or transport manure. These barns are used by a very small percentage of the industry and are typically used at smaller feedlots.

4.4.3.4 *Climate*

Climate plays a large role in the design and operation of a feedlot. The metabolic requirement for maintenance of an animal typically increases during cold weather, reducing weight gain and increasing feed consumption to provide more net energy. Feed consumption typically declines under abnormally high temperatures, therefore reducing weight gain. Investigations in California have shown that the effects of climate-related stress could increase feed requirements as much as 33 percent (Thompson et al., 1983). As a result, waste (manure) generation would also increase.

In cold areas, feedlots typically provide a roof of some sort for the cattle. Sheltered cattle gain weight faster and more efficiently during winter than unsheltered cattle. Areas that receive substantial rainfall require mud control and paved feeding areas, since higher precipitation results in greater runoff volumes. In hot, semiarid areas, sun shades are typically provided for the cattle. A dry climate requires generally 75 square feet of pen space per head whereas a wet climate may require up to 400 square feet of pen space per head (Thompson et al., 1983). Feedlots typically use misting sprinklers or watering trucks to control dust problems in dry climates.

4.4.4 Backgrounding Operations

Backgrounding operations feed calves, after weaning and before they enter a feedlot using pasture and other forages. These operations allow calves to grow and develop bone and muscle without becoming fleshy or gaining fat covering. Weaned calves are typically sent to backgrounding operations to allow producers to:

- Develop replacement heifers;
- Retain rather than sell at weaning when prices are typically low;
- Use inexpensive home-grown feeds, crop residues, pasture or a combination of these to put weight on calves economically;
- Put weight on small calves born late in the calving season before selling; and/or

- Put minimal weight on calves during winter before grazing on pasture the following spring and summer.

Calves are normally kept at the operation from 30 to 60 days but can be kept up to 6 months (approximately 400 pounds) (Rasby et al., 1996). Typical diets consist of equal proportions of roughage and grains that produce a moderate gain of 2 to 2.5 pounds per day. Backgrounding operations typically keep calves on pasture during their entire stay; however, these operations may operate similarly to a beef feedlot, using pens to confine calves, and feedbunks to feed.

4.4.5 Veal Operations

Veal operations raise calves, usually obtained from dairy operations, for slaughter. Dairy cows must give birth to continue producing milk. Female dairy calves are raised to become dairy cows; however, male dairy calves are of little or no value to the dairy operation. Therefore, these male dairy calves are typically sent to feedlots or veal operations. Calves are normally separated from the cows within 3 days after birth. Veal producers typically obtain calves through livestock auctions, although in some cases the calves may be taken directly from the dairy farm to the veal operation (Wilson et al., 2000).

The majority of veal calves are “special-fed” or raised on a low-fiber liquid diet until about 16 to 20 weeks of age, when they weigh about 450 pounds. Calves slated for “Bob” veal, which are marketed up to 3 weeks of age, when they weigh about 150 pounds; these constitute about 15 percent of the veal calves sold (USDA, 1998).

Calves are fed a milk-replacer diet composed of surplus dairy products, including skim milk powder and whey powder. Their diet also includes plant- and animal-derived fats, proteins, and other supplements such as minerals and vitamins (Wilson et al., 2000). Calves spend their entire growing-out period on a liquid diet.

Veal calves are generally grouped by age in an environmentally controlled building. The majority of veal operations utilize individual stalls or pens. Floors are constructed of either wood slats or plastic-coated expanded metal, while the fronts and sides are typically wood slats. The slotted floors allow for efficient removal of waste. The back of the stall is usually open, and calves may be tethered to the front of the stall with fiber or metal tethers. Individual stalls allow regulation of air temperature and humidity through heating and ventilation, effective management and handling of waste, limited cross-contamination of pathogens between calves, individual observation and feeding, and, if necessary, examination and medical treatment (Wilson et al., 2000). The stalls provide enough room for the calves to stand, stretch, groom themselves, and lie down in a natural position.

Veal waste is are very fluid, diluted by various volumes of wash water used to remove them from the building (see Section 6.4 for a discussion of veal manure characteristics). Therefore, manure is typically handled in a liquid waste management system. Manure, hair, and feed are regularly washed from under the stalls to reduce ammonia, odor, and flies in the room. Manure is typically washed out twice daily so that if the calf is having health problems, it is easily observed.

Approximately 10 percent to 30 percent of the wastewater generated at a veal operation comes from scrubbing rooms and stalls after calves have been shipped to market.

The most common method for handling manure and wash water is using a sloping gutter under the rear of the stalls, allowing manure to continuously drain into a manure storage system. Tanks, pits, and lagoons are used to store manure until it is spread on fields. Storage pits may also be built directly under buildings; however, this produces higher levels of ammonia and other pit gases that require increased ventilation and higher fuel costs in the winter (Meyer, 1987).

4.4.6 Cow-Calf Operations

Cow-calf operations breed mature cows and yearling heifers with bulls to produce calves and can be located in conjunction with a feedlot, but they are more often as stand-alone operations. A herd of mature cows, some replacement heifers, and a few bulls are typically maintained at cow-calf operations on a year-round basis. Offspring calves remain with the cows until weaned and then may be held in different pastures to grow until they weigh between 650 to 750 pounds when they are sold to feedlots as yearlings. These operations may also sell their calves to backgrounding operations or dairy operations. Artificial insemination is not commonly used at cow-calf operations. Bulls are typically used for breeding and are placed with cows at the proper time to ensure spring calves.

The number of bulls required at a cow-calf operation depends on the number of cows and heifers, size and age of bulls, crossbreeding program, available pasture, and length of breeding season. One bull is typically provided for each set of 25 cows or heifers. Bulls are usually pastured away from the cows, and they may be penned separately from each other to prevent fighting (Bodman, 1987).

Outdoor calving requires clean, well-drained, and wind-protected pastures. Separate feed areas are provided for mature cows, first calf heifers, bulls, and calves (Loudon, 1985). In cold climates, a calving barn may be needed to reduce the risk of death. These barns typically include a loose housing observation area, individual pens, and a chute for holding and treating cows. Typically, a barn is provided for 5 percent to 10 percent of the cow herd in mild climates, and for 15 percent to 20 percent of the herd in more severe weather or during artificial insemination (Bodman, 1987).

4.4.7 Waste Management Practices

Waste from a beef feedlot may be handled as a solid or liquid; both management methods have advantages and disadvantages. Waste from a veal operation is handled as a liquid. Solid waste is typically found in calving pens and in open lots with good drainage. Semisolid waste has little bedding and no extra liquid is added. Waste treated as a solid has a reduced total volume and weight because it contains less water; therefore, its management may cost less and require less power.

Slurry waste has enough water added to form a mixture that can be handled by solids handling pumps. Liquid waste is usually less than 8 percent solids, and large quantities of runoff and precipitation are added to dilute it. Wastes treated as a liquid are easier to automate and require less daily attention; however, the large volumes of added water increase the volume of waste. As a result, the initial cost of the liquid-handling equipment is greater (USDA NRCS, 1992).

4.4.7.1 *Waste Collection*

Beef cattle are confined on unpaved, partially paved, or totally paved lots, and much of their manure is deposited around feedbunks and water troughs. Feedlots typically collect these wastes from the feedlot surface after shipping each pen of cattle (Sweeten, n.d.).

The following methods are used in the beef industry to collect waste:

- <u>Scraping</u> - This is the most common method of collecting solid and semisolid manure from both barns and open lots. Solids can be moved with a tractor scraper and front-end loader. A tractor scraper may be used in irregularly shaped alleys and open areas. Mechanical scrapers are typically used in the pit under barns with slotted floors and propelled using electrical drives attached by cables or chains. Tractors have fewer problems and work better on frozen manure; however, mechanical scrapers reduce labor requirements. Removing manure regularly reduces odor in enclosed areas. Scraping is common for medium and large feedlots (Loudon, 1985).

- <u>Slotted Flooring</u> - This term refers to slats and perforated or mesh flooring and is a method of rapidly removing manure from an animal's space. Most slats are reinforced concrete, but can be wood, plastic, or aluminum, and are designed to support the weight of the slats plus live load, which includes animals, humans, and mobile equipment. Manure drops between slats, which keeps the floor surface relatively clean. Wide slats (between 4 and 8 inches) are commonly used with 1.5 to 1.75 inches between slats (Loudon, 1985).

- <u>Flushing System</u> - This type of system dilutes manure from beef feedlots with water to allow for automated handling. Diluting the manure increases its volume and therefore requires a larger capital investment for equipment and storage facilities. The system uses a large volume of water to flush manure down a sloped gutter to storage, where the liquid waste can be transferred to a storage lagoon or basin. The amount of water typically used for cleaning is 100 gallons per head at least twice a day. Grade is critical for the flush alleys as is amount of water used (Loudon, 1985). This system is not very common for large feedlots; however, this type of system is widely used at veal operations.

Waste collection is easiest on paved lots. On unpaved lots, cattle traffic tends to form a seal on the soil that reduces the downward movement of contaminated water; however, deep scraping can destroy the interface layer that forms between the manure and the soil and acts as a seal to decrease the chance of pollutants from entering the groundwater.

To reduce the production of unnecessary waste, clean water can be diverted away from the feedlot area. For example, uncontaminated water can be directed away from the waste and carried outside of the feedlot area. Roof runoff can be managed using gutters, downspouts, and underground outlets that discharge outside the feedlot area. Unroofed confinement areas can include a system for collecting and confining contaminated runoff. Paved lots generally will have more runoff per square foot than unpaved lots, but due to a smaller total area, they will have less total runoff per animal.

4.4.7.2 *Transport*

Waste collected from the feedlot may be transported within the site to storage, treatment, and use or disposal areas. Solids and semisolids are typically transported using mechanical conveyance equipment, pushing the waste down alleys, and transporting the waste in solid manure spreaders. Flail-type spreaders, dump trucks, or earth movers may also be used to transport these wastes. Liquids and slurries, typically found at veal operations, are transferred through open channels, pipes, or in a portable liquid tank. These wastes can be handled by relying on gravity or pumps as needed.

4.4.7.3 *Storage, Treatment, and Disposal*

Beef feedlot operations typically use a settling basin to remove bulk solids from the liquid waste stream, reducing the volume of solids before the stream enters a storage pond, thereby increasing storage capacity. A storage pond is typically designed to hold the volume of manure and wastewater accumulated during the storage period, the depth of normal precipitation minus evaporation, the depth of the 25-year, 24-hour storm event, and an additional 1 foot of freeboard. Solid manure storage can also range from simply constructed mounds to manure sheds that are designed to prevent runoff and leaching.

Beef feedlot operations may also use other types of technologies, such as composting or mechanical solids separation, when managing animal waste and runoff. Typical manure and waste handling, storage, and treatment technologies used at beef feedlots are discussed in detail in Section 8.2. The majority (approximately 83 percent) of beef feedlots dispose of their waste through land application (USDA APHIS, 2000a).

Veal operations typically use an underground storage pit or a lagoon for waste storage and treatment. Veal operations also typically dispose of their waste through land application.

The amount of cropland and pastureland that is available for manure application varies at each beef operation. Generally, operations in the beef industry can be categorized into three groups with respect to available cropland and pastureland: (1) those with sufficient land so that all manure can be applied without exceeding agronomic application rates, (2) those without sufficient land to apply all of their manure at agronomic rates, and (3) those without any available cropland and pastureland. Operations without sufficient land, or any land, often have agreements with other farmers allowing them to apply manure on their land. Depending on the size of the beef operation, 1997 Census of Agriculture data indicate that the average acreage of cropland at beef feedlots with at least 500 head is between 550 to 850 acres and the average acreage of pastureland is between 50 and 110 acres (Kellogg, 2000).

USDA conducted an analysis of the 1997 Census of Agriculture data to estimate the manure production at livestock farms. As part of this analysis, USDA estimated the number of confined livestock operations that produce more manure than they can apply on their available cropland and pastureland at agronomic rates for nitrogen and phosphorus and the number of confined livestock operations that do not have any available cropland or pastureland. The analysis assumed land application of manure would occur on 1 of 24 typical crops or pastureland (Kellogg, 2000). Using the percentage of these facilities estimated by USDA against the total number of livestock facilities, one can also estimate the number of facilities that have sufficient cropland and pastureland for agronomic manure application. Table 4-82 summarizes the percentage of beef feedlots that have sufficient, insufficient, and no land for manure application at agronomic application rates for nitrogen and phosphorus. EPA assumes that all veal operations have sufficient land to apply their manure.

Table Table 4-82. Percentage of Beef Feedlots With Sufficient, Insufficient, and No Land for AgronomicApplication of Manure

Size Class	Sufficient Land		Insufficient Land		No Land[a]
	Nitrogen Application	Phosphorus Application	Nitrogen Application	Phosphorus Application	
300 - 1,000 head	84	62	9	31	7
1,000 - 8,000 head	6	22	21	67	11
> 8,000 head	8	1	53	6	39

[a] No acreage of cropland (24 crops) or pastureland.
Source: Kellogg, 2000

4.5 References

Abt. 1998. *Preliminary study of the livestock and poultry industry: Appendices*. Abt Associates Inc., Cambridge, Massachusetts.

Adams, R. S., et al. 1995. *Dairy reference manual*. 3rd ed. Northeast Regional Agricultural Engineering Service Cooperative Extension.

AAFC. 1999. *Farming for tomorrow: Conservation facts. Rotational grazing: The rest and recovery method of pasture management*. Agriculture and Agri-Food Canada, <http://aceis.agr.ca/pfra/land/fft10.htm>. Accessed February 2000.

Aust, P. 1997. *An institutional analysis of vertical coordination versus vertical integration: The case of the US broiler industry*. Michigan State University, Department of Agricultural Economics, East Lansing, Michigan.

Bagely, P.C. and Evans, R.R. 1998. *Broiler litter as a feed or fertilizer in livestock operations.* Mississippi State University Extension Service, cooperating with U.S. Department of Agriculture, Washington, DC. <http://www.ext.msstate.edu/pubs/pub1998.htm>.

Bartlett, F., J. Laird, C. Addison, and R. McKellar. 1993. The analysis of egg wash water for the rapid assessment of microbial quality. *Poultry Science.* 72:1584-591.

Bickert, W.G., G.R. Bodman, B.J. Holmes, D.W. Kammel, J.M. Zulovich, and R. Stowell. 1997. *Dairy freestall housing and equipment*. 6th ed. Midwest Plan Service, Agricultural and Biosystems Engineering Department.

Bocher, L. W. 2000. *Custom heifer grower, specialize in providing replacements for dairy herds*, Hoard's Dairyman.

Bodman, G.R., D.W. Johnson, D.G. Jedele, V.M. Meyer, J.P. Murphy, and H.L. Person. 1987. *Beef housing and equipment handbook.* 4th ed. Midwest Plan Service.

Bradley, F., D. Bell, R. Ernst, D. McMartin, and J. Milliam. 1998. *Animal care series: Egg-type layer flock care practices*. California Poultry Workgroup, University of California Cooperative Extension, University of California Publishing, Davis, California.

Brodie, H.L. Carr, and C. Miller. 2000. *Structures for broiler litter manure storage*. Cooperative Extension System, University of Maryland System, College Park, Maryland <http://www.hermes.ecn.purdue.edu/cgi/convertwq?5343>. Accessed November 2000.

CIAS. 2000a. *Grazing's potential: Predicting expansion's cost, profit*. Center for Integrated Agricultural Systems, <http://www.wisc.edu/cias/pubs/resbrief/030.html>. Accessed May 2000.

CIAS. 2000b. *Outwintering dairy cattle: Animal health issues*. Center for Integrated Agricultural Systems, <http://www.wisc.edu/cias/pubs/resbrief/027.html>. Accessed May 2000.

CIAS. 2000c. *Outwintering dairy cattle: Manure management issues*. Center for Integrated Agricultural Systems, <http://www.wisc.edu/cias/pubs/resbrief/028.html>, Accessed May 2000.

CIAS. 2000d. *Dairy grazing can provide good financial return*. Center for Integrated Agricultural Systems, <http://www.wisc.edu/cias/pubs/resbrief/050.html>. Accessed May 2000.

Dougherty, M., L.D. Geohring, and P. Wright. 1998. *Liquid manure application systems*, Northeast Regional Agricultural Engineering Service, NRAES-89.

Emmicx, D.L. 2000. *ABC's of rotational grazing: Questions and answers.* King Conservation District, WA. <http://www.kingcd.org/stewardship/Ag%20Pr...ces/Pastures/ABCsofRotationalGrazing.html>. Accessed February, 2000.

ERG. 2000a. Stand alone dairy heifer raising operations. Memorandum from Birute Vanatta, Eastern Research Group, Inc. to Ron Jordan, U.S. Environmental Protection Agency.

ERG. 2000b. Facility counts for beef, dairy, veal, and heifer operations. Memorandum from Deb Bartram, Eastern Research Group, Inc., to the Feedlots Rulemaking Record. November 2000.

Faust, M.A. 2000. *Dairy replacement heifer enterprises*. Department of Animal Science, Iowa State University. Obtained from the Internet on February 14, 2000.

Goan, C. 2000. *Storage facilities for broiler litter*. University of Tennessee Extension Service, pb-1476.tn. Tennessee <http://hermes.ecn.purdue.edu/cgi/convertwq?7146>. Accessed November 20, 2000

Hamm, D., G. Searcy, and A. Mercuri. 1974. A study of the waste wash water from egg washing machines. *Poultry Science*. 53:191-197.

Hansen, D. 2000. State regulatory issues and implications: Eastern USA, in *Proceedings: 2000 National Poultry Waste Management Symposium*, Ocean City, Maryland.

Hutchinson, L.J. 1988. Animal health, pest management and environment. In *Proceedings of Pasture in the Northeast Region of the United States*. U.S. Department of Agriculture, Soil Conservation Service, Northeast National Technical Center, Chester, Pennsylvania.

Kellogg, R.L., C. Lander, D. Moffitt, and N. Gollehon. *Manure nutrients relative to the capacity of cropland and pastureland to assimilate nutrients: Spatial and temporal trends for the U.S.* April 27, 2000.

Loudon, T.L., D.D. Jones, J.B. Petersen, L.F. Backer, M.F. Brugger, J.C. Converse, C.D. Fulhage, J.A. Lindley, S.W. Nelvin, H.L. Person, D.D. Schulte, and R. White. 1985. *Livestock waste facilities handbook.* 2nd ed. Midwest Plan Service.

Martinez, S.W. 1999. *Vertical coordination in the pork and broiler industries: Implications for pork and chicken products.* Agriculture Economic Report No. 777. U.S. Department of Agriculture, Economic Research Service, Food and Rural Economics Division, Washington, DC.

Meyer, D. J. 1987. *Animal manure–Veal calf management*. Prepared under the direction of the Manure Management Work Group of the Agricultural Advisory Committee to the Pennsylvania Department of Environmental Resources, Robert E. Graves, ed.

<http://www.inform.umd.edu:8080/EdRes/topic/
AgrEnv/ndd/watermgt/ANIMAL_MANURE_VEAL_CALF_MANAGEM.html>.

Moats, W.A. 1978. Factors Affecting Bacterial Loads on Shells of Commercially Washed Eggs. *Poultry Science* 60:2084-2090.

Murphy, B. 1988. Voisin grazing management in the Northeast. In *Proceedings of Pasture in the Northeast Region of the United States*. U.S. Department of Agriculture, Soil Conservation Service, Northeast National Technical Center, Chester, Pennsylvania.

NCBA. 1999. *Comments on the draft industry profile*. National Cattlemen's Beef Association.

National Milk Producers Federation submittal to U.S. Environmental Protection Agency on 3/1/99: State Level Milk Production.

NCSU. 1998a. *Draft of swine and poultry industry characterization, waste management practices and modeled detailed analysis of predominantly used systems.* North Carolina State University, September 30.

NCSU. 1998b. Nutritional strategies to reduce swine and poultry waste quantity and N and P in waste. North Carolina State University.

Noyes, T.E. *Heifer raising conference*. Wayne County Dairy Newsletter. The Ohio State University Extension. Updated October, 1999. Obtained from the Internet on December 3, 1999. <http://www.ag.ohio-state.edu/~wayn/dairy/darnews.htm>.

NPPC. 1996. *Swine care handbook.* National Pork Producers Council, Des Moines, Iowa, <http://nppc.org/prod/swinecarehandbook.html>. Accessed August 17, 1999.

NPPC. 1998. *Environmental assurance program survey*.

NPPC. 1999. *Pork facts 1998/99.* National Pork Producers Council, Des Moines, Iowa, <http://nppc.org/prod/swinecarehandbook.html>. Accessed August 15, 1999.

NRC. 1989. *Nutrient requirements of dairy cattle,* 6th rev. ed. National Research Council.

PPRC. 1996. *Impacts of intensive rotational grazing on stream ecology and water quality.* Pacific Northwest Pollution Prevention Resource Center, <http://www.pprc.org/pprc/rpd/fedfund/usda/sare_nc/impactsi.html>. Accessed February, 2000.

PADER. 1986. *Swine manure management*. Pennsylvania Department of Environmental Resources, Harrisburg, Pennsylvania.

Jordan, Larry. Personal communication, South East Regional Director for the Professional Dairy Heifer Growers Association. December 8, 1999.

Gardner, Don. Personal communication, South East District Director for the Professional Dairy Heifer Growers Association. December 9, 1999.

Cady, Roger. Personal communication, Monsanto Company and Founder of the Professional Dairy Heifer Growers Association. February 18, 2000.

Hannawald, Jim. Personal communication, U.S. Department of Agriculture. April 4, 2000.

NCC. 1999. Comments on EPA profile of broiler industry. National Chicken Council, Washington, DC.

Rasby, R., I. Rush, and R. Stock. 1996. *Wintering and backgrounding beef calves*. NebGuide. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, <http://www.ianr.unl.edu/PUBS/BEEF/g1228.htm>.

Sawyer, G. 1997. *The agribusiness poultry industry*. Exposition Press, New York. 1971. Cited in August, 1997.

Stull, C.E., S. Berry, and E. DePeters. 1998. *Animal care series: Dairy care practices*. 2nd ed. Dairy Workgroup, University of California Cooperative Extension.

Sweeten, J. n.d. *Manure management for cattle feedlots*. Great Plains Beef Cattle Handbook. Cooperative Extension Service - Great Plains States.

Thompson, G.B. and C.C. O'Mary. 1983. *The feedlot*. 3rd ed. Lea & Febiger, Philadelphia, Pennsylvania.

Thorne, J. 1999. Proposed EPA Project XL: United egg producers. Capitolink LLC, Washington, DC.

Tyson, T. 1996. Planning and managing lagoons for poultry layer waste treatment. Alabama Cooperative Extension Service, Auburn, Alabama.

UCD. 1998. *Egg type- Layer flock care practices.* California Poultry Workgroup, University of California at Davis, Davis, California. May 1998.

UEP. 1998. UEP (Egg Producers) Data Package. United Egg Producers. Submitted to USEPA.

USDA. *Safety of veal, from Farm to table*. U.S. Department of Agriculture, Food Safety and Inspection Service, <http://www.fsis.usda.gov/oa/pubs/veal/htm>. Accessed April 14, 1999.

USDA 1997. Chapter 5: Management of grazing lands. In: *National range and pasture handbook*. U.S. Department of Agriculture (USDA).

USDA APHIS. 1993. *National Dairy Heifer Evaluation Project, Contract heifer raising*. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA APHIS. 1995. *Swine '95 Part 1: Reference of 1995 swine management practices*. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA APHIS. 1996a. *National Animal Health Monitoring System, Part I: Reference of 1996 dairy management practices*. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA APHIS. 1996b. *National Animal Health Monitoring System, Part III: Reference of 1996 dairy health and health management*. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA APHIS. 1996c. *Swine '95 Part II: Reference of 1995 grower/finisher health and management*. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA APHIS. 1999. *Swine '95 Reference of 1995 swine management practices.* Additional data queries run at the request of EPA for new region and size categories. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA APHIS. 2000a. *National Animal Health Monitoring System, Part I: Baseline reference of feedlot management practices*. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA APHIS. 2000b. *Part II: Reference of 1999 table egg layer management in the United States (Layer '99).* U.S. Department of Agriculture (USDA), Animal Plant Health Inspection Service (APHIS). Fort Collins, Colorado.

USDA BAMN. 1997. *A guide to dairy calf feeding and management.* U.S. Department of Agriculture (USDA), Bovine Alliance on Management & Nutrition (BAMN) <http://www.aphis.usda.gov/vs/ceah/cahm/ File bamnfeed.htm>.

USDA ERS. 1997. *The U.S. Pork industry: As it changes, consumers stand to benefit* U.S. Department of Agriculture (USDA), Economic Research Service (ERS), Washington, DC.

USDA NAHMS. 1999. *Data aggregated from Swine '95 data* by Eric Bush, Centers for Epidemiology and Animal Health. U.S. Department of Agriculture (USDA), Animal Plant

Health Inspection Service (APHIS), National Animal Health Monitoring System, Fort Collins, Colorado.

USDA NAHMS. 2000. *Data Aggregated from Layer 99 data* by Lindsey Garber, Centers for Epidemiology and Animal Health. U.S. Department of Agriculture (USDA), Animal Plant Health Inspection Service (APHIS), National Animal Health Monitoring System (NAHMS). Fort Collins, Colorado.

USDA NASS. 1995b. *Milk: Final estimates 1988-1992.* Statistical Bulletin 909. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1998a. *Agricultural statistics*. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1998b. *Chickens and eggs final estimates 1994-97*. Statistical Bulletin No. 944. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1998c. *Poultry production and value, final estimates 1994-97*. Statistical Bulletin No. 958. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1999a. *Hogs and Pigs: Final estimates* 1993-1997. Statistical Bulletin Number 951. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1999b. *1997 census of agriculture*. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1999c. Queries run by NASS for USEPA on the 1997 census of agriculture data. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1999d. *Milking cows and production: Final estimates 1993-1997*. Statistical Bulletin 952. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NASS. 1999e. *Cattle: Final estimates 1994-1998*. 1999. Statistical Bulletin 953. U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Washington, DC.

USDA NRCS. 1992. *Agricultural waste management field handbook, National engineering handbook (NEH)*, Part 651. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Washington, DC.

USDA NRCS. 1996. *Dairy farmer profitability using intensive rotational stocking: Better grazing management for pastures.* U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Grazing Lands Technology Institute. Washington, DC.

USDA NRCS, 1998. *Nutrients available from livestock manure relative to crop growth requirements*. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Washington, DC.

USEPA. 1998. Feedlot industry sector profile. Revised draft report. Prepared for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, Virginia.

USEPA. 1999. *Draft profile of the poultry industry*. U.S. Environmental Protection Agency, Washington, DC.

Vest, L. n.d. *Layer production*. Georgia Farm*A*Syst. Cooperative Extension Service, University of Georgia, College of Agricultural and Environmental Sciences. Athens, Georgia.

Wilson, L.L., C.L. Stull, and T.L. Terosky. 2000. Scientific advancements and legislation addressing veal calves in North America. In: *Veal Perspectives to the Year 2000, Proceedings of an International Symposium*. September 12 and 13, 1995, LeMans, France.

CHAPTER 5

INDUSTRY SUBCATEGORIZATION FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS

5.0 INTRODUCTION

The Clean Water Act requires EPA to consider a number of different factors when developing Effluent Limitations Guidelines and Standards (ELG) that represent the best available technology economically achievable for a particular industry category. These factors include the age of the equipment and facilities, the manufacturing processes employed, the types of treatment technology to reduce effluent discharges, and the cost of effluent reductions. One way the Agency takes these factors into account is by breaking down categories of industries into separate classes of similar characteristics. The division of a point source category into groups called "subcategories" provides a mechanism for addressing variations among products, raw materials, processes, and other parameters that can result in distinct effluent characteristics. This provides each subcategory with a uniform set of effluent limitations guidelines that take into account technology achievability and economic impacts unique to that subcategory.

In developing the CAFO ELG, EPA assessed the factors described above and developed additional factors that specifically address the characteristics unique to CAFOs. Furthermore, EPA reviewed the existing ELG supporting documents for the basis for subcategorization. Finally, it is EPA's goal to simplify this regulation by revising both the ELG and the NPDES permit regulations together, and to develop a subcategorization scheme consistent with both regulations. For this proposal, EPA considered the following factors:

- 5.1.1 Basis for the existing ELG (40 CFR Part 412)
- 5.1.2 Production processes
- 5.1.3 Animal type
- 5.1.4 Water use practices
- 5.1.5 Wastes and wastewater characteristics
- 5.1.6 Facility age
- 5.1.7 Facility size
- 5.1.8 Geographical location
- 5.1.9 Pollution control technologies
- 5.1.10 Non-water quality environmental impacts

5.1 Factors Considered as the Basis for Subcategorization

EPA considered a number of potential subcategorization approaches for CAFOs. EPA used information collected during site visits as well as outreach communications with the industry to develop these approaches. A brief discussion of each approach is presented below.

5.1.1 Basis for Subcategorization in the Existing ELG

EPA developed the subcategorization in the existing ELG (40 CFR Part 412) on the basis of animal type, housing, and numbers of animals (USEPA, 1974). As one option for revision, EPA considered maintaining the existing basis of subcategorization, and refining the performance standards for these facilities (described in Chapter 9 as Regulatory Scenario 4 where the ELG applicability is established at 1,000 AU). EPA also considered expanding the scope of the ELG, and considered the existing subcategorization as the basis (described in Chapter 9 as Regulatory Scenarios 2 and 3). The subcategories analyzed under the existing ELG are listed below:

- beef cattle, open lot
- beef cattle, housed lot
- dairy cattle, stall barn
- dairy cattle, free stall barn
- dairy cattle, cowyard with milking center
- swine, open dirt or pasture
- swine, slotted floor house
- swine, solid concrete floor
- chickens, broilers
- chickens, layers
- chickens, layer breed and replacement
- turkeys, open lot
- turkey, housed lot

EPA developed model farms to distinguish animal type, current housing types, and numbers of animals that could be used to evaluate costs for each existing potential subcategory. EPA notes that the industries have changed operational practices considerably in the past few decades. EPA and industry stakeholders both agreed that the basis for subcategorization needed to reflect current industry trends. Stakeholders suggested EPA should consider elimination of any reference to outdated technologies such as continuous flow watering systems for poultry. EPA also notes that changes in production processes have essentially excluded swine nurseries and dairy heifer operations. Finally, EPA notes that the analysis for the animal types listed above reflect assumptions regarding animal sizes, ages, and/or weights that were common to the industry in 1974. In many cases, these parameters are substantially different today than they were in 1974 (See Chapter 4). Nevertheless, EPA determined animal types were still an important factor that needed to be further evaluated. Animal type is further described in section 5.1.3.

5.1.2 Production Processes

EPA interpreted "production processes" to be the production of meat, eggs, or milk by CAFOs. The production process also includes the housing systems commonly used. Manure handling and treatment are discussed in section 5.1.9. One basis for subcategorization is the type of production system in place; for example, the swine production pyramid of breeding, nursery, and finishing could be used as a basis of subcategorizing swine CAFOs. In consultation with the industry, EPA determined there were too many life-cycle variables to allow reasonable subcategorization, and that segmentation based on these variables was unlikely to result in substantially different effluent guidelines and standards. In the case of chickens, such an approach would result in over a dozen subcategorizations that overlap. The applicable subcategory could also vary for each group of animals produced at a given operation. EPA determined segmentation in this fashion would complicate rather than simplify the regulation.

Another approach could be based on building type or confinement practice; for example, open lots, stall barns, and total confinement housing could be used as a basis for subcategorization. EPA collected sufficient data to warrant development of a new subcategory for veal, which was previously included in the beef cattle subcategory. Veal operations confine fewer animals than do many beef feedlots, and veal are usually maintained in housing where wastes are stored in lagoons or tanks. As discussed in Chapter 10, EPA also found the bases for BAT and NSPS for veal operations are different than that for beef cattle.

EPA also determined that the previous basis for separating wet and dry poultry operations was inappropriate. EPA developed model farms by size (number of birds), location (region), and function (broiler or layer) to further evaluate production processes. EPA did not find that these factors influenced the ability for the regulated industries to achieve the performance standards. Furthermore, since broilers and layers both are mostly dry manure systems, and since it would complicate the regulation by segmenting each subsector, EPA decided not to segment the industry for the proposed rule.

For the other animal sectors, EPA looked at and determined that there was no reason to segment the industry. EPA's data and site visits indicated that facilities often managed animals in more than one fashion at a single location, and furthermore, that such a subcategorization could actually provide disincentives for facilities to employ new technologies. Nevertheless, EPA acknowledges production processes are an important factor in distinguishing various facilities, and developed its cost models to reflect the differences in production processes. Cost estimates developed for the various technology options described in Chapter 10 indicate that differences in production processes do not consistently influence the ability of the facility to achieve the performance standards.

5.1.3 Animal Type

EPA considered both animal type and animal maturity as a possible means of subcategorization. Animal type is clearly a significant factor and was successfully used as the first level of categorization in the existing ELG. However, the animal breed, animal weight, number of turns produced, feed and water consumption, manure production, manure contents, and production system vary not only by animal type, but also by animal function and maturity. These differences suggest further evaluation of animal function and animal maturity for the purposes of subcategorization. For example, sows for breeding are often confined, fed, housed, and maintained differently from nursery pigs or finishing pigs. Chickens raised for meat production are a different breed of chicken, have a different weight, eat a different diet, and are raised differently than those used for egg production. Such an approach could also mean a beef feedlot would have to track the average weights of each animal breed and age on the facility. Many other production related factors are necessarily complicated, such as fluctuating market demands, number of turns the facility produces annually, efficiency of a given animal or breed of animal to assimilate feed, costs and makeup of feed, and many other highly variable factors. These factors do not lend themselves to industry segmentation.

EPA notes two cases where the existing regulation needed clarification regarding scope of certain animal types: immature swine and immature dairy. The existing regulation only counted those swine that weigh more than 55 pounds, and accounts for only the confined mature dairy (whether milked or dry) when determining the applicability for the dairy operation. Some stakeholders perceive an inconsistency between sectors and how CAFOs are defined, and consider the inconsistency a major loophole. Therefore, EPA collected data on the numbers and sizes of operations that confine immature animals.

In the 1970s, farms that confined only nursery pigs were relatively scarce. The vast majority of these operations maintained all phases of swine production (farrow to finish) at one location. The size of a swine operation was readily identified by the number of sows or the number of finishing pigs kept on site. Swine nurseries may have been located in separate buildings, but the animals were still maintained at the same site. Since the regulations applied to the entire facility and all animals kept in confinement, once a facility was defined as CAFO for one group of animals, all animals and manure generated in confinement were considered part of the CAFO. Though half of the swine industry today still practices farrow-to-finish production, and the vast majority of the remaining operations are grow-finish operations, the increased use of contracts to handle certain phases of production and the increased specialization found in the swine production pyramids has resulted in the emergence of operations that solely confine nursery pigs (i.e. swine weighing less than 55 pounds). Even in the 1990s, there were an estimated 100 operations that only confine immature swine (i.e. nurseries). However, EPA data indicates such operations are increasing in both number and size, and looked at ways to subcategorize these operations and include them under the revised regulatory scope.

EPA considered a number of mechanisms for covering immature swine. The simplest approach is to count all swine, regardless of size or age. EPA determined counting all animals would double the effective size of operations that have breeding functions. While this would include nursery facilities, this approach also changes the existing basis without improving the regulation. Alternatively, all swine would be counted but a weighting factor could be used to distinguish animal sizes. This approach is inconsistent with EPA's attempt to simplify the regulations by removing mixed animal multipliers and animal unit calculations. Furthermore EPA believes the current subcategorization is still effective for regulating all but those facilities that house immature swine only. To target the perceived immature animal loophole, EPA selected the approach of counting both numbers of mature swine and numbers of immature swine, either one of which could define the facility as a CAFO. Once a facility is defined as a CAFO for either age group of animals, all animals in confinement would be considered as part of the CAFO. This approach minimizes changes to the applicability to most facilities with mature swine, though it is possible some breeding facilities with high numbers of pigs per litter could now be defined as a CAFO.

The existing regulation also applies to operations confining mature dairy, whether milked or dry. In the 1970s, most dairies maintained calves and heifers for replacement on site, though such animals were frequently kept on pasture. The number of heifers and calves kept varied from year to year and by season, but the milking herd was relatively constant. Bulls, when kept on site at all, were few in number. The threshold for dairy already takes into account housing and management of animals at dairies, including the frequent use of pasture to keep some animals. EPA still believes the threshold based on mature dairy inherently accounts for some calves and heifers being kept in confinement. For reasons described above, EPA elected to continue to count only mature animals at a dairy.

Since the 1970s, some dairy operations have focused time and resources on the actual milking herd, and have elected not to keep heifers and calves on site. An estimated 18% dairies use contract heifer operations to keep the heifers until needed. Though EPA estimates there are fewer than100 large heifer operations, the trend continues for offsite management of heifers. Such heifer operations may use pasture, but more commonly use a feedlot type system for maintaining the animals. Therefore, EPA proposes to count heifers maintained separately from the milking herd using the same basis as beef cattle. Note that both beef cattle and heifers are counted together under this approach.

In addition to animal type and age, EPA performed additional analysis on animal function: pullets for replacement, turkeys for breeding, swine breeding facilities, swine finishing facilities, swine nurseries (swine under 55 pounds), and beef backgrounding yards. However, EPA believes segmentation of the industry to reflect these other animal functions would not improve practicability of the regulation. Many facilities could fall under more than one applicability, causing additional confusion in implementing applicable regulatory requirements. EPA concluded size and age of animal was only appropriate for the purpose of including those animals previously unspecified in the applicability of the ELG.

5.1.4 Water Use Practices

EPA considered water use practices at dairy, swine, and layer facilities employing liquid or semi-solid based technologies such as flush waste handling systems, deep pits, and scrapers. In considering these practices as a basis for subcategorization, first EPA costed the dairy industry for scrape or flush, and conservatively costed all swine facilities as utilizing flush type manure handling systems. EPA costed these sectors for the various technology options, and concluded water use practices did not prevent a facility from achieving performance standards. EPA determined a subcategorization based on water use practices could in some cases provide a disincentive for a facility to reduce fresh water consumption. Therefore, EPA did not select water use practices as a basis for subcategorization.

5.1.5 Wastes and Wastewater Characteristics

EPA analyzed data available from USDA, universities, industry, and the literature. For a given animal type, there is reasonably consistent manure generation, and similar pollutant generation. However, site specific factors such as animal management, feeding regiments, and manure handling will affect the form and quantity of the final waste products.   EPA determined nutrients were the primary pollutant of concern, and evaluated some methods of subcategorization based on nutrient generation.

EPA considered a method for comparing sows and nursery pigs to finishing pigs where the method looks at manure, nitrogen, phosphorus, BOD_5, and volatile solids (VS) on a per pound (lb) animal basis. Depending on the metric used, from 9,000 to 12,000 immature pigs equate to 2,500 finishing pigs (or equivalent to 1,000 AU of swine). Therefore EPA selected 10,000 swine under 55 pounds as the equivalent of 2,500 mature swine. See Section 5.1.3 for additional discussion of immature animals.

Manure/litter can be treated and reused as bedding materials, and wastewaters can be recycled for washing or flushing, but ultimately all manure nutrients will be land applied. Even manure processed into value added products (such as pelletizing or composting) or used for alternative uses (such as incineration or digestion) will eventually be land applied. Therefore, EPA considered an approach that evaluated the nutrient content of the manure, namely phosphorus. One method of nutrient based subcategorization would use published USDA NRCS manure nutrient values to determine a threshold at which a facility would be defined as a CAFO. One limitation to such an approach is that it would not encourage management strategies to reduce nutrient content of the manure, and the approach does not consider the form of the nutrient, only the presence of the nutrient. Form of the nutrient (i.e. organic or inorganic) is especially important where land application of manure should be done with the intention of nutrient assimilation by the crop and soil.

EPA considered another approach by which the mass of a particular nutrient (i.e. phosphorus) could be used as a basis for categorization. This approach encourages nutrient management and conservation, however this approach was not selected due to its costs, complexity, and potential additional requirements for rigorous sampling. Furthermore, the approach would not allow for site specific determination of the land application rate for any other nutrient. EPA also did not select a particular pollutant such as nutrients as a basis for subcategorization because nutrients (such as phosphorus) may be an important consideration today, but in the future the focus may shift to some other parameter such as metals or pathogens.

5.1.6 Facility Age

EPA evaluated the age of facilities as a possible means of subcategorization because older facilities may have different processes and equipment which could result in different wastewater characteristics. These differences may require significantly greater or more costly control technologies to comply with regulations.

During site visits EPA looked at facilities of all ages. EPA believes these older facilities are subject to full compliance with state and federal regulations just like the newer facilities. In addition, many older facilities are similar to newer facilities because they have improved, replaced, or modified equipment and practices over time. For example, many wet layer facilities are retrofitting to dry manure systems, few if any large swine facilities use open lots, and ventilation systems are replaced with newer technologies. Even though confinement housing may be considered to have a 20 to 30 year useful life, modifications are continuously made to the internal structures such as replacement of floor materials, new feeding systems, and updated drinking water equipment. These and other examples are documented in the record (See W-00-27, Section 5.3).

As described in Chapter 6, wastes and wastewater characteristics are predominantly dependent on animal type and animal age. The age of the facility is also taken into consideration through the production process factor. Treatment, storage, method of manure handling, and other forms of manure management will affect the form of the manure and wastewaters generated. However, the age of the facility does not have an appreciable impact on the wastewater characteristics and was not considered as a basis for subcategorization.

5.1.7 Facility Size

EPA considered subcategorization on the basis of facility size. EPA analyzed several size groups for each major livestock sector, including the existing ELG applicability threshold of 1,000 AU (see Chapter 11 for the size groups analyzed). Within each size group EPA considered the predominant practices, and developed cost models to reflect these baseline practices. EPA found facilities may use different treatment, storage, and handling practices based on size, but for the size of facilities under consideration for revisions to the ELG (i.e. >300 AU), facilities of all sizes generally use similar practices. The animal breeds (i.e. preferred animal strains and genetics) maintained also do not vary measurably by facility size, and therefore there is very little variation in manure and waste characteristics.

EPA adjusted costs for each size group modeled to reflect these baseline characteristics. Essential requirements governing waste management are closely related for all sized facilities. For some technology options the costs to meet the performance standards may affect more smaller operations, such as fixed costs for groundwater assessments. For other technology options, such as land application standards, smaller facilities are better able to meet the performance standards. EPA did not find that farm size consistently influenced the ability of the facilities to achieve the performance standards for each technology option (see the EA for more information on impacts). Furthermore, pollution potential from AFOs (i.e. >300 AU) is approximately the same per unit of animal production for all sizes of facilities. Finally, to minimize confusion, inconsistencies, and administrative burden, EPA intends to set the ELG to apply to anyone defined as a CAFO. EPA thus determined that the industry should not be subcategorized on the basis of facility size.

5.1.8 Geographical Location

EPA considered subcategorization on the basis of geographical location. EPA analyzed key production regions for each major livestock sector (see Chapter 11 for definitions of the regions analyzed). Animal breeds maintained and therefore manure and waste characteristics do not vary measurably by region. Within each region EPA considered the predominant practices (see Chapter 4), and developed cost models to reflect these baseline practices. EPA identified different treatment, storage, and handling practices based on location for the size of facilities under consideration for revisions to the ELG (i.e. >300 AU). Treatment technologies vary by location, as does performance of technologies such as anaerobic lagoons, evaporation ponds, and methane recovery lagoons. Costs to install and operate certain technologies such as storage and manure handling equipment will vary by location. This distribution of costs and practices by location suggests subcategorization based on geographic distribution. EPA also recognizes geographic location may have an affect on the market for raw materials and products, the predominance of contractual relationships, and the value of the products. These issues are addressed in the Economic Assessment Document (EA).

Two factors are especially subject to geographical location, specifically the availability of cropland for application of manure and the selection of manure handling and storage practices appropriate to the local climate. However, these factors encourage conservation by efficient use of water, including recycle and reuse, and encourages the installation of practices for the entire category to reduce treatment costs, reduce hauling costs, improve distribution of manure nutrients, and improve pollutant removals. These new practices may also positively affect non-water quality environmental impacts. Ultimately, the impact of location and climate is so highly variable as to prove unreliable in defining subcategories.

5.1.9 Pollution Control Technologies

EPA evaluated water pollution control technologies currently being used by the industry as a basis for establishing regulations. Treatability of wastes was not a factor for categorization since wastes from CAFOs are concentrated and present in such quantities that no direct discharge from the production area is allowed. Furthermore, pollution control technologies are often complementary to or directly part of the production process, and the rationale for not using production processes as a basis for subcategorization also apply. See 5.1.2 for a further discussion of production processes. Finally, use of pollution control technologies to segment the industry may result in disincentives for new and innovative treatment technologies.

5.1.10 Non-Water Quality Environmental Impacts

Non-water quality impacts from the CAFO result from transportation of manure and wastes to off-site locations, and emissions of volatile organic compounds to the air. While non-water quality characteristics are of concern to EPA, the impacts are the result of individual facility practices and do not apply uniformly to different industry segments. To the extent there are similarities, these similarities do not lend themselves towards subcategorization of the industry in a way that provides better controls than the proposed approach. Therefore non-water quality impacts are not an appropriate basis for subcategorization. Chapter 13 provides further information concerning non-water quality impacts of CAFOs.

5.2 Proposed Revised Subcategories

Animal type is a significant factor and was used as the first level of subcategorization. Animal age was used as the second level of subcategorization for swine and mature dairy cattle. EPA is not proposing changes to the ELG for the sheep or lambs, horses, or ducks subcategories. The proposed revisions to the ELG subcategories are presented in the following table. The table indicates the minimum number of animals that defines the facility as a CAFO in the NPDES regulations. Once defined as a CAFO, the ELG applies to that facility.

Table 5-1. Revised ELG Applicability

Subcategory	Minimum Number of Animals to be Defined as a CAFO	
	Two-Tiered NPDES Scenario	Three-Tiered NPDES Scenario
Veal	500	300
Mature dairy cattle (whether milked or dry)	350	200
Cattle other than mature dairy or veal	500	300
Swine each weighing over 25 kilograms	1,250	750
Swine each weighing less than 25 kilograms	5,000	3,000
Turkeys	27,500	16,500
Chickens	50,000	30,000

5.3 References

USEPA. 1974. Development Document for Effluent Limitations Guidelines and New Source Performance Standards - Feedlots Point Source Category. U.S. Environmental Protection Agency, Washington, DC.

CHAPTER 6

WASTEWATER CHARACTERIZATION AND MANURE CHARACTERISTICS

6.0 INTRODUCTION

This chapter describes waste streams generated by the animal feeding industry. Differences in waste composition and generation between animal types within each sector are highlighted.

The types of animal production and housing techniques determine whether the waste will be managed as a liquid, semisolid, or solid (Figure 6-1). The type of manure and how it is collected have a direct impact on the nutrient value of the waste and its value as a soil amendment or for other uses.

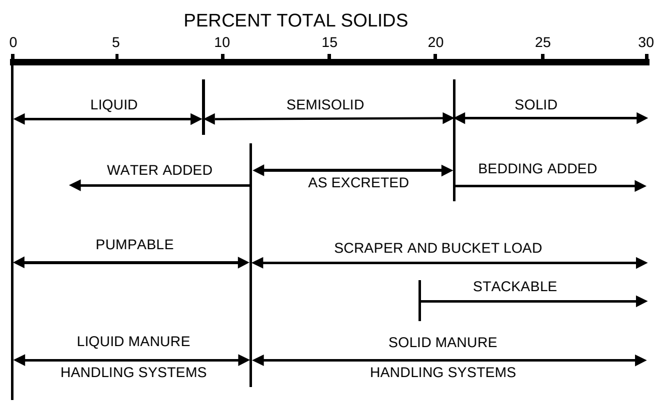


Figure 6-1. Manure characteristics that influence management options (after Ohio State University Extension, 1998).

6.1 Swine Waste

Swine waste contains numerous chemical and biological constituents such as nutrients, heavy metals, and pathogens that can potentially contaminate the environment. The composition of swine waste and rate of its excretion by the pig vary with the stage of physical development, the pig's gender, and if a female whether she is farrowing. As noted in Chapter 4, during the course of their life cycle, pigs receive up to six different diets to maximize growth at each stage of physical development. Each diet is composed of a unique mix of nutrients and minerals and those differences are reflected in the different composition of manure generated over the pig's life.

Swine waste also undergoes physical and chemical changes after it has been excreted by the pig. For example, swine waste volume and composition change after the waste becomes mixed with water, feed, and bedding materials. Furthermore, microbial activity alters the chemical makeup of the waste by metabolizing organic matter and generating chemical by-products. Additional chemical changes can occur depending on how the waste is stored and whether it is treated.

For swine operations, typical manure handling practices are designed to produce either a liquid or a semi-solid. Thus, the nutrient component of manure usually becomes more dilute because of the addition of water used to aid in collection of the manure. In addition, ammonia volatilization reduces nitrogen concentrations in both liquid and dry manure handling systems. Phosphorus concentrations increase in manure that is handled dry as the water content decreases.

As discussed in Chapter 4, swine manure typically is collected and stored by means of pit storage, lagoons, or a combination of the two. Most lagoons operate anaerobically. Aerated lagoons have received less attention because of their higher costs; however, the potential for decreased odor might increase their use. Svoboda (1995) achieved nitrogen removal ranging from 47 to 70 percent (depending on aeration) through nitrification and denitrification in an aerobic treatment reactor using whole pig slurry. The proportion of phosphorus and potassium typically remaining after storage is higher than nitrogen. However, up to 80 percent of the phosphorus in lagoons is found in the bottom sludge versus the water fraction (MWPS, 1993).

Jones and Sutton (1994) analyzed manure nutrient content just before land application in liquid manure pit and anaerobic lagoon samples. On a mass basis for pit storage, nitrogen decreases ranged from 11 to 47 percent; phosphorus, 9 to 67 percent; and potassium, 5 to 42 percent. In the water fraction of lagoons, nitrogen decreases ranged from 76 to 84 percent; phosphorus, 78 to 92 percent; and potassium, 71 to 85 percent. Nitrogen decreases in these two storage systems were primarily due to volatilization; phosphorus and potassium decreases were due to accumulation in sludge. Boland et al. (1997) found that for deep pit systems almost four times as much land was needed when applying manure based on phosphorus rather than nitrogen, 2.5 times for tank storage, and 1.7 times for lagoon systems. These differences can be attributed to less ammonia volatilization in deep pit systems and solids settling in lagoons.

A field study of Missouri swine lagoon surface-to-volume ratios found that large swine lagoons have significantly higher total nitrogen concentrations than small lagoons. This finding suggests that nutrient concentrations and thus land application of treated swine manure should be based on the design and performance characteristics of the lagoon rather than on manure production alone (Fulhage, 1998).

The use of evaporative lagoon systems has increased in arid regions. These systems rely on evaporation to reduce wastewater with pollutants accumulating in the lagoon sludge. This approach results in reduced or no land application of wastes. For example, due to a lack of adequate land disposal area in Arizona, Blume and McCleve (1997) increased the evaporation of wastewater from a 6,000-hog flush/lagoon treatment system by spraying the wastewater into the air. Although information on volatilization was not available, the evaporative increase from spraying and pond evaporation versus pond evaporation alone was 51 percent.

The following sections characterize swine waste in terms of generation rates and chemical and biological contaminants. Differences between swine types and operations and changes to the waste after it leaves the pig are also characterized.

6.1.1 Quantity of Manure Generated

Table 6-1 shows the quantity of manure generated by different types of swine. Variation in these quantities can be attributed to different ages and sizes of animals within a group (USDA, 1992). Manure production can also vary depending on the digestibility of feed rations. For example, corn, which is 90 percent digestible, results in less total solids in manure than a less digestible feed such as barley, which is 70 percent digestible (USDA, 1992).

Table 6-1. Quantity of Manure Excreted by Different Types of Swine

Type of Swine	Manure Mass (lb/yr/1,000 lb of animal mass)			
	Maximum Reported	**Minimum Reported**	**USDA 1998 Value**	
Grower-Finisher	44,327[a]	14,600[a]	Grower-Finisher 29,380[d]	Farrow to Finish 38,940[e]
Replacement Gilt	29,872[a]	11,972[a,b]		
Boar	31,527[a]	7,483[b]	Farrow 12,220[d]	
Gestating Sow	18,250[a]	9,928[b]		
Lactating Sow	32,120[a]	21,900[a,b]		
Sow and Litter	21,900[c]	21,900[c]		
Nursery Pig	54,142[a]	23,981[c]	---	

[a]NCSU, 1994.
[b]USDA, 1992.
[c]MWPS, 1993.
[d]USDA, 1998.
[e]Adapted from USDA, 1998.
--- Not available.

As described in Chapter 3, there are three stages of swine production—farrow, nursery, and grower-finisher. Some swine operations encompass all three stages, whereas others specialize in just one. This section discusses the type of animal included in each operation and summarizes data on the quantity of manure produced by different operations.

Farrowing Operations

Farrowing operations include boars, gestating sows, lactating sows, and the sows' litters. Newborn pigs remain at the farrowing facility until they are weaned, which typically takes 3 to 4 weeks. Lactating sows and their litters produce the most manure, whereas boars produce the least. Manure production values for 1,000 lb of animal in a farrowing operation range from 7,483 (USDA, 1992) to 32,120 lb/yr (NCSU, 1994), as shown in Table 6-2.

Nursery Operations
After farrowing and weaning, young pigs are moved to a nursery, which is the second phase of swine production, at approximately 15 pounds. They remain in the nursery for 7 to 8 weeks until they weigh approximately 60 pounds and are then transferred to a grower-finisher operation. Nursery pigs produce manure at rates of 23,981 (MWPS, 1993) to 54,142 lb/yr/1,000 lb of animal (NCSU, 1994) (Table 6-2).

Grower-Finisher Operations
In a finishing operation pigs are raised to market weight, which is approximately 240 to 280 pounds. This third stage of swine production is typically 15 to 18 weeks long, after which finished hogs are sent to market at approximately 26 weeks of age. A grower-finisher operation raises pigs over a relatively long period of time, during which their weight changes substantially. This weight change affects the quantity of manure produced (USDA, 1992). Values for manure production from growing-finishing pigs range from 11,972 (USDA, 1992) to 44,327 lb/yr/1,000 lb of animal (NCSU, 1994) (Table 6-2).

Farrow to Finish Operations
A farrow to finish operation includes all three stages of swine production. Because of the large variability in animal types present in this type of operation, manure production values vary widely, from 7,483 lb/yr/1,000 lb of animal for boars (USDA, 1992) to 54,142 lb/yr/1,000 lb of animal for nursery pigs (NCSU, 1994) (Table 6-1).

6.1.2 Description of Waste Constituents and Concentrations

Swine waste contains substantial amounts of nitrogen, phosphorus, potassium, and pathogens and smaller amounts of other elements and pharmaceuticals. This section provides a summary of the constituents of swine waste as reported in the literature. There is significant variability in the generation rates presented below; this variability can be attributed to different nutritional needs for swine in the same operation type (sows and boars, for example) and for swine of different ages and sizes grouped in the same operation. Also, as shown earlier in Table 6-1, different types of swine produce different quantities of manure.

Nitrogen
Nitrogen is usually measured as total nitrogen or as total Kjeldhal nitrogen (TKN). Although TKN does not include nitrate-nitrogen (NO_3-N), it may be considered equal to total nitrogen because NO_3-N is present only in very small quantities in swine manure (0.051 to 1.241 lb/yr/1,000 lb of animal) (NCSU, 1994; USDA, 1998). Published values for nitrogen production range from 54.8 (USDA, 1992) to 228.8 lb/yr/1,000 lb of animal (NCSU, 1994) in swine manure, as shown in Table 6-2. In general, boars produce the least amount of nitrogen per thousand pounds of animal and grower-finisher pigs produce the most.

Table 6-2. Quantity of Nitrogen Present in Swine Manure as Excreted

Operation Type	Nitrogen (lb/yr/1,000 lb of animal mass)		
	Maximum Reported	Minimum Reported	USDA 1998 Value
Farrow to Finish	NA	NA	220.0[c]
Grower-Finisher	228.8[a]	87.6[b]	166.0[d]
Farrow	214.0[a]	54.8[b]	81.0[d]
Nursery	224.1[a]	134.0[a]	---

[a]NCSU, 1994.
[b]USDA, 1992.
[c]Adapted from USDA, 1998.
[d]USDA, 1998.

Phosphorus

The quantity of phosphorus as excreted in swine manure is shown in Table 6-3 for different types of swine operations. Phosphorus content ranges from 18.3 (USDA, 1992) to 168.2 lb/yr/1,000 lb of animal (NCSU, 1994)—boars excrete the least amount of phosphorus in manure per thousand pounds of animal, whereas grower-finisher pigs excrete the most.

Table 6-3. Quantity of Phosphorus Present in Swine Manure as Excreted

Operation Type	Phosphorus (lb/yr/1,000 lb of animal mass)		
	Maximum Reported	Minimum Reported	USDA 1998 Value
Farrow to Finish	NA	NA	64.1[d]
Grower-Finisher	168.2[a]	29.2[b]	48.3[e]
Farrow	68.3[a]	18.3[b]	26.2[e]
Nursery	93.4[a,b]	54.6[c]	---

[a]NCSU, 1994.
[b]USDA, 1992.
[c]MWPS, 1993.
[d]Adapted from USDA, 1998.
[e]USDA, 1998.

Potassium

Table 6-4 shows the range of measured potassium quantities in manure for each type of swine operation. Boars produce the least amount of potassium at 36.50 lb/yr/1,000 lb of animal (USDA, 1992), whereas grower-finisher pigs produce the most at 177.4 lb/yr/1,000 lb of animal (NCSU, 1994).

Table 6-4. Quantity of Potassium Present in Swine Manure as Excreted

Operation Type	Potassium (lb/yr/1,000 lb of animal mass)		
	Maximum Reported	Minimum Reported	USDA 1998 Value
Farrow to Finish	NA	NA	154.79[d]
Grower-Finisher	177.4[a]	47.45[b]	116.79[e]
Breeder	136.6[a]	36.50[b]	47.96[e]
Nursery	130.6[a]	103.88[c]	---

[a]NCSU, 1994.
[b]USDA, 1992.
[c]MWPS, 1993.
[d]Adapted from USDA, 1998.
[e]USDA, 1998.

Table 6-5 shows differences in the quantity of nutrients in manure at different stages of storage and handling. The data shows a decrease in nutrient quantities from a manure slurry, which is untreated, to lagoon liquid and finally to secondary lagoon liquid. Lagoon sludge contains less nitrogen and potassium but more phosphorus than lagoon liquid, because phosphorus tends to be associated with the particulate fraction of manure, and nitrogen and potassium are usually in dissolved form. Table 6-6 shows the percent of manure nutrient content as excreted that is retained using different manure management systems. Table 6-7 shows manure nutrient concentrations in pit storage and anaerobic lagoons.

Table 6-5. Comparison of Nutrient Quantity in Manure for Different Storage and Treatment Methods

Nutrient	Mean Quantity in Manure (lb/yr/1000 lb of animal mass)					Land-Applied Quantity After Losses[b]	
	Paved Surface Scraped Manure[a]	Liquid Manure Slurry[a]	Anaerobic Lagoon Liquid[a]	Anaerobic Secondary Lagoon Liquid[a]	Anaerobic Lagoon Sludge[a]	Farrow	Grower
Nitrogen	137.65	164.44	34.71	28.79	6.57	20.29	17.23
Phosphorus	61.05	51.28	6.06	4.47	6.18	22.12	17.11
Potassium	79.81	78.20	29.84	23.13	1.46	43.01	43.75

[a]NCSU, 1994.
[b]USDA, 1998.

Table 6-6. Percent of Original Nutrient Content of Manure Retained by Various Management Systems

Management System	Nitrogen	Phosphoru s	Potassium
Manure stored in open lot, cool humid region	55-70	65-80	55-70
Manure liquids and solids stored in an uncovered, essentially watertight structure	75-85	85-95	85-95
Manure liquids and solids (diluted less than 50%) held in waste storage pond	70-75	80-90	80-90
Manure stored in pits beneath slatted floor	70-85	90-95	90-95
Manure treated in anaerobic lagoon or stored in waste storage pond after being diluted more than 50%	20-30	35-50	50-60

Source: Adapted from Jones and Sutton, 1994.

Table 6-7. Nutrient Concentrations for Manure in Pit Storage and Anaerobic Lagoons for Different Types of Swine

Animal Type	Manure Produced 1000 gal/yr	Nitrogen lb N/1000 gal/yr	Phosphorus lb P/1000 gal/yr	Potassium lb K/1000 gal/yr
Pit Storage				
Grower-Finisher	0.53	32.75	11.55	22.41
Lactating Sow	1.4	15.00	5.25	9.13
Gestating Sow	0.5	25.00	13.55	22.41
Nursery	0.13	25.00	8.44	18.26
Anaerobic Lagoon				
Grower-Finisher	0.95	5.60	1.639	3.486
Lactating Sow	2.10	4.10	0.874	1.660
Gestating Sow	0.90	4.40	1.857	3.320
Nursery	0.22	5.00	1.398	2.656

Source: Adapted from Jones and Sutton, 1994.

Metals and Other Elements

Other elements present in manure include the micronutrients calcium, chlorine, magnesium, sodium, and sulfur, and heavy metals such as arsenic, cadmium, iron, lead, manganese, and nickel. Many of these elements are found in swine feed; others, such as heavy metals, are found in pharmaceutical feed additives. Table 6-8 shows the range of quantities of these elements in manure as excreted, after storage, at different stages of treatment, and when it is land applied.

Table 6-8. Comparison of the Mean Quantity of Metals and Other Elements in Manure for Different Storage and Treatment Methods

	Quantity produced in manure (lb/yr/1000 lb animal mass)					
Element	**As Excreted**	**Paved Surface Scraped Manure[a]**	**Liquid Manure Slurry[a]**	**Anaerobic Lagoon Liquid[a]**	**Anaerobic Secondary Lagoon Liquid[a]**	**Anaerobic Lagoon Sludge[a]**
Aluminum	1.340[a]	0.797	3.289	0.176	---	---
Arsenic	0.252[a]	---	0.003	0.004	---	---
Boron	1.132[b]-1.232[a]	0.239	0.086	0.042	0.037	0.004
Cadmium	0.010[a.b]	0.001	0.002	0.002	---	0.001
Calcium	120.45[b]-121.468[a]	117.932	48.433	7.547	6.459	6.373
Chlorine	93.335[a]-94.9[b]	90.615	27.073	18.571	---	0.378
Cobalt	0.014[a]	0.013	---	0.002	---	---
Copper	0.437[a]-0.438[b]	0.960	0.665	0.073	0.036	0.082
Chromium	---	---	---	---	---	0.007
Iron	5.84[b]-6.606[a]	16.858	4.643	0.486	0.292	0.713
Lead	0.030[a]-0.031[b]	0.019	---	0.033	---	0.007
Magnesium	25.55[b]-27.064[a]	33.766	16.884	2.461	1.587	1.837
Manganese	0.640[a]-0.694[b]	4.573	0.790	0.055	0.022	0.082
Molybdenum	0.010[a,b]	0.001	---	0.001	---	0.003
Nickel	0.029[a]	0.048	0.016	0.130	---	0.003
Selenium	---	---	---	0.000	---	---
Sodium	23.980[a]-24.455[b]	24.536	18.148	10.396	---	0.536
Sulfur	27.192[a]-27.74[b]	24.791	14.702	2.089	1.542	1.333
Zinc	1.825[b]-1.855[a]	2.414	2.210	0.191	0.036	0.212

[a]NCSU, 1994.
[b]ASAE, 1998.

Swine manure contains many kinds of bacteria, several of which are naturally present in the digestive systems of the animals. Others are in the pigs' general environment and can be ingested but are not a necessary component of digestion. Table 6-9 presents a summary of measured values of these bacteria in swine manure as excreted and at various stages of treatment.

Table 6-9. Comparison of the Mean Concentration of Pathogens in Manure for Different Storage and Treatment Methods

Type of Bacteria	Quantity Present in Manure (bacterial colonies per pound of manure)				
	Manure As Excreted	Paved Surface Scraped Manure	Liquid Manure Slurry	Anaerobic Lagoon Liquid	Anaerobic Lagoon Sludge
Enterococcus bacteria	3.128E+09	1.395E+09	3.839E+09	1.232E+06	---
Escherichia coliform bacteria	4.500E+07	5.400E+07	1.302E+08	---	---
Facultative bacteria	---	5.400E+11	5.164E+11	---	---
Fecal coliform bacteria	1.106E+09	4.800E+08	1.777E+07	2.502E+06	---
Fecal streptococcus bacteria	2.873E+10	---	2.276E+07	2.285E+06	---
Streptococcus bacteria	1.980E+08	2.205E+10	1.995E+10	---	---
Total aerobic bacteria	---	2.745E+11	1.269E+11	---	---
Total anaerobic bacteria	---	5.400E+11	1.092E+11	---	---
Total bacteria	---	---	---	3.885E+08	7.769E+09
Total coliform bacteria	2.445E+09	1.598E+09	9.551E+07	1.083E+07	---

Source: NCSU, 1994.

Pharmaceuticals

To promote growth and to control the spread of disease, antibiotics and other pharmaceutical agents are often added to feed rations. Many of these chemicals are transformed or broken down through digestion and their components are excreted in manure. Table 6-10 lists several common pharmaceuticals added to swine feed and their frequency of use as reported in *Swine '95 Part I: Reference of 1995 Swine Management Practices* (USDA APHIS, 1995).

Table 6-10. Type of Pharmaceutical Agents Administered in Feed, Percent of Operations that Administer them, and Average Total Days Used

Antibiotic/Agent in Feed	Percent Operations	Standard Error	Average Total Number Days	Standard Error
Chlortetracycline/Sulfathiazole/Penicillin	6.7	2.1	33.8	5.3
Chlorotetracycline/Sulfamethazine/Penicillin	6.4	2.0	23.6	3.6
Tylosin/Sulfamethazine	4.8	2.1	45.6	4.1
Carbadox	12.4	2.5	31.2	2.1
Lincomycin	4.3	1.4	60.3	17.6
Apramycin	2.8	1.2	50.9	22.7
Chlortetracycline	41.1	4.0	58.1	4.6
Oxytetracycline	9.6	2.2	39.2	6.6
Neomycin/Oxytetracycline	10.4	3.0	55.3	14.6
Tylosin	30.4	3.7	57.4	5.1
Bacitracin (BMD)	52.1	4.1	72.2	4.0
Virginiamycin	3.8	1.3	65.1	11.6
Zinc oxide	5.0	2.1	81.2	22.9
Copper sulfate	6.1	1.9	62.8	11.3
Other	4.6	2.2	97.6	11.8

Source: USDA APHIS, 1995.

Physical Characteristics
Tables 6-11 and 6-12 lists several characteristics of swine manure as excreted by pigs classified by different operation types and with different types of storage and treatment methods.

Table 6-11. Physical Characteristics of Swine Manure by Operation Type and Lagoon System

Characteristic	Physical Characteristics in Swine Manure (lb/yr/1000 lb unless otherwise noted)						
	Grower-Finisher as Excreted	Farrow as Excreted	Farrow to Finish as Excreted	Liquid Manure Slurry[b]	Anaerobic Lagoon Sludge[b]	Anaerobic Lagoon Liquid[b]	Anaerobic Secondary Lagoon Liquid[b]
Manure	11,972[a]-33,830[b]	7,483[a]-27,313[b]	7,483[a]-39,586[b]	6,205	270	7,381	7,381
Urine	42.1[b]-49.0[b]	---	39.0[b]-74.0[b]	---	---	---	---
Density (lb/ft^3)	61.8[b]-62.8[b]	---	61.3-62.8	8.4	8.9	8.4	8.35
Moisture (%)	90[a]-91[a]	90[a]-97[a]	90[a]-97[a]	---	92[a]	100[a]	---
Total solids	3.28[a]-6.34[a]	1.9[a]-6.0[a]	1.9[a]-11.0[a]	---	7.60%[c]	0.25%[c]	---
Total dissolved solids	1.29[a]	---	1.29[a]	---	---	---	---
Volatile solids	2.92[a]-5.40[a]	1.00-5.40	1.00-8.80	---	379.89 [c] lb/1000 gal	10.00 [c] lb/1000 gal	---
Fixed solids	0.36[a]-0.94[a]	0.30[a]-0.60[a]	0.30[a]-1.80[a]	---	253.27 [c] lb/1000 gal	10.83 [c] lb/1000 gal	---
C:N ratio	6[a]-7[a]	3[a]-6[a]	3[a]-8[a]	---	8[a]	---	2[a]

[a]USDA, 1992.
[b]NCSU, 1994.
[c]USDA, 1996.

Table 6-12. Physical Characteristics of Different Types of Swine Wastes

Physical Characteristic	lb/yr/1000 lb	lb/ 1000 gallons	
	Paved Surface Scraped Manure[a]	Feedlot Runoff Water[b]	Settling Basin Sludge[b]
Manure	21,089	---	---
Density (lb/ft^3)	62.4	---	---
Moisture (%)	---	98.50	88.8
Total solids	---	1.50	11.2

[A]NCSU, 1994
[b]USDA, 1996

6.2 Poultry Waste

Poultry wastes differ in composition between the three bird types addressed in this document - layers, broilers, and turkeys. Each bird type is raised for a specific role and is provided with a diet tailored to its nutritional needs. Hence, layers are fed diets to maximize egg production whereas broilers are fed diets to promote growth and development. Within each subsector, however, variation in manure composition as excreted is quite small due to the high degree of integration, use of standardized feed, and total confinement (USEPA, 1999). However, there are differences in composition and quantity generated between operations due to variations in length and type of manure storage employed by the operation.

Broilers and turkeys have similar production regimes in terms of manure production, manure handling, and nutrient recovery. The floor of the house is covered with a bedding material that absorbs liquid. During the growth of the flock, continuous air flow removes ammonia and other gasses resulting in lower nitrogen content of the litter (manure and bedding). Another result of continuous air flow is a reduction in the moisture content of the litter over that of freshly excreted manure.

Manure produced by the laying industry typically includes no bedding. Two main types of manure handling are handling as excreted manure (with no bedding) and water-flushed collection. In high-rise cages or scrape-out/belt systems, manure is excreted onto the floor below with no bedding to absorb moisture. The ventilation system dries the manure as it is stored. Nutrients are more concentrated without bedding than with bedding, as in the broiler and turkey manure handling procedures. Flushing layer manure with water results in diluted nutrient concentrations, but increases the amount of waste that must be disposed.

As shown in Table 6-13, manure generation rates differ considerably between layers and broilers. The maximum reported generation rate for broilers is over 30 percent greater than for layers. Pullets have the lowest generation rate- almost half the rate of manure production for broilers and only 70 percent of the production rate for layers.

6.2.1 Broiler Waste Characteristics

6.2.1.1 *Quantity of Manure Generated*

Manure production is frequently presented as volume or weight of manure produced per 1,000 pounds of animal mass. There is significant variation between the minimum and maximum reported values for manure generation in broilers. Table 6-13 contains the minimum, maximum, and 1998 USDA reported values for manure generation rates for broilers. The 1998 USDA reported value for manure generation was utilized in EPA's analyses.

Table 6-13. Quantity of Manure Excreted for Broilers

Manure Mass (lb/yr/1,000 lb of animal mass)		
Minimum Reported	**Maximum Reported**	**USDA 1998 Value**
25,550[a]	31,025[b]	29,940[c]

[a]MWPS, 1993.
[b]ASAE, 1998.
[c]USDA, 1998.

6.2.1.2 *Description of Waste Constituents and Concentrations*

Broiler waste contains nitrogen, phosphorus, potassium, and smaller amounts of other elements and pathogens. This section provides a summary of the constituents of broiler manure and litter as reported in the literature.

Table 6-14 shows selected physical and chemical characteristics for broiler manure as excreted and after application of different storage practices. Manure quantity decreases under dry storage practices, especially when stored as a manure cake.

Table 6-14. Consistency of Broiler Manure as Excreted and for Different Storage Methods

	Physical Characteristics of Manure (lb/yr/1,000 lb of animal mass unless otherwise noted)					
Physical Characteristic	**As Excreted**	**Broiler Litter[d]**	**Broiler House Litter[c]**	**Broiler House Manure Cake[c]**	**Broiler Litter Stockpile[c]**	**Broiler-Roaster House Litter[c]**
Manure/Litter	25,550[a]–31,025[b]	12,775	7,449	2,364	6,733	5,710
Density	63.0[a]–63.7[c]	---	31.7	34.3	33.1	29.0
Moisture	75[d]	24	---	---	---	---
Total solids	7,300[d]–8,030[b]	9,673	5,857	1,429	4,083	4,349
Volatile solids	5,475[d]–8,030[a]	7,811	4,666	1,110	2,903	3,349
Fixed solids	1,825[d]	1862	---	---	---	---
C:N ratio	8[d]	9	---	---	---	---

[a]ASAE, 1998.
[b]MWPS, 1993.
[c]NCSU, 1994.
[d]USDA, 1992.

Broilers excrete numerous nutrients including nitrogen, phosphorous, and potassium. As shown in Table 6-15, nitrogen is excreted at the highest rate of the three nutrients. In general, broilers produce more nitrogen and potassium per pound of bird than do layers, although potassium production rates are near equivalent on a time-averaged basis (USDA, 1998). These levels are altered when manure is stored and or treated. Liquid manure volumes and nutrient concentrations are presented in Table 6-16 for raw and stored manure. Table 6-17 shows nutrient production after application of storage practices. Storage as a manure cake significantly reduces nutrient content, especially nitrogen. Table 6-18 shows metals in broiler manure as excreted and for different storage and treatment methods. The concentration of bacteria in broiler house litter is shown in Table 6-19.

Table 6-15. Nutrient Quantity in Broiler Manure as Excreted

Nutrient	Quantity Present in Manure (lb/yr/1,000 lb of animal mass)		
	Minimum Reported	Maximum Reported	Time-Averaged Value
Nitrogen	310.25[a]	401.50[b,c]	401.65[e]
Phosphorus	71.68[a]	124.10[b]	116.77[e]
Potassium	139.27[d]	167.90[b]	157.04[e]

[a]MWPS, 1993.
[b]USDA, 1992.
[c]ASAE, 1998.
[d]NCSU, 1994.
[e]USDA, 1998.

Table 6-16. Broiler Liquid Manure Produced and Nutrient Concentrations for Different Storage Methods

Storage Method	Manure Produced (1000 gal/yr)	Nutrient Concentration (lb nutrient/1000 gal)		
		Nitrogen	Phosphorus	Potassium
Raw Manure	0.006	130.4	36.3	44.3
Pit Storage [a]	0.010	63.00	17.48	24.07
Anaerobic Lagoon Storage [b]	0.016	8.50	1.88	2.91

Source: MWPS, 1993 as presented by Jones and Sutton, 1994.
[a] Includes dilution water.
[b] Includes rainfall and dilution water.

Table 6-17. Nutrient Quantity in Broiler Litter for Different Storage Methods

Nutrient	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)				
	Broiler Litter[a]	Broiler House Litter[b]	Broiler House Manure Cake[b]	Broiler Litter Stockpile[b]	Broiler-Roaster House Litter[b]
Nitrogen	248.20	26.59	53.80	109.87	196.71
Phosphorus	124.10	112.70	27.18	112.70	87.09
Potassium	146.00	144.06	35.37	89.52	110.67

[a]USDA, 1992.
[b]NRCS, 1994.

Table 6-18. Quantity of Metals and Other Elements Present in Broiler Manure as Excreted and for Different Storage Methods

Element	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)				
	As Excreted	Broiler House Litter[a]	Broiler House Manure Cake[a]	Broiler Litter Stockpile[a]	Broiler-Roaster House Litter[a]
Aluminum	---	4.901	---	---	---
Arsenic	---	0.176	---	---	---
Barium	---	0.148	---	---	---
Boron	0.795[a]	0.211	0.052	0.131	0.133
Cadmium	0.017[a]	0.012	0.002	0.001	0.014
Calcium	136.626[a]–149.650[b]	158.424	40.197	212.888	117.184
Chlorine	296.537[a]	47.694	---	51.803	---
Cobalt	---	0.007	---	---	---
Copper	0.331[a]–0.358[b]	1.984	0.481	0.968	1.389
Chromium	---	0.566	0.185	0.006	0.942
Iron	29.509[a]	4.381	1.420	5.991	4.553
Lead	0.033[a]	0.151	0.054	---	0.204
Magnesium	50.336[a]–54.750[b]	32.871	8.225	27.596	24.046
Manganese	2.378[a]	2.957	0.815	2.344	2.170
Mercury	---	0.001	---	---	---
Molybdenum	0.134[a]	0.003	0.001	0.002	0.002
Nickel	0.111[a]	0.427	0.217	0.008	0.352
Selenium	---	0.002	---	---	---
Silicon	---	5.323	---	---	---
Sodium	50.336[a]–54.750[b]	48.668	12.390	22.290	37.143
Strontium	---	0.339	---	---	---
Sulfur	28.763[a]–31.025[b]	45.749	10.876	33.892	39.229
Zinc	1.208[a]–1.314[b]	2.652	0.713	2.112	1.932

[a]NCSU, 1994.
[b]ASAE, 1998.

Microbial populations are very active in broiler litter and include enterococcus, fecal coliform, salmonella, and streptococcus. Table 6-19 shows bacteria levels per pound of manure.

Table 6-19. Concentration of Bacteria in Broiler House Litter

Parameter	Concentration of Bacteria (bacteria colonies/lb manure)
Total bacteria	4.775E+11
Total coliform bacteria	2.285E+06
Fecal coliform bacteria	7.758E+06
Streptococcus bacteria	6.728E+09
Salmonella	2.048E+06
Total aerobic bacteria	7.107E+09

Source: NCSU, 1994.

6.2.2 Layer Waste Characteristics

6.2.2.1 *Quantity of Manure Generated*

Manure production is frequently presented as volume or weight of manure produced per 1,000 pounds of animal mass. There is less variation between the minimum and maximum reported values for manure generation in layers than for broilers. Table 6-20 contains the minimum, maximum, and 1998 USDA reported values for manure generation rates for layers. The 1998 USDA reported value for manure generation was utilized in EPA's analyses.

Table 6-20. Quantity of Manure Excreted for Layers

Manure Mass (lb/yr/1,000 lb of animal mass)		
Minimum Reported	**Maximum Reported**	**USDA 1998 Value**
19,163[a]	23,722[b]	22,900[c]

[a]MWPS, 1993.
[b]NCSU, 1994.
[c]USDA, 1998.

6.2.2.2 *Description of Waste Constituents and Concentrations*

Layer waste contains nitrogen, phosphorus, potassium, and smaller amounts of other elements and pathogens. This section provides a summary of the constituents of layer manure as reported in the literature. Table 6-21 shows selected physical and chemical characteristics for layer manure as excreted and after application of different storage and treatment practices. Manure quantity decreases under dry storage practices but increases significantly when converted to a slurry or stored and treated in an anaerobic lagoon.

Table 6-21. Physical Characteristics of Layer Manure as Excreted and for Different Storage Methods

Physical Characteristic	Physical Characteristics of Manure (lb/yr/1,000 lb of animal mass unless otherwise noted)						
	As Excreted	High-rise Litter[d]	Paved Surface Scraped Manure[b]	Unpaved Deep Pit Stored Manure[b]	Liquid Manure Slurry[b]	Anaerobic Lagoon Liquid[b]	Anaerobic Lagoon Sludge[b]
Manure	19,163[a]–23,722[b]	14126	9877	32534	53598	9881	98805
Density (lb/ft^3)	60.0[a,c]–65.1[d]	62.4	51.3	7.8	8.4	8.4	8.4
Moisture (%)	74.8[a]–75.0[d]	---	---	---	---	---	---
Total solids	5,512[d]–6,019[b]	4979	5216	3646	265	1633	1633
Total suspended solids	2,477[b]	---	---	748	101	---	---
Volatile solids	3,942[d]–4,440[b]	3483	3137	2401	119	722	722
Volatile suspended solids	481[b]–4,380[c]	---	---	637	52	---	---
Fixed solids	1,570[d]	---	---	---	---	---	---
C:N ratio	7[d]	---	---	---	---	---	---

[a]MWPS, 1993.
[b]NCSU, 1994.
[c]ASAE, 1998.
[d]USDA, 1992.

Layers excrete numerous nutrients including nitrogen, phosphorous, and potassium. As shown in Table 6-22, nitrogen is excreted at the highest rate of these three nutrients. Nutrient concentrations of liquid manure are shown in Table 6-23. Table 6-24 shows nutrient production after application of storage and/or treatment practices. Table 6-25 shows metals in layer manure as excreted and for different storage and treatment methods.

Table 6-22. Quantity of Nutrients in Layer Manure as Excreted

Nutrient	Quantity Present in Manure (lb/yr/1,000 lb of animal mass)		
	Minimum Reported	Maximum Reported	Time-Averaged Value
Nitrogen	264.63[a]	315.43[b]	308.35[d]
Phosphorus	99.55[a]	113.15[c]	114.27[d]
Potassium	106.05[a]	124.10[c]	119.54[d]

[a]MWPS, 1993.
[b]NCSU, 1994.
[c]USDA, 1992.
[d]USDA, 1998.

Table 6-23. Annual Volumes of Liquid Layer Manure Produced and Nutrient Concentrations

Storage Method	Manure Produced (1000gal/yr)	Nutrient (lb nutrient/1000 gal)		
		Nitrogen	Phosphorus	Potassium
Raw Manure	0.011	110.2	35.4	37.7
Pit Storage [a]	0.017	60.00	19.67	23.24
Anaerobic Lagoon Storage [b]	0.027	7.00	1.75	2.91

Source: MWPS, 1993 as presented by Jones and Sutton, 1994.
[a] Includes dilution water.
[b] Includes rainfall and dilution water.

Table 6-24. Nutrient Quantity in Layer Litter for Different Storage Methods

Nutrient	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)					
	High-rise Litter[a]	Paved Surface Scraped Manure[b]	Unpaved Deep Pit Stored Manure[b]	Liquid Manure Slurry[b]	Anaerobic Lagoon Liquid[b]	Anaerobic Lagoon Sludge[b]
Nitrogen	199.44	165.79	238.42	42.35	24.63	24.63
Phosphorus	97.60	110.21	94.55	4.77	39.87	39.87
Potassium	114.40	107.96	114.40	54.75	9.60	9.60

[a]USDA, 1992.
[b]NCSU, 1994.

Table 6-25. Quantity of Metals and Other Elements Present in Layer Manure as Excreted and for Different Storage Methods

Element	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)						
	As Excreted	High-rise Litter[c]	Paved Surface Scraped Manure[a]	Unpaved Deep Pit Stored Manure[a]	Liquid Manure Slurry[a]	Anaerobic Lagoon Liquid[a]	Anaerobic Lagoon Sludge[a]
Aluminum	9.987[a]	2.161	---	4.039	---	---	---
Arsenic	0.050[a]	---	---	---	0.002	---	---
Boron	0.651[a]–0.657[b]	0.157	0.178	0.125	0.059	0.041	0.041
Cadmium	0.014[a,b]	0.001	---	---	0.000	0.007	0.007
Calcium	474.500[b]–491.891[a]	288.598	375.753	138.050	6.945	55.653	55.653
Chlorine	204.400[b]–242.608[a]	28.394	---	27.554	21.777	---	---
Cobalt	0.029[a]	---	---	---	---	---	---
Copper	0.303[b]–0.308[a]	0.244	0.285	0.302	0.030	0.167	0.167
Chromium	---	0.114	0.188	---	0.002	---	---
Iron	21.900[b]–24.143[a]	2.936	14.008	7.089	0.387	5.727	5.727
Lead	0.270[b]–0.274[a]	0.135	0.656	---	0.005	0.023	0.023
Magnesium	51.100[b]–51.129[a]	58.577	28.306	16.495	2.188	13.629	13.629
Manganese	1.945[a]–2.227[b]	2.032	2.165	1.579	0.044	1.896	1.896
Mercury	---	---	---	---	0.000	---	---
Molybdenum	0.109[a]–0.110[b]	0.002	0.002	---	---	---	---
Nickel	0.091[a,b]	0.351	0.418	---	0.075	0.029	0.029
Selenium	0.010[a]	---	---	---	---	---	---
Sodium	36.500[b]–43.292[a]	19.646	16.268	20.082	11.755	3.958	3.958
Sulfur	51.053[a]–51.100[b]	49.971	23.554	16.762	3.918	8.414	8.414
Zinc	1.640[a]–6.935[b]	2.162	1.721	1.609	0.100	1.346	1.346

[a]NCSU, 1994.
[b]ASAE, 1998.
[c]USDA, 1992.

Microbial populations are quite active in layer litter and include enterococcus, fecal coliform, salmonella, and streptococcus. Table 6-26 shows bacteria levels per pound of manure. As shown in this table, converting the litter to a slurry substantially reduces the concentration of bacteria.

Table 6-26. Concentration of Bacteria in Layer Litter

Type of Bacteria	Concentration in Manure (bacterial colonies/lb manure)	
	As Excreted	Layer Liquid Manure Slurry
Enterococcus bacteria	2.786E+13	---
Fecal coliform bacteria	1.552E+13	1.058E+06
Fecal streptococcus bacteria	3.375E+13	---
Salmonella	1.327E+10	---
Streptococcus bacteria	6.237E+13	---
Total aerobic bacteria	8.568E+15	---
Total bacteria	9.716E+16	---
Total coliform bacteria	1.835E+14	7.547E+06
Yeast	1.327E+15	---

Source: NCSU, 1994.

6.2.3 Turkey Waste Characteristics

Turkey operations usually separate and handle the birds in groups according to age, gender, size, or special management needs such as hatcheries or breeder farms. The types of animals are

- Poults (young turkeys)
- Turkey hens for slaughter
- Turkey toms for slaughter
- Hens kept for breeding

Although three major strains of turkeys are grown, the high degree of industry integration, standardized feed, and complete confinement has resulted in very little variation in manure characteristics. The exact quantity and composition of manure depends mostly on the specifics of farm management, such as precision feeding, control of wasted feed, and ammonia volatilization losses. Litter characteristics also vary according to material used for bedding.

6.2.3.1 *Quantity of Manure Generated*

Manure production is frequently presented as volume or weight of manure produced per 1,000 pounds of animal mass. Table 6-27 shows manure production as excreted for turkey hens and turkeys for slaughter.

Table 6-27. Annual Fresh Excreted Manure Production (lb/yr/1,000 lb of animal mass)

Animal Type	Range of Annual Manure Production Values	USDA 1998 Value
Turkeys for slaughter	15,914[a]-17,155[b]	16,360[c]
Hens for breeding		18,240[c]

[a]USDA, 1992.
[b]ASAE, 1998.
[c]USDA, 1998.

6.2.3.2 *Description of Waste Constituents and Concentrations*

Turkey waste contains nitrogen, phosphorus, potassium, and smaller amounts of other elements and pathogens. This section provides a summary of the constituents of turkey manure and litter as reported in the literature.

Composition of Manure

Exact manure composition depends on length and type of storage, as well as other management practices specific to each farm. Table 6-28 shows nutrients in turkey manure as excreted. Turkeys for slaughter produce more nitrogen and potassium in fresh excreted manure and breeding hens produce more phosphorus.

Table 6-28. Quantity of Nutrients Present in Fresh Excreted Turkey Manure (lb/yr/1,000 lb of animal mass)

	Nitrogen		Phosphorus		Potassium	
Animal Type	Range Includes Minimum	Maximum Reported	Minimum Reported	Range Includes Maximum	Range Includes Minimum	Maximum Reported
Turkeys for slaughter	248.34[a]	270.1[b]	84[c]	96.77[a]	94.97[a]	102.20[b]
Hens for breeding	204.38[a]			120.48[a]	69.31[a]	

[a]USDA, 1998.
[b]USDA, 1992.
[c]ASAE, 1998.

Composition of Litter

The nutrient content of turkey litter is usually lower than that for broiler litter, and brooder litter contains less manure nutrients than grower house litter. Exact manure composition depends on length and type of storage, as well as other management practices specific to each farm. After stockpiling, litter may lose up to half of the total nitrogen excreted. When manure is combined with bedding materials, the waste litter absorbs water content from the manure. Table 6-29 displays the water absorption capacity of commonly used bedding materials. Because of different types of litter composition for turkey operations, nutrient quantities per ton of litter vary (Table 6-30).

Table 6-29. Water Absorption of Bedding

Bedding Material	Pounds of Water Absorbed per Pound of Bedding
Wood	
Tanning Bark	4.00
Fine Bark	2.50
Pine	
Chips	3.00
Sawdust	2.50
Shavings	2.00
Needles	1.00
Hardwood Chips, Shavings or Sawdust	1.50
Corn	
Shredded Stover	2.50
Ground Cobs	2.10
Straw	
Flax	2.60
Oats	
Combined	2.50
Chopped	2.40
Wheat	
Combined	2.20
Chopped	2.10
Hay, Chopped Mature	3.00
Shells, Hulls	
Cocoa	2.70
Peanut, Cottonseed	2.50
Oats	2.00

Source: MWRA, 1993.

Table 6-30. Turkey Litter Composition in pounds per ton of litter[a]

Manure Type	Nitrogen	Phosphorus	Potassium
Brooder house litter after each flock [b]	45	23	27
Grower house litter after annual cleanout [b]	57	31	33
Stockpiled litter [b]	36	30[e]-31	25[e]-27
Tom growout [c]	52	33	35
Hen growout [c]	73	38	38
Brood house [d]	51	14	27
Growout house [d]	65	28[e]-31	33[e]-38

[a]Zublena, 1993
[b]NCSU, 1999
[c]Pennsylvania
[d]Arkansas
[e]NCSU, 1994.
P_2O_5 converted to P by multiplication of 0.437
K_2O converted to P by multiplication of 0.83

In those cases where litter is recycled from the brooder barn and used in the growout barn, nutrient values of litter increase to roughly 60 pounds of available nitrogen and phosphorus per ton of litter. Table 6-31 presents some metal components of turkey litter.

Table 6-31. Metal Concentrations in Turkey Litter (pounds per ton of litter)

Manure type	Ca	Mg	S	Na	Fe	Mn	B	Mo	Zn	Cu
Turkey, brooder	28.0	5.7	7.6	5.9	1.4	0.52	0.047	0.00081	0.46	0.36
Turkey, grower	42.0	7.0	10.0	8.4	1.3	0.65	0.048	0.00092	0.64	0.51

Source: NCSU, 1999.

The physical characteristics and nutrient content of turkey manure types and litter types is variable. As seen in Table 6-32, manure characteristics significantly differ from litter characteristics. Fresh manure contains more nutrients than manure cakes, but litter from grower houses may exceed fresh manure potassium amounts. Table 6-33 shows metal quantities in excreted turkey manure and litter types by gender and age of bird.

Table 6-32. Waste Characterization of Turkey Manure Types (lb/yr/1,000 lb of animal mass)

Parameter	Turkey fresh manure	Turkey hen house manure cake[a]	Turkey tom house manure cake[a]	Turkey house litter[a]	Turkey poult (brooder) house litter[a]	Turkey breeder house litter[a]	Turkey stockpiled litter[a]
Manure	15,914[c]-17,155[d]	1905.3	1905.3	---	---	---	---
Litter	---	---	---	5960.5	6953.25	4967.65	5420.25
Volume (ft^3/yr/1000 lb)	251.85[c]	---	---	---	---	---	---
Density(lb/ft^3)	63[d]-63.49[a]	32.3	---	---	22.91	62.43	24.1
TS (%wb)	4,179[a]-4,380[d]	1041.6	1041.6	4365.4	5527.96	3893.35	3316.90
VS (%db)	3,205[a]-3,541[c]	845.2	845.3	3182.8	4297.07	-	-
TKN	226.3[d]-231.0[a]	42.74	42.74	165.13	138.12	87.97	85.67
NO_3N	-	-	-	0.40	1.31		1.31
P	84.0[d]-87.8[a]	19.38	19.38	82.38	65.77	51.17	82.42
K	83.2[a]-87.6[d]	23.69	23.69	98.77	77.64	37.05	67.74

[a] NCSU, 1994.
[b] USDA, 1998.
[c] USDA, 1992.
[d] ASAE, 1998.

Table 6-33. Metals and Other Elements Present in Manure (lb/yr/1,000 lb of animal mass)

Metals/Elements	Turkey fresh manure	Turkey hen house manure cake[a]	Turkey tom house manure cake[a]	Turkey house litter[a]	Turkey poult (brooder) house litter[a]	Turkey breeder house litter[a]	Turkey stockpiled litter[a]
Calcium	223.205[a]-230.0[b]	25.003	25.003	112.165	91.871	178.376	120.888
Magnesium	25.649[a]-26.6[b]	5.11	5.11	22.083	17.849	11.498	19.199
Sulfur	25.887[a]	5.986	5.986	25.477	21.207	18.287	20.039
Sodium	23.172[a]-24.0[b]	5.256	5.256	22.703	162.06	10.622	15.367
Chlorine	16.8407[a]	---	---	35.186	6.278	---	21.608
Iron	26.556[a]-27.4[b]	1.168	1.168	4.176	6.935	2.519	5.585
Manganese	0.853[a]-0.9[b]	0.548	0.5475	2.3725	1.825	1.059	2.044
Boron	0.452[a]	0.037	0.0365	0.146	0.146	0.073	0.110
Molybdenum	0.076[a]	0.001	0.001	0.004	0.003	---	0.003
Aluminum	---	0.694	0.694	2.263	5.037	---	---
Zinc	5.127[a]-5.5[b]	0.438	0.438	1.971	1.606	1.241	1.716
Copper	0.252[a]-0.3[b]	0.475	0.475	1.789	1.351	0.986	1.132
Cadmium	0.009[a]	---	---	0.001	0.001	---	0.001
Nickel	0.063[a]	---	---	0.018	0.007	---	0.007
Lead	0.190[a]	---	---	---	---	---	---

[a]NCSU, 1994.
[b]ASAE, 1998.

Data on bacterial concentrations in turkey manure or litter are generally sparse. However, Table 6-34 shows concentrations of fecal coliform and total bacteria for manure and litter. Land applied quantities of turkey manure nutrients are shown in Table 6-35.

Table 6-34. Turkey Manure and Litter Bacterial Concentrations (bacterial colonies per pound of manure)

Bacteria Type	Excreted Manure	House Litter
Fecal coliform bacteria	1.31E+08	---
Total bacteria	---	2.53E+12

Source: NCSU, 1994.

Table 6-35. Turkey Manure Nutrient Composition After Losses–Land Applied Quantities

	Manure Composition (lb/yr/1,000 lb of animal mass)		
Animal	Nitrogen	Phosphorus	Potassium
Turkeys for slaughter	132.35 (116.0)	82.29 (14.5)	85.40 (9.6)
Hens for breeding	102.14 (102.2)	102.42 (18.1)	62.38 (6.9)

Source: USDA, 1998.
In parentheses are the differences between fresh excreted manure content and after losses content.

6.3 Dairy Waste

This section describes the characteristics of dairy manure and waste. In this section, manure refers to the combination of feces and urine and waste refers to manure plus other material, such as hair, bedding, soil, wasted feed, and water that is wasted or used for sanitary and flushing purpose. Due to the nature of dairy operations, however, even fresh manure may also contain small amounts of hair, bedding, soil, feed, and water.

This section discusses the following:

- Section 6.3.1: The quantity of manure generated; and
- Section 6.3.2: Description of waste constituents and concentrations.

6.3.1 Quantity of Manure Generated

Numerous analyses have estimated average manure quantities from dairy cattle. Four major data sources that contain mean values for dairy manure characteristics are identified below:

- American Society of Agricultural Engineers (ASAE) Standard D384.1: Manure Production and Characteristics, 1999. This data source contains national fresh (as-excreted) manure characteristic values by animal type (e.g., dairy, beef, veal, swine).

- USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. This data source contains national manure characteristic values for fresh and managed manure (e.g., lagoon supernatant, feedlot runoff) by animal type including subtypes such as lactating cow, dry cow, heifer, sow, and boar.

- North Carolina State University (NCSU), *Livestock Manure Production and Characterization in North Carolina*, 1994. This data source contains regional manure characteristic values for fresh and managed manure by animal type including subtypes.

- Midwest Plan Service-18 (MWPS): *Livestock Waste Facilities Handbook*, 1985. This data source contains national fresh manure characteristic values by animal type and animal weight.

A recent analysis conducted by Charles Lander, et al. of the USDA/NRCS used a composite of three of these data sources (Lander et al., 1998). Lander removed ASAE data before averaging to prevent double counting of the ASAE information that is included in the Midwest Plan Service data. This analysis assumed that the average weight of a lactating cow is 1,350 pounds and the average weight of a heifer is 550 pounds. Table 6-36 presents the fresh or "as-excreted" manure estimates from this analysis. North Carolina's updated data contains the as-excreted manure estimates for dairy calves which are assumed to weigh 350 pounds. Table 6-36 also presents the fresh manure estimates for dairy calves.

Table 6-36. Weight of Dairy Manure, "As-Excreted"

Quantity of Manure (wet basis)	Lactating Cow[a]	Heifer[a]	Calf[b]
Weight (lb/day/1,000-lb animal)	83.5	66	65.8
Weight (lb/year/1,000-lb animal)	30,478	24,090	24,017

[a] Source: Lander, 1998.
[b] Source: NCSU, 1994.

6.3.2 Description of Waste Constituents and Concentrations

The composition and concentrations of dairy waste varies from the time that it is excreted to the time it is ultimately used as a fertilizer and/or soil amendment. Nutrients and metals are expected to be present in dairy waste due to the constituents of the feed. This section discusses the following:

- Section 6.3.2.1: Composition of "as-excreted" manure;
- Section 6.3.2.2: Composition of stored or managed waste; and
- Section 6.3.2.3: Composition of aged manure/waste.

6.3.2.1 *Composition of "As-Excreted" Manure*

Data are presented for 16 nutrients and metals found in fresh dairy manure. Nitrogen is present in manure in four forms: ammonium-N, nitrate-N, nitrite-N, and organic-N. The total nitrogen (N) is the sum of these four components, while the total Kjeldahl nitrogen (TKN) is the sum of the organic-N and ammonium-N. Phosphorus is present in manure in inorganic and organic form and presented as total phosphorus. Colonies of the pathogens coliform and streptococcus bacteria have also been identified in dairy manure.

Manure characteristics for dairy cattle are highly variable and can be affected by animal size and age, management choices, feed ration, climate, and milk production. For example, dairy feeding systems and equipment often produce considerable feed waste, which in most cases is added to the manure. In addition, dairy stall floors are often covered with organic and inorganic bedding materials (e.g,. hay, straw, wood shavings, sawdust, soil, sand, ground limestone, dried manure) that improve animal comfort and cleanliness. Virtually all of this material will eventually be pushed, kicked, and carried from the stalls and added to the manure, and their characteristics imparted to the manure (Lander et al., 1998). In addition, the nutrient content (N, P, and K) of dairy manure can vary significantly due to differences in voluntary feed intake, differing supplemental levels, and differing amounts of nutrients removed during milking (USDA NRCS, 1992). The volatile solids content of dairy manure is often compared to milk production, which is also presented in USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. The volatile solids content of manure for an entire dairy herd can be calculated by using data for lactating and dry cows. For example, EPA's analysis assumed the dairy herd is made up of 83 percent lactating and 17 percent dry cows at any given time. The volatile solids content for the dairy herd, using USDA data, therefore, was calculated as (8.5 lb/day/1,000 animal * 83 percent) + (8.1 lb/day/1,000 animal * 17 percent) = 8.45 lb/day/1,000 animal.

Table 6-37 presents averages for fresh dairy cow and heifer manure characteristics that are reported in the four major data sources identified above.

Table 6-37. Fresh (As-Excreted) Dairy Manure Characteristics Per 1,000 Pounds Live Weight Per Day

Parameter	Unit[a]	Mean	Standard Deviation
Moisture	%	87.2	-
Weight	lb	86	17
Total solids	lb	12	2.7
Volatile solids	lb	10	0.79
Biochemical oxygen demand (BOD), 5-day	lb	1.6	0.48
Chemical oxygen demand (COD)	lb	11	2.4
pH	unitless	7	0.45
Nitrogen (Total Kjeldahl)	lb	0.45	0.096
Nitrogen (Ammonia)	lb	0.079	0.083
Phosphorus (Total)	lb	0.094	0.024
Orthophosphorus	lb	0.061	0.058
Potassium	lb	0.29	0.094
Calcium	lb	0.16	0.059
Magnesium	lb	0.071	0.016
Sulfur	lb	0.051	0.010
Sodium	lb	0.052	0.026
Chloride	lb	0.13	0.039
Iron	lb	0.012	0.0066
Manganese	lb	0.0019	0.00075
Boron	lb	0.00071	0.00035
Molybdenum	lb	0.000074	0.000012
Zinc	lb	0.0018	0.00065
Copper	lb	0.00045	0.00014
Cadmium	lb	0.0000030	-
Nickel	lb	0.00028	-
Total coliform bacteria	colonies	500	1,300
Fecal coliform bacteria	colonies	7.2	13
Fecal streptococcus bacteria	colonies	42	63

[a]All values wet basis.
Source: ASAE, 1993.

Lander averaged values from the Midwest Plan Service, USDA, and NCSU data sets for N, P, and K. In all cases, EPA compared the averaged values to ASAE's data and determined them to be comparable to the lactating cow numbers. As stated earlier in this section, the milking status of dairy cattle can affect the excreted levels of N, P, and K. Lactating cows are expected to have a higher nutrient content in their manure because they typically are fed a higher energy diet. Table 6-38 presents the nutrient values in dairy manure from Lander's analysis.

Table 6-38. Average Nutrient Values in Fresh (As-Excreted) Dairy Manure

Parameter	Dairy Cow (lb/day/1,000-lb animal) [a]
Nitrogen (Total Kjeldahl)	0.45
Phosphorus (Total)	0.08
Potassium	0.28

Source: Lander, 1998.
[a] Lander's analysis relied on 1990 North Carolina State University data, while the North Carolina State University data presented in this report is from 1994.

6.3.2.2 *Composition of Stored or Managed Waste*

Dairy manure is often combined with large amounts of water and collected and stored in a number of different ways (see Section 4.3.5 for a detailed discussion of dairy waste management). This wastewater, therefore, has different physical properties than "as-excreted" manure. This section presents dairy waste values for waste from milking centers and waste managed in lagoons.

Milking Centers

Milking centers, which include the milk room, milking parlor, and holding area, produce about 15 percent of the total solids, at a dairy. Milking centers that do not practice waste flushing use about 1 to 3 gallons of fresh water per day for each cow milked. However, dairies that use flush cleaning and automatic cow washing use as much as 30 to 50 gallons/day/cow or more (Loudon et al., 1985).

Waste associated with milking centers varies among the different rooms. Milk room waste typically consists of wash water associated with cleaning pipelines and holding tanks. This waste could be disposed of via septic tank systems, but many dairies include it in their manure waste management systems. Milk parlor waste typically consists of some manure and wash water from cleaning the milking equipment. Holding area waste generally contains more manure than the milk parlor and also contains wash water from cleaning the cows and flush water from cleaning the area. Many dairies remove solids from milking center waste prior to storing the liquid waste in a lagoon. Table 6-39 presents USDA/NRCS data characterizing dairy waste from milking centers.

Table 6-39. Dairy Waste Characterization—Milking Center

Component	Units	Milking Center			
		Milk Room	Milk Room + Milk Parlor	Milk Room + Milk Parlor + Holding Area[a]	Milk Room + Milk Parlor + Holding Area[b]
Volume	ft^3/d/1,000#	0.22	0.6	1.4	1.6
Moisture	%	99.72	99.4	99.7	98.5
Total Solids	% wet basis	0.28	0.6	0.3	1.5
Volatile Solids	lb/1,000 gal	12.9	35	18.3	99.96
Fixed Solids	lb/1,000 gal	10.6	15	6.7	24.99
COD	lb/1,000 gal	25.3	41.7	-	-
BOD	lb/1,000 gal	-	8.37	-	-
N	lb/1,000 gal	0.72	1.67	1	7.5
P	lb/1,000 gal	0.58	0.83	0.23	0.83
K	lb/1,000 gal	1.5	2.5	0.57	3.33
C:N ratio	unitless	10	12	10	7

[a] Holding area scraped and flushed - manure removed via solids separator.
[b] Holding area scraped and flushed - manure included.
Source: USDA/NRCS, 1992.

Lagoons

Lagoons that receive a significant loading of waste (e.g., from the holding area, freestall barn, and dry lots) generally operate in an anaerobic mode. Anaerobic dairy lagoon sludge accumulates at a rate of about 0.073 ft^3/pounds of total solids. This is equivalent to about 266 ft^3/year/1,000-pound lactating cow, assuming that 100 percent of the waste is placed in the lagoon (USDA NRCS, 1992).

Typically, storage and/or treatment reduces nitrogen in dairy manure by 30 percent to 75 percent through volatilization with only minor decreases in potassium and phosphorus. Although the values of potassium and phosphorus are low in the supernatant, which is removed on a regular basis, a disproportionate amount of the phosphorus and potassium can be found concentrating in the bottom sludge in lagoons and storage areas (Lander, 1999). Table 6-40 presents data on dairy waste managed in lagoons.

Table 6-40. Dairy Waste Characterization—Lagoons

Component	Units	Lagoon		
		Anaerobic - Supernatant	Anaerobic - Sludge	Aerobic - Supernatant
Moisture	%	99.75	90	99.95
Total Solids	% wet basis	0.25	10	0.05
Volatile Solids	lb/1,000 gal	9.16	383.18	1.67
Fixed Solids	lb/1,000 gal	11.66	449.82	2.5
COD	lb/1,000 gal	12.5	433.16	1.25
BOD	lb/1,000 gal	2.92	-	0.29
N	lb/1,000 gal	1.67	20.83	0.17
NH4-N	lb/1,000 gal	1	4.17	0.1
P	lb/1,000 gal	0.48	9.16	0.08
K	lb/1,000 gal	4.17	12.5	-
C:N ratio	unitless	3	10	-
Copper	lb/lb	-	7.64×10^{-4}	-
Zinc	lb/lb	-	1.22×10^{-3}	-

Source: USDA/NRCS, 1992 and NCSU, 1994.

6.3.2.3 *Composition of Aged Manure/Waste*

Dairy manure characteristics after excretion vary from operation to operation, and within the same operation during the year. Manure undergoes many changes after excretion, including moisture change (dilution or consolidation), volatilization, oxidation, and reduction. These changes always affect the "as-excreted" manure characteristics. For example, it is estimated that as much as 50 percent to 60 percent of nitrogen in the urine portion of the manure can be lost during the first hours after excretion if some measure is not taken to preserve it (Lander, 1999). Phosphorus and potassium losses during storage are considered negligible except in open lots or lagoons. In open lots, about 20 percent to 40 percent of phosphorus and 30 percent to 50 percent of potassium can be lost by runoff and leaching. Up to 80 percent of the phosphorus in lagoons can accumulate in bottom sludges (USDA ARS, 1998).

Characteristics of stored manure either are altered over time, or they are conserved (mass). Nitrogen, for example, is volatilized in the form of ammonia and is lost from the system. On the other hand, most of the compounds in manure (e.g., phosphorus, metals) remain in the manure over time, and are considered to be conserved. Treating the manure often reduces the concentration of nonconservative elements, such as nitrogen and the organic compounds, thus reducing oxygen demands in further treatment (Lander, 1999). Table 6-41 presents North Carolina State University data on scraped dairy manure from a paved surface.

Table 6-41. Dairy Manure Characteristics Per 1,000 Pounds Live Weight Per Day From Scraped Paved Surface

Parameter	Unit[a]	Value
Total solids	lb	13.7
Volatile solids	lb	11.5
Nitrogen (Total Kjeldahl)	lb	0.32
Nitrogen (Ammonia)	lb	0.077
Phosphorus (Total)	lb	0.097
Potassium	lb	0.22

[a]All values wet basis.
Source: NCSU, 1994.

6.4 Beef and Heifer Waste

This section describes the characteristics of beef and heifer manure and waste. In this section, manure refers to the combination of feces and urine and waste refers to manure plus other material, such as hair, soil, and spilled feed. Due to the nature of beef and veal operations, however, even fresh manure may also contain small amounts of hair, soil, and feed.

This section discusses the following:

- Section 6.4.1: The quantity of manure generated; and
- Section 6.4.2: Description of waste constituents and concentrations.

6.4.1 Quantity of Manure Generated

Numerous analyses have estimated average manure quantities from beef cattle. Four major data sources that contain mean values for beef manure characteristics are identified below:

- American Society of Agricultural Engineers (ASAE) Standard D384.1: *Manure Production and Characteristics*, 1999. This data source contains national fresh (as-excreted) manure characteristic values by animal type (e.g., dairy, beef, veal, swine).

- USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. This data source contains national manure characteristic values for fresh and managed manure (e.g., lagoon supernatant, feedlot runoff) by animal type including subtypes such as lactating cow, dry cow, heifer, sow, and boar.

- North Carolina State University (NCSU), *Livestock Manure Production and Characterization in North Carolina*, 1994. This data source contains regional manure characteristic values for fresh and managed manure by animal type including subtypes.

- Midwest Plan Service-18 (MWPS): *Livestock Waste Facilities Handbook*, 1985. This data source contains national fresh manure characteristic values by animal type and animal weight.

A recent analysis conducted by Charles Lander, et al. of the USDA/NRCS used a composite of three of these data sources (Lander et al., 1998). Lander removed ASAE data before averaging to prevent double counting of the ASAE information that is included in the Midwest Plan Service data. Table 6-42 presents the fresh or "as-excreted" manure estimates from Lander's analysis for beef and heifer cattle. In this analysis the average weight of a heifer was assumed to be 550 pounds and the only data source with heifer manure weight information was North Carolina State University.

Table 6-42. Weight of Beef and Heifer Manure, "As-Excreted"

Quantity of Manure (wet basis)	Steer, Bulls, and Calves	Beef Cows	Heifers
Weight (lb/day/1,000-lb animal)	58	63	66
Weight (lb/year/1,000-lb animal)	21,170	22,995	24,090

Source: Lander, 1998.

6.4.2 Description of Waste Constituents and Concentrations

The composition and concentrations of beef and heifer waste varies from the time that it is excreted to the time it is ultimately used as a fertilizer and/or soil amendment. Nutrients and metals are expected to be present in beef waste due to the constituents of the feed. This section discusses the following:

- Section 6.4.2.1: Composition of "as-excreted" manure;
- Section 6.4.2.2: Composition of beef feedlot waste;
- Section 6.4.2.3: Composition of aged manure; and
- Section 6.2.2.4: Composition of runoff from beef feedlots.

6.4.2.1 *Composition of "As-Excreted" Manure*

Data are presented in Table 6-43 for 13 metals and nutrients found in fresh beef cattle manure. Nitrogen is present in manure in four forms: ammonium-N, nitrate-N, nitrite-N, and organic-N. The total nitrogen (N) is the sum of these four components, while the total Kjeldahl nitrogen (TKN) is the sum of the organic-N and ammonium-N. Phosphorus is present in manure in inorganic and organic forms and presented as total phosphorus. Colonies of the pathogens coliform and streptococcus bacteria have also been identified in beef manure.

Manure characteristics for beef cattle are highly variable and greatly influenced by the diet and age of the animals. Differences in weather, season, degree of confinement, waste collection systems, and overall management procedures used by feedlots across the nation add to the variability of manure characteristics in feedlots. The largest variable in fresh manure is moisture content, which significantly decreases over time. Another major variable is the ash content, which depends on the amount of soil entrained in the manure. Ash content also depends on the degree to which the manure has been degraded, which is a function of time since deposition, moisture conditions, temperature, and oxygen saturation (Sweeten et al., 1997). Ash content for fresh manure has been reported as 15.3 percent dry basis (Sweeten, 1995), while ash content for aged feedyard waste has been reported as high as 66 percent dry basis (TAES, 1996).

The nitrogen content of manure can begin to decrease rapidly after excretion. The urea-nitrogen fraction part of the fecal protein rapidly converts to ammonia. Some measurements of ammonia concentrations in air around feedyards have indicated that about half of the nitrogen deposited in urine, or about one-fourth of the total N deposition of the feedlot surface, is lost to the atmosphere as ammonia gas (NH_3). The rate of ammonia emissions depends on temperature, pH, humidity, and moisture conditions, and it has been found to nearly triple as manure dries after rainfall (Sweeten et al., 1997).

Table 6-43 presents beef and veal manure characteristics data, which are averages reported in the scientific literature and compiled by ASAE. Lander averaged values from the Midwest Plan Service, USDA-NRCS, and North Carolina State data sets for N, P, and K. Table 6-44 presents Lander's averaged values.

Table 6-43. Fresh Beef and Veal Manure Characteristics Per 1,000 Pound Live Weight Per Day

Parameter	Unit[a]	Beef		Veal	
		Mean	Standard Deviation	Mean	Standard Deviation
Moisture	%	88.4	-	97.5	-
Weight	lb	58	17	62	24
Total solids	lb	8.5	2.6	5.2	2.1
Volatile solids	lb	7.2	0.57	2.3	-
BOD (5-day)	lb	1.6	0.75	1.7	-
COD	lb	7.8	2.7	5.3	-
pH	lb	7.0	0.34	8.1	-
Nitrogen (Total Kjeldahl)	lb	0.34	0.073	0.27	0.045
Nitrogen (Ammonia)	lb	0.086	0.052	0.12	0.016
Phosphorous (Total)	lb	0.092	0.027	0.066	0.011
Orthophosphorus	lb	0.030	-	-	-
Potassium	lb	0.21	0.061	0.28	0.10
Calcium	lb	0.41	0.11	0.059	0.049
Magnesium	lb	0.049	0.015	0.033	0.023
Sulfur	lb	0.045	0.0052	-	-
Sodium	lb	0.0030	0.023	0.086	0.063
Iron	lb	0.0078	0.0059	0.00033	-
Manganese	lb	0.0012	0.00051	-	-
Boron	lb	0.00088	0.000064	-	-
Molybdenum	lb	0.000042	-	-	-
Zinc	lb	0.0011	0.00043	0.013	-
Copper	lb	0.00031	0.00012	0.000048	-
Total coliform bacteria	colonies	29	27	-	-
Fecal coliform bacteria	colonies	13	12	-	-
Fecal streptococcus bacteria	colonies	14	21	-	-

[a] All values wet basis.

Source: ASAE, 1993.

Table 6-44. Average Nutrient Values in Fresh (As-Excreted) Beef Manure

Parameter	Beef (lb/day/1,000-lb animal)[a]
Nitrogen (Total Kjeldahl)	0.32
Ammonia	Not provided
Phosphorus (Total)	0.098
Potassium	0.23

[a] Lander's analysis relied upon 1990 North Carolina State University data, while the North Carolina State University data presented in this report is from 1994.

Manure characteristics of heifers is limited to two data sources, North Carolina State University and USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. Table 6-45 presents the fresh (as-excreted) manure characteristics for heifers.

6-45. Fresh Heifer Manure Characteristics Per 1,000 Pounds Live Weight Per Day

Parameter	Unit[a]	USDA Mean Value	NCSU Mean Value
Moisture	%	89.3	--
Weight	lb	85	68.4
Total solids	lb	9.14	7.35
Volatile solids	lb	7.77	5.34
Biochemical oxygen demand (BOD), 5-day	lb	1.3	0.89
Chemical oxygen demand (COD)	lb	8.3	5.68
Nitrogen (Total Kjeldahl)	lb	0.31	0.23
Phosphorus (Total)	lb	0.04	0.16
Potassium	lb	0.24	0.16

[a]All values wet basis.
Sources: USDA, 1996; NCSU, 1994

6.4.2.2 *Composition of Beef Feedlot Waste*

The characteristics of beef cattle feedlot wastes vary widely because of differences in climate, rainfall, diet, feedlot surface, animal density, and cleaning frequency. Wasted feed and soil in unpaved beef feedlots is readily mixed with the manure because of animal movement and cleaning operations (Arrington et al., 1981). Therefore, due to the incorporation of more solids and exposure to the elements, the moisture content of beef feedlot waste is significantly lower than for "as-excreted" beef manure.

Table 6-46 presents characteristics of beef waste, as collected, from unpaved and paved feedlots (USDA NRCS, 1992). Most feedlots are unpaved; however, for paved lots, concrete is the most common paving material, although other materials (e.g., fly ash) have been used (Suszkiw, 1999).

Table 6-46. Beef Waste Characterization—Feedlot Waste

Component	Units	Unpaved Lot[a]	Paved Lot[b]	
			High-Forage Diet	High-Energy Diet
Weight	lb/d/1000#	17.5	11.7	5.3
Moisture	%	45	53.3	52.1
Total Solids	% wet basis	55	46.7	47.9
Total Solids	lb/d/1000#	9.6	5.5	2.5
Volatile Solids	lb/d/1,000#	4.8	3.85	1.75
Fixed Solids	lb/d/1,000#	4.8	1.65	0.76
N	lb/d/1,000#	0.21	-	-
P	lb/d/1,000#	0.14	-	-
K	lb/d/1,000#	0.03	-	-
C:N ratio	unitless	13	-	-

[a] Dry climate (annual rainfall less than 15 inches); annual manure removal.
[b] Dry climate; semiannual manure removal.
Source: USDA NRCS, 1992.

Table 6-47 presents North Carolina State University data on scraped beef manure from an unpaved surface.

6-47. Beef Manure Characteristics Per 1,000 Pounds Live Weight Per Day From Scraped Unpaved Surface

Parameter	Unit[a]	Value
Total solids	lb	9.4
Volatile solids	lb	5.3
Nitrogen (Total Kjeldahl)	lb	0.20
Nitrogen (Ammonia)	lb	0.38
Phosphorus (Total)	lb	0.062
Potassium	lb	0.14

Sweeten, et al., compiled and compared feedlot waste data representing "as-collected" waste, composted waste, and stockpiled waste from one area of the country (Sweeten et al., 1997). Overall, the as-collected, composted, and stockpiled data were similar, indicating that once manure is exposed to the elements, its nutrient composition does not significantly change even if it is composted or stockpiled.

6.4.2.3 *Composition of Aged Manure*

Beef cattle feedlots typically scrape and remove the manure that is deposited on the ground about every 120 to 365 days, as opposed to dairy operations that scrape or remove manure as often as every day. During this "aging" process, nutrients are lost due to ammonia volatilization, runoff, and leaching. Mathers, et al., determined average nutrient concentrations in aged manure ready for land application from 23 beef cattle feedlots in the Texas High Plains (Mathers et al., 1972). Since national data on aged manure characteristics have not been identified, these local data are presented in Table 6-48 to demonstrate the significant difference in characteristics of fresh and aged manure.

These data show the aged beef manure nitrogen concentration is 40.3 percent of the fresh manure concentration, while phosphorus and potassium in aged manure are 50.9 percent and 64.5 percent of their concentrations, respectively, in fresh manure. Nitrogen losses as high as 50 percent have been reported in aged beef manure, due to temperature, moisture, pH, and C:N ratio. Phosphorus and potassium losses are primarily due to runoff but some leaching may also occur.

Table 6-48. Percentage of Nutrients in Fresh and Aged Beef Cattle Manure

Parameter	Unit	Fresh Manure	Aged Manure
Moisture	%	88	34
N	% dry basis	5.08	2.05
P	% dry basis	1.59	0.81
K	% dry basis	3.55	2.29

Source: Mathers, 1972.

6.4.2.4 *Composition of Runoff from Beef Feedlots*

Numerous analyses characterizing the runoff from beef feedlots have been conducted on a local level. However, manure characteristics data collected at a local level may not be representative of the beef industry as a whole. Since the constituent concentration of feedlot runoff varies among different areas of the country, this report presents only nationally available manure characteristics and regional estimates of feedlot runoff characteristics.

As with feedlot wastes, constituent characteristics of beef feedlot runoff also vary across the country. The factors that are responsible for runoff waste variations are similar to those for feedlot wastes (i.e., climate, rainfall, diet, feedlot surface, animal density, and cleaning frequency). Paved feedlots produce more runoff than unpaved lots and areas of high rainfall and low evaporation produce more runoff than arid areas.

The USDA/NRCS Agricultural Waste Management Field Handbook characterizes both the supernatant and sludge from beef feedlot runoff lagoons. Table 6-49 presents these waste characteristics.

Table 6-49. Beef Waste Characterization—Feedlot Runoff Lagoon

Component	Units	Runoff Lagoon	
		Supernatant	Sludge
Moisture	%	99.7	82.8
Total Solids	% wet basis	0.3	17.2
Volatile Solids	lb/1,000 gal	7.5	644.83
Fixed Solids	lb/1,000 gal	17.5	788.12
COD	lb/1,000 gal	11.67	644.83
N	lb/1,000 gal	1.67	51.66
NH_4-N	lb/1,000 gal	1.5	-[a]
P	lb/1,000 gal	-[a]	17.5
K	lb/1,000 gal	7.5	14.17
Copper	lb/lb	-	1.94×10^{-4}
Zinc	lb/lb	-	9.29×10^{-4}

[a] Data not available.
Source: USDA NRCS, 1992; NCSU, 1994.

6.5 Veal Waste

This section describes the characteristics of veal manure and waste. In this section, manure refers to the combination of feces and urine and waste refers to manure plus other material, such as hair, soil, and spilled feed. Due to the nature of veal operations, however, even fresh manure may also contain small amounts of hair and feed.

This section discusses the following:

- Section 6.5.1: The quantity of manure generated; and
- Section 6.5.2: Description of waste constituents and concentrations.

6.5.1 Quantity of Manure Generated

National data on veal waste characteristics are available from the following three data sources:

- American Society of Agricultural Engineers (ASAE) Standard D384.1: *Manure Production and Characteristics*, 1999. This data source contains national fresh (as-excreted) manure characteristic values by animal type (e.g., dairy, beef, veal, swine).

- USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. This data source contains national manure characteristic values for fresh and managed manure (e.g., lagoon supernatant, feedlot runoff) by animal type including subtypes such as lactating cow, dry cow, heifer, sow, and boar.

- North Carolina State University (NCSU), *Livestock Manure Production and Characterization in North Carolina*, 1994. This data source contains regional manure characteristic values for fresh and managed manure by animal type including subtypes.

Table 6-50 presents the average as-excreted manure characteristics for veal from these three data sources.

6-50. Average Weight of Veal Manure, "As-Excreted"

Quantity of Manure (wet basis)	Veal Calves
Weight (lb/day/1,000-lb animal)	61
Weight (lb/year/1,000-lb animal)	22,265

Sources: ASAE, 1999; UDSA, 1996; NCSU, 1994.

6.5.2 Description of Waste Constituents and Concentrations

The composition and concentrations of veal waste varies from the time that it is excreted to the time it is ultimately used as a fertilizer and/or soil amendment. Nutrients and metals are expected to be present in veal waste due to the constituents of the feed. This section discusses the composition of "as-excreted" manure.

Data are presented in Table 6-51 for nine metals and nutrients found in fresh veal manure. Veal manure is very fluid, with the consistency of a sloppy mortar mix, and is often diluted by large volumes of wash water (Meyer, 1987). The moisture content of fresh veal manure is approximately 98 percent (USDA NRCS, 1992).

Veal manure is typically stored in tanks, basins, and pits until it is pumped out on the land as fertilizer. However, most of the fertilizer value of veal manure remains in the solids in a settling tank (Meyer, 1987). Over time, the most significant compositional change in veal manure, stored in pits, is the conversion of organic-N in fresh manure to ammonium and loss of total nitrogen to the atmosphere in the form of ammonia. Much of the high ammonia loss is due to microbial degradation of the organic matter including total nitrogen components (Sutton et al., 1989).

6-51. Fresh Veal Manure Characteristics Per 1,000 Pound Live Weight Per Day

Parameter	Unit[a]	Mean Values from Data Sources		
		ASAE	USDA	NCSU
Moisture	%	97.5	97.5	--
Weight	lb	62	60	61.8
Total solids	lb	5.2	1.5	4.0
Volatile solids	lb	2.3	0.85	2.1
BOD (5-day)	lb	1.7	0.37	0.83
COD	lb	5.3	1.5	1.5
pH	lb	8.1	--	7.7
Nitrogen (Total Kjeldahl)	lb	0.27	0.20	0.24
Nitrogen (Ammonia)	lb	0.12	--	0.11
Phosphorous (Total)	lb	0.066	0.03	0.053
Potassium	lb	0.28	0.25	0.27
Calcium	lb	0.059	--	0.059
Magnesium	lb	0.033	--	0.33
Sodium	lb	0.086	--	0.16
Iron	lb	0.00033	--	0.00033
Zinc	lb	0.013	--	0.013
Copper	lb	0.000048	--	0.000048

[a] All values wet basis.
Source: ASAE, 1999; USDA, 1996; NCSU, 1994.

6.6 References

Arrington, R.M. and C.E. Pachek. 1981. *Soil Nutrient Content in Manures in an Arid Climate.* In: Livestock Waste: A Renewable Resource, Proceedings of the Fourth International Symposium on Livestock Waste, 1980. pp. 15-152. American Society of Agricultural Engineers, St. Joseph, Michigan.

ASAE, 1998. ASAE Standards 1998, 45th Edition. American Society of Agricultural Engineers, St. Joseph, MI.

ASAE, 1999. *Manure Production and Characteristics*. American Society of Agricultural Engineers, St. Joseph, MI.

Blume and McCleve. 1997. *Disposal of Swine Wastewater Using Spray Nozzle*. ASAE Paper No. 974072. Presented at the ASAE Annual International Meeting. American Society of Agricultural Engineers, Minneapolis, Minnesota, August 10-14, 1997.

Boland et al. 1997. *Analysis of Manure Management Systems and Phytase Adoption by Pork Producers.* Livestock Environment 5, Volume 2. Proceedings of the Fifth International Symposium, Bloomington , Minnesota, USA, May 29-31, 1997. Pp. 702-709.

Fulhage. 1998. *Composting Dead Animals- The Missouri Experience.* Presented at the ASAE Annual International Meeting. American Society of Agricultural Engineers, Orlando, Florida, July 12-16, 1998.

Jones, Don D., and Alan Sutton. 1994. *"Treatment Options for Liquid Manure" in Liquid Manure Application Systems: Design, Management, and Environmental Assessment, Proceedings from the Liquid Manure Application Systems Conference*. Rochester, New York, Dec. 1-2, 1994.

Lander, C.H., D. Moffitt, and K. Alt. 1998. *Nutrients Available from Livestock Manure Relative to Crop Growth Requirements*. U.S. Department of Agriculture. Natural Resources Conservation Services. Washington, D.C.

Lander, C.H. 1999. *Dairy Manure Characteristics*. National Milk Producers Federation submittal to EPA.

Loudon, T.L., et. al. 1985. *Livestock Waste Facilities Handbook*, 2nd ed., Midwest Plan Service.

Mathers, A.C., B.A. Stewart, J.D. Thomas, and B.J. Blair. 1972. *Effects of Cattle Feedlot Manure on Crop Yields and Soil Conditions*. USDA Southwestern Great Plains Research Center Tech. Rep. No. 11, Bushland, TX.

Meyer, D. J. 1987. *Animal Manure—Veal Calf Management*. Prepared under the direction of the Manure Management Work Group of the Agricultural Advisory Committee to the Pennsylvania Department of Environmental Resources, Robert E. Graves, Ed. <http://www.inform.umd.edu:8080/EdRes/topic/AgrEnv/ndd/watermgt/ANIMAL_MANURE_VEAL_CALF_MANAGEM.html>

Midwest Planning Service. *Livestock Waste Facilities Handbook*, 1985.

MWPS. 1993. MWPS-18: *Livestock Waste Facilities Handbook - 3rd Edition*. Midwest Plan Service, Iowa State University, Ames, IA.

NCSU. 1994. *Livestock Manure Production and Characterization in North Carolina*. North Carolina Cooperative Extension Service. Raleigh, NC.

Suszkiw, J. 1999. *Low-Cost Way to Pave Feedlots*. Agricultural Research.

Sutton. A.L., M.D. Cunningham, J.A. Knesel, and D.T. Kelly. 1989. *Veal Calf Waste Production and Composition*. Applied Engineering in Agriculture, Vol 5, No. 1.

Svoboda. 1995. *Nitrogen Removal from Pig Slurry by Nitrification and Denitrification*. Proceedings of the Seventh International Symposium on Agricultural and Food Processing Wastes, Chicago, Illinois, USA, June 18-20, 1995. Pp. 702-709.

Sweeten, J.M. and S.H. Amosson. 1995. *Total Quality Manure Management*, Texas Cattle Feeders Association. Chapter 4: Manure Quality and Economics.
USDA ARS. 1998. *Agricultural Uses of Municipal, Animal and Industrial Byproducts*. U.S. Department of Agriculture (SDA), Agricultural Research Service (ARS). <http://www.ars.usda.gov/is/np/agbyintro.htm>

Sweeten, J.M., S.H. Amosson, and B.W. Auvermann. 1997. *Manure Quality and Economics*. Proceedings of Texas Biomass Energy Opportunities Workshop Series #1: Livestock Waste Streams: Energy and Environment. Texas A&M University Agricultural Research and Extension Center.

TAES. 1996. *Manure Analysis Summary—Coal Ash Surfacing vs Control Treatments for Beef Cattle Feedyards*. Result Demonstration Report. Texas Agricultural Extension Service (TAES).

USDA. 1992. National Engineering Handbook: Agricultural Waste Management Field Handbook. United States Department of Commerce, National Technical Information Service. Springfield, VA. Handbook also revised July 1996.

USDA. 1998. Nutrients Available from Livestock Manure Relative to Crop Growth Requirements. U.S. Department of Agriculture, Natural Resources Conservation Service, Resource Assessment and Strategic Planning Working Paper 98-1. <http://www.nhq.nrcs.usda.gov/land/pubs/nlweb.html>. Accessed August 23, 1998.

USDA. 1999. 1997 Agricultural Resource Management Study (ARMS). Economic Research Service, 2/18/99.

USDA APHIS. 1995. *Swine '95 Part I: Reference of 1995 Swine Management Practices*. <http://www.aphis.usda.gov/vs/ceah/cahm/>. File sw95des1.pdf accessed October 15, 1998. U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

USDA NRCS. 1992. *Agricultural Waste Management Field Handbook, National Engineering Handbook (NEH),* Part 651. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). <http://www.ncg.nrcs.usda.gov/awmfh.html>

Van Horn, H.H., G.L. Newton, R.A. Nordstedt, E.C. Krench, G. Kidder, D.A. Graetz, and C.F. Chambliss. 1998. *Circular 1016: Dairy Manure Management: Strategies for Recycling Nutrients to Recover Fertilizer Value and Avoid Environmental Pollution.* Dairy and Poultry Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Zublena, J. P., Barker, Parker, and Stanislaw. 1993. *Soil Facts*. North Carolina Cooperative Extension Service.

CHAPTER 7

POLLUTANTS OF INTEREST

7.0 INTRODUCTION

Pollution generated at feedlot operations can arise from multiple sources. These sources, including animal waste, process wash waters, litter, animal carcasses, spills of pesticides, and pharmaceuticals, are the primary sources of potential environmental contamination.

Excreted animal waste contains undigested and partially digested feed, partially metabolized organic material, dead and living microorganisms from the digestive tract, cell wall material and other organic debris from the digestive tract, excess digestive juices, and other organisms that might have grown in the wastes after excretion. Depending on the type of feed provided to the animals and whether feed additives have been used, animal wastes can also contain pharmaceuticals and inorganics such as trace elements.

Animal carcasses, which may contain pathogens, nutrients, and chemical toxicants, can pose an environmental problem, especially in the poultry industry where many operations have historically used burial as a means for disposal. For example, during 1990, several state agencies in Arkansas tested the management of dead-bird disposal pits and found high soil concentrations of ammonium (USEPA, 1999). Improper disposal of poultry carcasses has been implicated in ground water contamination; however, in recent years, greater regulation of animal disposal has reduced the risk of environmental contamination from buried animal carcasses. Arkansas, for example, has outlawed the use of dead-bird disposal pits. Other states have also issued guidelines or regulations for disposal of animal carcasses and require operators to use specific practices such as composting.

In the preliminary study on environmental impacts from animal feedlot operations, EPA (1998) identified and described the major animal waste constituents that can adversely affect the environment. Additional information on potential impacts can be found in the *Environmental Assessment of Proposed Revisions to the National Pollutant Discharge Elimination system Regulation and Effluent Limitations Guidelines for Concentrated Animal Feeding Operations* (USEPA, 2000). As demonstrated in Chapter 6, the physical and chemical characteristics of manure differ between animal sectors as well as within animal sectors. The following pollutants of interest identified by EPA in its preliminary feedlots study are described below:

- Biochemical oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Total suspended solids
- Nutrients (nitrogen, phosphorus)
- Pathogens
- Other contaminants, including salts, trace elements, and pharmaceuticals

7.1 <u>Conventional Waste Pollutants</u>

Biochemical Oxygen Demand

BOD is a measure of the oxygen-consuming requirements of organic matter decomposition. When animal waste is discharged to surface water, it is decomposed by aquatic bacteria and other microorganisms. Decomposing organic matter consumes oxygen and reduces the amount available for aquatic animals. Severe reductions in dissolved oxygen levels can lead to fish kills. Even moderate decreases in oxygen levels can adversely affect waterbodies through decreases in biodiversity as manifested by the loss of fish and other aquatic animal populations.

Total Suspended Solids

Suspended solids can clog fish gills and increase turbidity. Increased turbidity reduces penetration of light through the water column, thereby limiting the growth of desirable aquatic plants that serve as a critical habitat for fish, shellfish, and other aquatic organisms. Solids that settle out as bottom deposits can alter or destroy habitat for fish and benthic organisms. Solids also provide a medium for the accumulation, transport, and storage of other pollutants, including nutrients, pathogens, and trace elements. Sediment-bound pollutants often have an extended interaction with the water column through cycles of deposition, resuspension, and redeposition.

Fecal Coliform Bacteria

Manure contain diverse microbial populations. Included are members of the normal gastrointestinal tract flora, such as members of the fecal coliform and fecal streptococcus groups of bacteria. These are the groups of bacteria commonly used as indicators of fecal contamination and the possible presence of pathogenic species. A discussion of the different types of pathogens found in the waste of AFOs is given in section 7.2.

7.2 <u>Nonconventional Pollutants</u>

Nutrients (Nitrogen, Phosphorus)

Because of its nutrient content, animal manure can serve as a valuable agricultural resource. In an area where the amount of nutrients in manure generated from animal feedlot operations is greater than the nutrient requirements of the crops grown in the area, excess land application might occur, leading to increased nutrient runoff and seepage and subsequent degradation of water resources.

As noted in Chapter 6, wastes contain significant quantities of nutrients, particularly N and P. Manure N occurs primarily in the form of organic N and ammonia-N compounds. In organic form, N is unavailable to plants. However, through bacterial decomposition, organic N is transformed into ammonia, which is oxidized (by nitrification) to nitrite and ultimately nitrate. Ammonia and nitrate are bioavailable and therefore have fertilizer value. These forms can also produce adverse environmental impacts when they are transported in excess quantities to the environment.

Ammonia. "Ammonia-N" includes the ionized form (ammonium) and the un-ionized form (ammonia). Ammonium is produced when microorganisms break down organic N products, such as urea and proteins, in manure. This decomposition can occur in both aerobic and anaerobic conditions. Both forms are toxic to aquatic life, although the un-ionized form (ammonia) is much more toxic.

Ammonia is of environmental concern because it exerts a direct biochemical oxygen demand on the receiving water. Ammonia can lead to eutrophication, or nutrient overenrichment, of surface waters. Ammonia itself is a nutrient and is also easily transformed to nitrate (another nutrient form of N) in the presence of oxygen. Although nutrients are necessary for a healthy ecosystem, the overabundance of nutrients (particularly N and P) can lead to nuisance algae blooms.

Nitrate. In the biochemical process of nitrification, aerobic bacteria oxidize ammonium to nitrite (NO_2) and then to nitrate (NO_3). Nitrite is toxic to most fish and other aquatic species, but it usually does not accumulate in the environment because of its rapid conversion to nitrate in an aerobic environment.

Nitrate is a valuable fertilizer because it is biologically available to plants. Excessive levels of nitrate in drinking water, however, can produce adverse human health and environmental impacts. For example, human infants exposed to high levels of nitrate can develop methemoglobinemia, commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, EPA has set a drinking water maximum contaminant level (MCL) of 10 mg/L for nitrate-N.

Phosphorus. Animal wastes contain both organic and inorganic forms of P. As with N, the organic form must mineralize to the inorganic form to become available to plants. Mineralization occurs as the manure ages and the organic P hydrolyzes to inorganic phosphate-containing compounds. Phosphorus is of concern in surface waters because it is a nutrient that can lead to eutrophication and the resulting adverse impacts—fish kills, reduced biodiversity, objectionable tastes and odors, increased drinking water treatment costs, and growth of toxic organisms. At concentration levels greater than 1.0 mg/L, P can interfere with coagulation in drinking water treatment plants (Bartenhagen et al., 1994).

Phosphorus is of particular concern in fresh waters, where plant growth is typically limited by phosphorous levels. Under high pollutant loads, however, fresh water may become nitrogen-limited (Bartenhagen et al., 1994). Thus, both N and P loads may contribute to eutrophication.

Chemical Oxygen Demand

COD is another measure of oxygen-consuming pollutants in water, but it measures the amount of oxygen required to oxidize all organic material present. COD differs from BOD in that it test oxidizes organic material regardless of how biological assimilability of the substance. BOD only measures the oxygen required to oxidize the biologically degradable material. COD is based on the fact that all organic compounds, with few exceptions, can be oxidized by the action of strong oxidizing agents under acidic conditions. COD is usually coincident with BOD, exacerbating the adverse effects of organic matter degradation.

Pathogens

Manure contains diverse microbial populations. There are many examples that demonstrate that pathogens from manure can be a problem. Other studies show that manured fields do not pose a significant threat to surface waters. Most pathogens are from the gastrointestinal tract and can be divided into those pathogens that are highly host-adapted and not considered to be zoonoses (diseases naturally transmissible between vertebrates and man) and those that are capable of causing infection in humans. For example, most *Salmonellae* are zoonoses, but *S. pulloram* and *S. gallinarum*, which might be present in poultry manures, are not. However, both may be included in gross estimates of *Salmonella* densities. The pathogens that might be present in poultry and swine manures also can be divided into those microorganisms which commonly are present and those which are less common. For example in poultry manures, *Campylobacter jejuni* is commonly present while *Mycobacterium avium* is less common. These distinctions are important in assessing the potential public health risks associated with poultry and swine operations, as well as other animal feeding operations.

The interactions between pathogens, cattle, and the environment are not well understood but current literature suggests that dairy and beef cattle shed pathogens that are known to be infectious to humans. The threat posed by pathogens in animal manure is influenced by the source, pH, dry matter, microbial, and chemical content of the feces. Solid manure that is mixed with bedding material is more likely to undergo aerobic fermentation in which temperature increases reduce the number of viable pathogens. However, some pathogens grow under a wide range of conditions that makes their control very difficult. Quantifying the risk associated with these pathogens is thus challenging. Rapidly changing pathogen numbers, changes in the infective status of the host, and survivability of the pathogens all make it increasingly difficult to determine how much of a threat animal-excreted pathogens are to society. Moreover, methods of pathogen detection produce varying results, making it difficult to compare studies that use different analyses (Pell, 1997).

Although manures may contain a variety of pathogens capable of causing infectious diseases in humans, it appears that *Salmonellae*, *Campylobacter jejuni*, *Clostridium perfringens* type A, and possibly *Pasteuralla multocida* should be of greatest concern. Only swine manure is a potential source of either *Giardiasis* or *Cryptosporidiosis* infections in humans, and swine manure appears to be far less significant than cattle manure as a source of the responsible protozoans.

Other Potential Contaminants

Animal wastes can contain other chemical constituents that could adversely affect the environment. These constituents include salts, trace elements, and pharmaceuticals, including antibiotics. Although salts are usually present in waste regardless of animal or feed type, trace elements and pharmaceuticals are typically the result of feed additives to help prevent disease or promote growth. Accordingly, concentrations of these constituents will vary with operation type and from facility to facility.

Salts and trace elements. Animal manure contains dissolved mineral salts. The major cations contributing to salinity are sodium, calcium, magnesium, and potassium; the major anions are chloride, sulfate, bicarbonate, carbonate, and nitrate. In land-applied wastes, salinity is a concern because salts can accumulate in the soil and become toxic to plants; they can also deteriorate soil quality by reducing permeability and contributing to poor tilth. Direct discharges and salt runoff to fresh surface waters contribute to salinization and can disrupt the balance of the ecosystem. Leaching salts can deteriorate ground water quality, making it unsuitable for human consumption. Trace elements such as arsenic, copper, selenium, and zinc are often added to animal feed as growth stimulants or biocides (Sims, 1995). When applied to land, these elements can accumulate in soils and become toxic to plants, and they can affect human and ecological health.

Antibiotics and hormones. A number of pharmacologic agents are used in the production of poultry and swine, among them a variety of antibiotics. Nonantibiotic antimicrobials, such as sulfonamides, and some antibiotics, such as streptomycin, are used primarily for therapeutic use. However, most of the antibiotics used in both the swine and the poultry industries are used both therapeutically and as feed additives to promote growth or improve feed conversion efficiency or both. When antibiotics are used to promote growth or improve feed conversion, the dosage rates are substantially lower than when they are administered for therapeutic use.

While specific hormones are used to increase productivity in the beef and dairy industries, hormones are not used in the poultry or swine industries. Thus, hormones present in poultry and swine manures are only in naturally occurring concentrations.

Despite the fact that there is little information in the literature about concentrations of antibiotics in poultry and swine manures, it is known that the primary mechanisms of elimination are in urine and bile (Merck and Company, 1998). Essentially all of an antibiotic administered is eventually excreted. The form excreted, the unchanged antibiotic or metabolites or some combination thereof, is antibiotic specific, as is the mass distribution among mechanisms of excretion. These compounds may pose risks to humans and the environment. For example, chronic toxicity may result from low-level discharges of antibiotics. In addition, estrogen hormones have been implicated in the drastic reduction in sperm counts among men (Sharpe and Skakkebaek, 1993) and reproductive disorders in a variety of wildlife (Colburn et al., 1993).

7.3 Priority Pollutants

The Clean Water Act (CWA) requires states to adopt numeric criteria for priority toxic pollutants if the USEPA has published criteria guidance and if the discharge or presence of these pollutants could reasonably be expected to interfere with the designated uses of the state's waters. The USEPA currently lists a total of 126 toxic priority pollutants in 40 CFR 122, Appendix D. Other metal and organic chemicals, however, can cause adverse impacts.

Animal wastes may contain a variety of priority pollutants, including the potentially toxic metals: arsenic, cadmium, chromium, copper, lead, molybdenum, nickel, selenium, and zinc (Overcash et al., 1983; ASAE, 1999). In promulgating standards for the disposal of sewage sludges by land application, USEPA has established maximum allowable concentrations and cumulative loading limits for each of these metals. Although information about the concentrations of these metals in poultry and livestock manures, and its variability, is quite limited, it generally has been assumed that these concentrations are well below those allowable for land application of wastewater treatment sludges. However, the issue of cumulative loading has been raised periodically in light of long-term use of cropland for manure disposal, especially in areas where poultry and livestock production is concentrated (Sims, 1995).

Given the degree of vertical integration that has occurred in both the poultry and the swine industries, much of the feed manufacturing for these industries is controlled by integrators. Thus, information about the current use of trace mineral supplements in formulating both poultry and swine feeds is difficult to obtain because the integrators consider it proprietary. However, it appears to be a reasonable assumption that arsenic, copper, selenium, and zinc are typically added to poultry feeds and that copper, selenium, and zinc are common components of trace mineral premixes used in the manufacturing of swine feeds. It is probable that commonly used feed supplements also contain some manganese.

Feed amendments of selenium (0.3 part per million) and arsenic (90 grams per ton of feed) are regulated by the U.S. Food and Drug Administration (Title 21, Part 573.920 of the Code of Federal Regulations). Levels of other trace minerals as feed supplements are regulated only indirectly by the FDA through maximum allowable concentrations in specified tissues at slaughter or in eggs.

Currently available information about metal concentrations in poultry and swine manures almost exclusively dates back to the 1960s and 1970s (Barker and Zublena, 1995). Kornegay's (1996) data are also somewhat dated, because they are averages over a 14-year period prior to 1992. When compared with Barker and Zublena's data for swine, Kornegay's data suggest that the concentrations of copper and zinc in swine manure have increased significantly over time. However, little is known about the current concentrations of trace metals in poultry and swine manures except that the variations in concentrations are substantial.

7.4 <u>References</u>

ASAE 1999. Manure production and characteristics. AS Data: AS D384.1. American Society of Agricultural Engineers, St. Joseph, Michigan.

Barker, J.C., and J.P. Zublena. 1995. Livestock manure assessment in North Carolina. In *Proceedings of the Seventh International Symposium on Agricultural and Food Processing Wastes*, American Society of Agricultural Engineers, St. Joseph, Michigan, pp. 98-106.

Bartenhagen, Kathryn, et al. 1994. *Water, Soil, and Hydro Environmental Decision Support System (WATERSHEDS*) NCSU Water Quality Group, <http://h20sparc.wq.ncsu.edu/info /phos.html. Accessed September 6, 1999.

Colburn, T., F.S. vom Sall, and A.S. Soto. 1993. Developmental effects of endocrine-disrupting chemicals in wildlife and humans. *Environmental Health Prospect*, 101:178. Cited in: Shore et al., 1995.

Kornegay, E.T. 1996. Nutritional, environmental, and economic considerations for using phytase in pig and poultry diets. In *Nutrient Management of Food Animals to Enhance and Protect the Environment*, ed. E.T. Kornegay, pp. 277-302.

Merck and Company, Inc. 1998. *The Merck Veterinary Manual.* 18th ed. Merck and Company, Inc., Whitehouse Station, New Jersey.

Overcash, M.R., F.J. Humenik, and J.R. Miner. 1983. *Livestock Waste Management.* Vol. I. CRC Press, Inc., Boca Raton, Florida.

Pell, Alice, 1997. Manure and Microbes: Public and Animal Health Problem? *Journal of Dairy Science* 80:2673-2681.

Sharpe, R.M., and N. Skakkebaek. 1993. Are Estrogens involved in falling sperm count and disorders of the male reproductive system? *Lancet* 341:1392. Cited in USEPA, 1998.

Sims, J.T. 1995. Characteristics of animal wastes and waste-amended soils: An overview of agricultural and environmental issues. In *Animal Wastes and the Land-Water Interface*, ed. K. Steele, pp. 1-13. CRC Lewis Publishers, Boca Raton, Florida.

USEPA. 1998. Appendix IV. Environmental data summary. In *Environmental impacts of animal feeding operations*. U.S. Environmental Protection Agency, Office of Water, Washington, DC. December 31, 1998.

USEPA. 1999. Success stories, Arkansas. U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/owow/NPS/Success3l9/AR.html. December 31, 1998. Accessed September 7, 1999.

CHAPTER 8

TREATMENT TECHNOLOGIES AND BEST MANAGEMENT PRACTICES

8.0 INTRODUCTION

This chapter provides an overview of treatment technologies and best management practices (BMPs) for pollution prevention at animal feeding operations (AFOs), as well as for the handling, storage, treatment, and land application of wastes. The discussion focuses on technologies and BMPs currently implemented at domestic AFOs, but it also describes technologies and BMPs that are under research and development, are undergoing laboratory or field testing, or are used in other countries.

Many waste management technologies and BMPs are used by more than one animal sector, and information on them is presented in a general discussion form. However, the manner in which a particular technology or BMP is used or its degree of acceptance can vary among sectors. These differences are presented by animal sector where necessary.

8.1 Pollution Prevention Practices

Pollution prevention practices can be divided into feeding strategies that reduce the concentration of pollutants in waste and practices that reduce the amount of water used in the handling of wastes. Reduced water use or handling of wastes in a dry or drier form lowers the risk of pollutants entering surface waters. Reduced water use has the added benefit of making the waste less expensive to move from the facility site.

8.1.1 Feeding Strategies

Feeding strategies designed to reduce nitrogen (N) and phosphorus (P) losses include more precise diet formulation, enhancing the digestibility of feed ingredients, genetic enhancement of cereal grains and other ingredients resulting in increased feed digestibility, and improved quality control. These strategies increase the efficiency with which the animals use the nutrients in their feed and decrease the amount of nutrients excreted in the waste. With a lower nutrient content, more manure can be applied to the land and less cost is incurred to transport excess manure from the farm. Strategies that focus on reducing P concentrations, thus reducing overapplication of P and associated runoff into surface waters, can turn manure into a more balanced fertilizer in terms of plant requirements.

Feeding strategies that reduce nutrient concentrations in waste have been developed for specific animal sectors, and those for the swine, poultry and dairy industries are presented separately in the following discussion. The application of these types of feeding strategies to the beef industry has lagged behind other livestock sectors and is not discussed here.

8.1.1.1 Swine Feeding Strategies

Practice: Precision Nutrition for Swine

Description: Current swine feed rations can result in overfeeding proteins and other nutrients to animals because they are designed to ensure that nutritional requirements are met and growth rate maintained. Precision nutrition entails formulating feed to meet more precisely the animals' nutritional requirements, causing more of the nutrients to be metabolized, thereby reducing the amount of nutrients excreted. For more precise feeding, it is imperative that both the nutritional requirements of the animal and the nutrient yield of the feed are fully understood.

When swine are fed typical diets, the P use efficiency is on the order of 10 to 25 percent, while the N use efficiency is on the order of 30 percent. These figures suggest that swine use these nutrients very inefficiently. An excess of N in the diet, principally from protein in feed, leads to inefficient utilization of nutrients. Phytate-phosphorus[1] (phytate-P), the most common form of P in feedstuffs (56 to 81 percent), is not well utilized by pigs because they lack intestinal phytase, the enzyme needed to remove the phosphate groups from the phytate molecule. Therefore, supplemental P is added to the diet to meet the pig's growth requirements, while phytate-P from the feed is excreted in the urine, thus increasing P concentrations in the manure. Because some feedstuffs are high in phytase, and because there is some endogenous phytase in certain small grains (wheat, rye, triticate, barley), there is wide variation in the digestibility of P in feed ingredients. For example, only 12 percent of the total P in corn is digestible whereas 50 percent of the total P in wheat is digestible. The P in dehulled soybean meal is more available than the P in cottonseed meal (23 versus 1 percent), but neither source of P is as highly digestible as the P in meat and bone meal (66 percent), fish meal (93 percent), or dicalcium phosphate (100 percent).

Application and Performance: Lenis and Schutte (1990) showed that the protein content of a typical Dutch swine ration could be reduced by 30 grams per kilogram without negative effects on animal performance. They calculated that a 1 percent reduction in feed N could result in a 10 percent reduction in excreted N. Monge et al. (1998) confirmed these findings by concluding that a 1 percent reduction in feed N yielded an 11 percent reduction in excreted N. According to Van Kempen and Simmins (1997), reducing the variation of nutrients in feed by using more appropriate quality control measures would reduce N waste by 13 to 27 percent. Experts believe that N losses through excretion can be reduced by 15 to 30 percent in part by minimizing excesses in diet with better quality control at the feed mill (NCSU, 1998).

---

[1]Most plant P occurs in the form of phytate, which is P bonded to phytic acid.

Plant geneticists have produced strains of corn that contain less phytate-P (i.e., low-phytate corn) and are more easily digested than typical strains, resulting in less P excreted in manure. Allee and Spencer (1998) found that hogs fed low-phytate corn excreted an average of 37 percent less P in manure, with no adverse effects on animal growth. In a study by Bridges et al. (1995), two weight classes of grower-finisher pigs (66.1 and 101.7 kg) were given maize-soybean meal diets lower in protein and P to determine the reduction in N and P in pig waste when compared with pigs fed a conventional diet. Total N waste was reduced by 32 percent and 25 percent for the two weight classes, while total P excretion was reduced by 39 percent and 38 percent, respectively. The study also modeled the impact of reductions in dietary protein and P over the complete grower-finisher period using the NCPIG model developed by the North Central Regional Swine Modeling Committee. Model results showed a reduction of approximately 44 percent in total N and P excretion compared with the conventional diet, with little impact on the time of production. In addition, the Fédération Européenne des Fabricants d'Adjuvants pour la Nutrition Animale in Belgium (FEFANA,1992) calculated that the selection of highly digestible feedstuffs should result in a 5 percent reduction in total waste.

Advantages and Limitations: Precision feeding results in a higher feed efficiency (less feed used per pound of pig produced); however, any cost savings are at least partially offset by the cost of analyzing the nutrient content of feedstuffs. Consumer reaction to use of genetically modified crops to feed swine has not been determined yet.

Operational Factors: Precision feeding requires that feed manufacturers have the necessary equipment and procedures to create precision feeds within specified quality control limits. In general, feed manufacturers have traditionally limited quality control to measuring N, which correlates poorly with amino acid content in feedstuffs (van Kempen and Simmins, 1997). Precision feeding will also increase the costs and complexity of feed storage at the feeding operation.

Demonstration Status: Data on the frequency of use of precision nutrition are not available. Much of the information available on precision nutrition is derived from small-scale research experiments at the USDA and universities.

Practice: Multiphase and Split-Sex Feeding for Swine

Description: Multiphase feeding involves changing diet composition weekly instead of feeding only two different diets during the period from the 45-kg size to slaughter. Multiphase feeding is designed to better match the diet with the changing nutritional requirements of the growing animals.

Application and Performance: Feeding three or four diets during the grow-finish period instead of only two diets will reduce N excretion. According to models such as the Dutch Technical Pig Feeding Model by van der Peet-Schwering et al. (1993), multiphase feeding reduces N and P excretion by 15 percent. The modeling results have been confirmed by animal trials that showed a 12.7 percent reduction in N excretion in urine and a 17 percent reduction in P excretion.

Advantages and Limitations: Dividing the growth period into more phases with less spread in weight allows producers to meet more closely the pig's protein requirements. Also, because gilts (females) require more protein than barrows (males), separating barrows from gilts allows lower protein levels to be fed to the barrows without compromising leanness and performance efficiency in the gilts.

Operational Factors: Multiphase and split-sex feeding require separate feeding areas and pens for the different types of animals. It is also more costly to produce a different feed every week.

Demonstration Status: The *Swine '95* report (USDA APHIS, 1995) showed that 96.2 percent of grower/finisher operations fed two or more different diets. Of these operations, 63.4 percent progressed to a different diet based on animal weight, 5.3 percent changed diets based on either age or the length of time on the feed, and 30.0 percent based diet changes on equal consideration of weight and time. Of the 96.2 percent of grower-finisher operations that feed more than one diet, 18.3 percent practiced split-sex feeding. Split-sex feeding is used much more frequently in medium (2,000-9,999 head) and large operations (10,000+ head) than in small operations (less than 2,000 head).

Practice: Improved Feed Preparation for Swine

Description: Milling, pelleting, and expanding are examples of technological treatments that improve the digestibility of feeds. By reducing the particle size, the surface area of the grain particles is increased, allowing greater interaction with digestive enzymes. NCSU (1998) reported that the industry average particle size was approximately 1,100 microns and that the recommended size is between 650 and 750 microns. Expanders and extruders are used mainly to provide flexibility in ingredient selection and to improve pellet quality rather than to improve nutrient digestion.

Application and Performance: As particle size is reduced from 1,000 microns to 700 microns, excretion of N is reduced by 24 percent. Vanschoubroek et al. (1971) reviewed many articles regarding the effect of pelleting on performance and found that not only did animals prefer pelleted feed over mash feed, but feed efficiency improved by 8.5 percent and protein digestibility improved by 3.7 percent with pelleted feed.

Advantages and Limitations: Although reducing particle size less than 650 to 750 microns can increase feed digestibility, it also increases greatly the costs of grinding and reduces the throughput of the feed mill. Smaller-sized particles can also result in an increased incidence of stomach ulcers in animals. In some cases, chemical changes resulting from the high temperatures created in grinding machines may decrease feed digestibility.

Operational Factors: A reduction in the particle size of the feed might result in manure with finer solids particles. This may affect the performance of manure management practices, including possible effects on the efficiency of manure solid-liquid separators.

Demonstration Status: Data on the frequency of use of feed preparation techniques are not available.

Practice: Feed Additives for Swine

Description: Enzymes are commonly used in feed to improve the digestibility of nutrients. For example, plant P is often present in the form of phytate, which is digested poorly in swine, resulting in most of the P in feedstuffs being excreted in the manure. To prevent P deficiency, digestible P is added to swine rations, resulting in even more P in the manure. The enzyme additive phytase has been shown to improve P digestibility dramatically, and can be used to reduce the need for digestible P additives.

Other enzyme additives facilitate the retention of amino acids and digestive fluids, decreasing the amount of N excreted. Enzymes such as xylanases, beta-glucanases, and proteases upgrade the nutritional value of feedstuffs. Xylanases and beta-glucanases are enzymes used to degrade nonstarch polysaccharides (NSP) present in cereals such as wheat and barley. Swine do not secrete these enzymes and therefore do not have the capability to digest and use NSP. Because the NSP fraction traps nutrients that are released only upon partial degradation of the NSP fraction, addition of xylanase or beta-glucanase or both to cereal-containing diets can result in improvements in both digestibility and feed efficiency. In addition, supplementing the diet with synthetic lysine to meet a portion of the dietary lysine requirement is an effective means of reducing N excretion by pigs. This process reduces N excretion because lower-protein diets can be fed when lysine is supplemented. The use of other amino acid feed supplements is being tested.

Application and Performance: Mroz et al. (1994) showed that phytase increases P digestibility in a typical swine diet from 29.4 percent to 53.5 percent. They also demonstrated that phytase addition improved the digestibility of other nutrients in the feed such as calcium, zinc, and amino acids that are bound by phytase. For example, the addition of phytase to a commercial diet increased the digestibility of lysine by 2 percent while the digestibility of protein improved from 83.3 to 85.6 percent. Van der Peet-Schwering (1993) demonstrated that the use of phytase reduced P excretion by 32 percent in nursery pigs (a finding similar to the FEFANA [1992] predictions). Lei et al. (1993) found that feeding pigs 750 phytase units per gram of basal diet yielded a decrease in fecal P excretion of 42 percent without adverse health effects. This addition resulted in a linear improvement in phytate-P utilization. Graham and Inborr (1993) reported that enzyme additions improved the digestibility of protein in a wheat/rye diet by 9 percent.

Beal et al. (1998) used proteases on raw soybeans and observed a significant improvement in daily gain (+14.8 percent); feed efficiency, however, was improved by only 4.3 percent. Dierick and Decuypere (1994) saw a substantial improvement in feed efficiency when using proteases in combination with amylases and beta-glucanases, an improvement larger than that achieved with each enzyme individually. Studies have shown that protein levels can be reduced by 2 percent when the diet is supplemented with 0.15 percent lysine (3 pounds lysine-HC1 per ton of feed) without harming the performance of grower-finisher pigs.

Advantages and Limitations: Feed additives, especially synthetic amino acids and enzymes, increase the cost of feeding. Phytase, for example, was once too expensive to use as a feed additive. This enzyme can now be produced at lower cost with recombinant DNA techniques. As technology improves, it is likely that the costs associated with other feed additives will decrease similarly.

Operational Factors: The level of phytase required in swine feed varies with the age of the animal. These different levels are likely determined by the development of digestive enzymes and intestines of the pig, with the younger pig being less developed. Lysine supplements can be used to achieve even greater reductions in the level of protein in diets, but only if threonine, tryptophan, and methionine are also supplemented.

Demonstration Status: The use of proteases in animal feeds is not widespread because of conflicting results from trials. With the advancement of enzyme-producing technology, as well as a better understanding of the role of enzymes in animal nutrition, proteases and other enzymes (e.g., pentosanases, cellulase, and hemicellulases, as tested by Dierick, 1989) are likely to play a greater role in animal nutrition. As their costs come down, the Amino Acid Council foresees an increased use of synthetic amino acids as a method of reducing N excretion as well as improving animal performance and decreasing feeding costs.

8.1.1.2 Poultry Feeding Strategies

Poultry operators have traditionally employed feeding strategies that focus on promoting animal growth rates or maximizing egg production. Feed additives have also been used to prevent disease and enhance bone and tissue development. As noted in Chapter 4, productivity has increased dramatically over the past several decades. The decrease in the average whole-herd feed conversion ratio (pounds of feed per pound of live weight produced) has translated into reduced feed input per bird produced. Smaller feed requirements can mean decreased manure output, but, until recently, development of better feeding strategies and advances in genetics have not focused on manure quality or quantity generated. Environmental issues associated with animal waste runoff have compelled the poultry industry to look for improved methods of waste prevention and management, including feeding regimes that can reduce the nutrient content of manure.

Dietary strategies to reduce the amount of N and P in manure include developing more precise diets and improving the digestibility of feed ingredients through the use of enzyme additives and genetic enhancement of cereal grains.

Practice: Precision Nutrition for Poultry

Description: Precision nutrition entails formulating feed to meet more precisely the animals' nutritional requirements, causing more of the nutrients to be metabolized, thereby reducing the amount of nutrients excreted. For more precise feeding, it is imperative that both the nutritional requirements of the animal and the nutrient yield of the feed are fully understood. Greater understanding of poultry physiology has led to the development of computer growth models that take into account a variety of factors, including strain, sex, and age of bird, for use in implementing a nutritional program. By optimizing feeding regimes using simulation results, poultry operations can increase growth rates while reducing nutrient losses in manure.

Application and Performance: The use of improved feeds tailored to each phase of poultry growth has improved productivity significantly. Feed conversion ratios for broilers and turkeys have decreased steadily over the past several decades. Egg production productivity has also been boosted as operators have introduced improved nutrient-fortified feed.

Advantages and Limitations: Improved precision in feeding strategies offers numerous advantages, including reduction of nutrients in animal manure and better feed conversion rates. Improved formulations are also cost-effective and reduce the probability of wasteful overfeeding of poultry.

Operational Factors: Precision nutrition requires detailed knowledge of poultry nutritional requirements and maintenance of detailed records to ensure that dietary adjustments are performed in a timely manner to maximize growth potential.

Demonstration Status: The use of precise nutrient formulations has already generated large increases in productivity in the poultry sector. Many of the poultry operations are under contract and receive feedstuffs with precise formulations from the integrator. Ongoing research will likely continue to result in productivity improvements.

Practice: Use of Phytase as a Feed Supplement for Poultry

Description: Phosphorus, an essential element for poultry growth and health, is typically added to poultry feed mixes. However, because poultry are deficient in the enzyme phytase and cannot break down the protein phytate, much of the P contained in feed cannot be digested (Sohail and Roland, 1999). Because poultry cannot produce phytase, up to 75 percent of the P contained in feed grains is excreted in manure (NCSU, 1999).

One feeding strategy used by poultry operators to reduce P levels in manure is to add microbial phytase to the feed mix.[2] This enzyme is produced by a genetically modified fungus, *Aspergillus*

[2]As noted in Chapter 4, some experts believe phytase should not be provided to poults because of the enzyme's adverse effect on bone development in turkeys, while other experts believe it will enhance growth.

niger. The final enzyme product is usually available in two forms, a powder or a liquid (Miller, 1998). The phytase enzyme reduces P excretion by releasing the phytate-P contained in the cell walls of feed grains. The released P can then be absorbed by the bird's intestine and used for its nutrient value. A secondary beneficial effect of using phytase is that manure P content is further reduced because less inorganic P needs to be added to poultry diets (Edens and Simons, 1998).

Application and Performance: Phytase can be used to feed all poultry. Phosphorus reductions of 30 to 50 percent have been achieved by adding phytase to the feed mix while simultaneously decreasing the amount of inorganic P normally added (NCSU, 1999).

Advantages and Limitations: Addition of phytase to feed significantly reduces P levels in poultry manure. The high cost of phytase application equipment has discouraged more widespread use.

Operational Factors: Because phytase is heat-sensitive, it must be added to broiler and turkey feeds after the pelleting process (NCSU, 1999). The phytase is added by spraying it on the feed. This can result in uneven distribution and variable doses. Studies have shown that phytase efficacy is related to calcium, protein, and vitamin B levels in a complex manner. Further, phytase efficacy can be degraded by excess moisture, which can be a problem if mash (wet) feed is used for broilers (Miller, 1998). The shelf life of phytase is usually not a problem, because feed is typically consumed within 2 weeks or less at most operations.

Demonstration Status: Phytase is in use at many poultry operations. Application equipment for adding phytase to large volumes of feed is undergoing field testing.

Practice: Genetically Modified Feed for Poultry

Description: Using genetically modified animal feed offers poultry operators another way to reduce P levels in bird manure. In 1992, a research scientist at the USDA Agricultural Research Service developed a nonlethal corn mutant that stored most of its seed P as P rather than as phytate. The total P content in the mutant corn was the same as that found in conventional corn, except that there was a 60 percent reduction in phytic acid. The P released by the reduction in phytic acid P becomes available to the consuming animal as inorganic P (Iragavarapu, 1999).

Application and Performance: Genetically modified feed can be used for all poultry types. The potential for reducing P levels is quite large. One variety of corn with a high available P content has 35 percent of the P bound in the phytate form compared with 75 percent for normal corn (NCSU, 1999). Recent tests of a new hybrid corn, developed by USDA and the University of Delaware, demonstrated a 41 percent decrease in P levels in manure. Soluble P levels in waste decreased by 82 percent, compared with the amount produced by poultry fed a standard commercial diet (UD, 1999).

Advantages and Limitations: New hybrid varieties of grain can increase poultry utilization of plant P. Adding phytase to the modified feed further reduces manure P levels and can eliminate the need for nutrient supplements. The increased cost of feed and phytase additives might limit their use.

Operational Factors: The use of genetically modified feed would not differ from the use of conventional feed, although the increase in available nutrients in the feed would diminish the need for supplements.

Demonstration Status: Since its discovery in 1992, the mutant corn has been made available to commercial companies for further research, development, and commercialization of hybrid grains. Some hybrid varieties are currently used; others are in the research or demonstration stage. As more of these products are developed and prices are lowered, the use of hybrid grains combined with enzyme additives will likely increase.

Practice: Other Feeding Strategies to Reduce Nutrient Excretion for Poultry

Poultry operators use additives other than phytase to reduce manure nutrient content. These additives include synthetic amino acids and protease, and they are designed to facilitate more efficient digestion of N compounds and allow the use of smaller proportions of nutrients in feed while not adversely affecting animal growth rates and health. Researchers have also demonstrated that feed enzymes other than phytase can boost poultry performance and reduce manure production (Wyatt, 1995). Enzymes currently added to barley and wheat-based poultry feed in Britain and Europe include xylanases and proteases. Currently, the use of additives such as synthetic amino acids and enzymes could significantly increase feed costs. These costs, however could be expected to decrease over time as the technology matures and is more widely used by animal feed operators.

8.1.1.3 Dairy Feeding Strategies

Feeding strategies to reduce nutrient losses from dairy operations, primarily N and P, are focused on improving the efficiency with which dairy cows use feed nutrients. A more efficient use of nutrients for milk production and growth means that a smaller portion of feed nutrients ends up in manure. Elimination of dietary excesses reduces the amount of nutrients in manure and is perhaps the easiest way to reduce on-farm nutrient surpluses (Van Horn et al., 1996). Reducing dietary P is the primary practice being used; however, a number of related management strategies also reduce nutrient levels in the manure by increasing the efficiency with which dairy cows use feed nutrients. These strategies include measuring the urea content of milk, optimizing feed crop selection, and exposing cows to light for a longer period of the day.

Practice: Reducing Dietary Phosphorus (P) for Dairy Cattle

Description: Reducing the level of P in the diets of dairy cows is the primary and most important feeding strategy for reducing excess nutrients given (1) P's central role as a limiting nutrient in many soils, (2) evidence indicating that dairy operators, as a whole, are oversupplying P in dairy diets, and (3) the N-P imbalance in cow manure, which favors reductions of P to produce a more balanced fertilizer. Reducing the amount of P in dairy diets has also been shown to reduce production costs and increase overall profitability.

The latest edition of the National Research Council's (NRC) nutrient requirements for dairy cows recommends dietary P levels of 0.36 to 0.40 percent of dry matter for high-producing dairy cows in lactation (NRC, 1989). Dietary P in excess of these requirements has been shown to have no beneficial effect on animal health or production. Most excess P passes through the cows' systems and is excreted as manure, which is later applied to land. Rations, however, typically average 0.50 percent P or more (Knowlton and Kohn, 1999). Supplemental feeding of dicalcium phosphate–often the second most expensive component in dairy cow diets–is the usual practice by which a dairy cow's rations achieve this level. A number of studies have addressed the adequacy of current dietary P recommendations. These studies include Steevens et al., 1971; Tamminga, 1992; McClure, 1994; and Chase, 1998.

Application and Performance: This practice should be applicable to all dairy operations. The amount of manure P resulting from a given level of dietary P is estimated using the following equation (Van Horn, 1991):

$$\text{Manure P} = 9.6 + 0.472*(\text{Intake P}) + 0.00126*(\text{Intake P})^2 - 0.323*\text{Milk}$$

Manure and intake P are measured in grams, and milk production is measured in kilograms. Based on this formulation, assuming that each lactating cow produces 65 pounds of milk a day, Table 8-1 quantifies reductions in manure P resulting from reduced P intake (Keplinger, 1998). Four scenarios are considered: a 0.53 percent P diet, which is considered the baseline, and three reduced P diet scenarios. Comparing the 0.40 percent scenario against the baseline, P intake during lactation is reduced by 25 percent, while manure P is reduced by 29 percent. During the entire lactation period, manure P is reduced by 14.63 pounds per cow from the baseline level of 50.45 pounds per cow. For the entire year (lactation and nonlactation periods), manure P per cow is reduced by 27 percent.

Table 8-1. Per Cow Reductions in Manure P Resulting from Reduced P Intake During Lactation

Percentage of P in Diet	Daily		Manure P (lb)		Reduction from Baseline (0.53%)		
	P Intake (lb)	Manure P (lb)	During Lactation	Entire Year	Amount (lb)	During Lactation	Entire Year
0.53	0.265	0.165	50.5	55.1	0.0	0	0
0.49	0.245	0.150	45.8	50.4	4.7	9	8
0.46	0.230	0.139	42.4	47.0	8.1	16	15
0.43	0.215	0.128	39.1	43.7	11.4	23	21
0.40	0.200	0.117	35.8	40.4	14.6	29	27

Advantages and Limitations: Supplemental feeding of dicalcium phosphate to dairy cows represents a substantial expense to dairy farmers–the second most expensive nutrient in a herd's mixed ration (Stokes, 1999). The economic advantages of reducing supplemental P, based on a study on the Bosque River watershed of Texas (Keplinger, 1998), suggest that a dairy operator who adopts a 0.40 percent P diet compared with the baseline 0.53 percent diet would save $20.81 per cow annually. A survey of scientific literature on the subject reveals no adverse impact on either milk production or breeding from reducing dietary P to NRC-recommended levels.

Another advantage to producers is the impact of reduced manure P on land application practices. Many states incorporate a P trigger in manure application requirements. For example, in Texas, state regulation requires waste application at a P rate (versus an N rate) when extractable P in the soil of an application field reaches 200 parts per million (ppm). Applying manure with a lower P concentration would slow and possibly eliminate the buildup of P in application fields, thereby delaying or eliminating the need to acquire or transform more land into waste application fields. When manure is applied at a P rate, greater quantities can be applied if it contains a lower P concentration. Thus, application fields would require less chemical N, because manure with lower P concentrations is a more balanced fertilizer. In addition, reduced land requirements for waste application fields would represent substantial savings to dairy producers in cases in which a P application rate is followed.

Operational Factors: It is possible that factors such as climate, temperature, and humidity, as well as operation-specific factors, influence the effectiveness of steps taken to reduce dietary P; however, there are no published studies that address this issue. Dairy cows, for instance, are more prone to disease in moist climates and suffer heat stress in hot climates. Average milk production per cow varies greatly across geographic regions of the United States–averaging 21,476 pounds in Washington state versus only 11,921 pounds in Louisiana (USDA, 1999). Because dairy cow productivity and health are influenced by climate, it is likely that climate may also influence the effectiveness of nutrient reducing feeding strategies, particularly those which depend on productivity gains. The magnitude and even the direction of the influence of factors such as temperature, humidity, and the like on nutrient-reducing feeding strategies, however, have not been established.

Demonstration Status: Dairy rations typically average 0.50 percent P or more (Knowlton and Kohn, 1999), much higher than the NRC recommendation of 0.40 percent. A survey of milk producers in north Texas by a milk producers' organization indicated dietary P averaged 0.53 percent. A 1997 survey of professional animal nutritionists in the mid-south region (Sansinena et al., 1999), indicates nutritionists' recommendations of dietary P averaged 0.52 percent, or 30 percent higher than the high end of NRC's current recommendation. Survey respondents cited several reasons for recommending final ration P in excess of NRC standards: "Almost half of the respondents (15 of 31) expressed a belief that lactating cows require more P than suggested by the NRC" (Sansinena et al., 1999). The next most prevalent reason given was that a safety margin was required. Justifications for the safety margin included a lack of confidence in published ingredient P values and concern for variable P bioavailability in feed ingredients. Professional opinion also suggests that dietary P in dairy cow diets averages around 0.52 percent throughout the nation, although this percentage may be declining. Because of the heightened awareness of both the environmental benefits and the cost savings attainable by reducing P in dairy cow diets, some operators have adopted the NRC recommendation. Recent articles in dairy trade magazines have recommended adoption of the NRC standard for both environmental and economic benefits.

Practice: Milk Urea N Testing for Dairy Cattle

Description: There have been significant developments recently in the use of milk urea N (MUN) as a method for testing and fine-tuning dairy cow diets for protein feeding. Measured MUN concentrations are used as a proxy for the nutritional well-being of the cow.

Research has shown that mean MUN concentration levels from a group of cows should fall into specific ranges. By comparing the results of MUN tests with these ranges, the tests can be used as a monitoring tool to evaluate a herd's protein nutritional status. For cows fed at optimal dry matter intake, expected mean values of MUN concentrations range from 10 to 14 milligrams per deciliter (mg/dL) (Ferguson, 1999; Jonker et al., 1998). Field studies of MUN levels of dairy herds in Pennsylvania (using a very large sample–312,005 samples) have reported average MUN concentrations of 14 mg/dL (Ferguson, 1999). Implicit in this level is that even allowing for the inherent large variability of MUN testing, the diets of some herds contain excess MUN levels that have no economic value; this also suggests that N in manure can be reduced by reducing excess N in dairy diets. The importance of reducing dietary protein levels is highlighted in a study (Van Horn, 1999) that estimates that for every 1 percent reduction in dietary protein, excretion of N may be reduced by 8 percent.

Application and Performance: This practice should be applicable to all dairy operations. The elimination of excess dietary protein with the use of the MUN test to evaluate protein levels in dairy cow feeds could reduce N levels in manure by 6 percent (Kohn, 1999). In addition, further methods to improve N utilization in dairy cows and raise the efficiency of feed delivery may be revealed by MUN testing.

Advantages and Limitations: Through MUN testing and the evaluation of other variables, farmers can identify which cows are eating too much protein, and fine-tune diets, thereby reducing N output in manure. Advantages of MUN testing are the possibilities of reducing ration costs by eliminating excess protein and improving the efficiency of feed delivery (Kohn, 1999). A disadvantage of animal group feeding strategies is that they become more difficult to set up and manage as group size decreases. The cost-effectiveness of custom feeding individual cows is as yet unproven.

Operational Factors: The large variability within and between herds and breeds of cows limits the usefulness of MUN testing, but it does not reduce the test's important role as a monitor of ration formulation.

Demonstration Status: This practice is primarily at the research stage and has not become widespread.

Practice: Diet Formulation Strategies for Dairy Cows

Description: Diet formulation strategies have received new examination. Alternative diet formulations to the NRC recommendations–notably the Cornell Net Carbohydrate and Protein model (CNCPS) (Sniffen et al., 1992)–that are more complicated than the NRC recommendations have been developed and they suggest feeding about 15 percent less protein to a herd at the same level of production for certain conditions (Kohn, 1996). Evaluations of the CNSPS model's performance have been mixed, and further research is needed. Thus, the CNCPS is not currently recommended for routine diet formulation.

Theoretically, protected amino acid supplements have the potential to be part of an important strategy in increasing the efficiency of protein use by dairy cows, thereby reducing N losses. If amino acid supplements can be made effectively for dairy cows (avoiding rumen-associated problems), they could replace large portions of a dairy cow's protein intake. In theory, protected amino acid supplements could significantly reduce N intake and hence N levels in manure. In practice, the benefits of using protected amino acid supplements may not be as dramatic because the need to balance diet formulations may create limitations.

Application and Performance: This practice should be applicable to all dairy operations. Some evaluation of the alternative diet formulation suggested by the CNCPS implies a significant increase in milk production (from 24,100 pounds/cow per year to more than 26,000 pounds/cow per year) and a large reduction in N excretion (of about one-third) (Fox et al., 1995). More recent evaluations using two different large data sets (Kalscheur et al., 1997; Kohn et al., 1998) present mixed results, with the CNCPS performing better in some aspects and the NRC recommendations in others. Thus, results of the CNCPS evaluation should be considered preliminary. In theory, the use of protected amino acid supplements has great potential to improve nutrient efficiency. A typical lactating cow is assumed to require 1.1 pounds per day of N intake; by successfully substituting protected methionine and lysine for feed protein, this N intake and resulting manure N could be dramatically reduced (Dinn et al., 1996), but this research is preliminary.

Advantages and Limitations: Alternative diet formulations could improve nutrient efficiency. Information on limitations is unknown at this time, and EPA is continuing research in this area.

Operational Factors: The cost of preparing and storing multiple feed stuffs limits the use of this practice to the number of diets that the operator feels justifies the additional expense. Additional research on this practice is needed.

Demonstration Status: This practice is primarily at the research stage and has not become widespread.

Practice: Animal Feed Grouping for Dairy Cows

Description: Grouping strategies offer another method of realizing gains in nutrient efficiency. When grouping does not occur and the whole herd receives the same diet, cows may receive suboptimal diets and nutrient export to manure may be greater. Using grouping strategies to their greatest effect to improve nutrient efficiency would entail individualized diets. Feeding strategies already reviewed, such as the MUN concentration test, can be used in conjunction with grouping strategies or individual diets.

Application and Performance: This practice should be applicable to all dairy operations. Grouping strategies have been shown to reduce nutrient intakes and manure nutrients. When all the lactating cows are fed together according to current recommendations, they consume 7 percent more N and P, and 10 percent more nutrients are excreted in manure, compared with the individualized feeding strategy. Half of the gains of individualized diets could be achieved with two groups (Dunlap et al., 1997).

Advantages and Limitations: This practice could improve nutrient efficiency. Information on limitations is unknown at this time, and EPA is continuing research in this area.

Operational Factors: As noted under diet formulation strategies, the cost of preparing and storing multiple feedstuffs limits the use of this practice to the number of diets that the operator feels justifies the additional expense. Additional management input is also required in separating the animals into groups.

Demonstration Status: Dairy operations currently employ a range of grouping strategies (from no grouping to individual diets) to improve the efficiency of feed nutrients.

Practice: Optimizing Crop Selection

Description: Optimizing crop selection is another potential strategy for reducing nutrient losses in combination with dairy diets to meet annualized herd feed requirements with minimal nutrient losses. In whole-farm simulation of various crop strategies (corn silage, alfalfa hay, and a 50:50 mixture) the 50:50 mixture was judged to have performed best (when evaluated by N losses per unit of N in milk or meat) (Kohn et al., 1998). Converting dairy operations from confined to pasture operations is also considered a strategy for reducing nutrient loss on a per cow or operation basis. Kohn's model, however, found that a strategy of grazing versus confinement for lactating cows produced higher N loss per unit of milk produced because the decline in milk production was greater than the decline in manure nutrients (Kohn et al., 1998).

Application and Performance: This practice should be possible at operations that have sufficient land. In simulation of crop selection strategies involving whole-farm effects, mixed alfalfa hay and corn silage (50:50) was judged the best strategy for minimizing nutrient flows from the farm. N losses were minimized to 2.9 units for every unit of N in meat or milk, compared with a loss of

3.5 units in the corn-based strategy, a 21 percent reduction (Kohn, 1999). Phosphorus accumulations did not tend to vary among the different strategies.

Advantages and Limitations: Optimal crop selection based on whole-farm effects suggests that the strategy that was most nutrient efficient in terms of N loss per unit of N in meat and milk is also the strategy that gains the most productivity from N; this strategy might, therefore, be the most cost-effective (Kohn et al., 1998). A grazing (versus confinement) strategy may or may not be cost-effective depending on the structure of individual dairy operations.

Operational Factors: Unknown at this time.

Demonstration Status: This practice is primarily at the research stage and has not come into widespread use.

Practice: Increasing Productivity

Description: The literature suggests that there are several feeding strategies that focus on increasing productivity as a route to nutrient efficiency. While the focus is on increased milk production, an important associated benefit of these strategies is that they result in greater milk production per unit of nutrient excreted. One approach involves exposing dairy cows to light for longer daily periods of the day through the use of artificial lighting. A longer daily photoperiod (18 hours light/6 hours dark) increases milk yields relative to those of cows exposed to the natural photoperiod (Dahl et al., 1996).

Application and Performance: This practice should be applicable at all operations that confine their animals. The artificial lighting technology to extend the daily photoperiod of dairy cows to 18 hours a day has been shown to be effective in increasing the nutrient efficiency of the farm. For an increase in milk production of 8 percent the herd’s feed nutrients would be required to increase by only 4.1 percent, and N and P excretions would rise by only 2.8 percent when compared versus a typical herd without artificial lighting (Dahl et al., 1996, 1998).

Advantages and Limitations: The artificial lighting technology is expected to be cost-effective. It is estimated that the initial investment in lighting can be recouped within 6 months. One observed advantage of milking three times a day rather than twice a day is that it reduces stress on the herd (Erdman and Varner, 1995). Because of the increased labor involved, the economic advantage of milking three times a day is variable and dependent on the individual farm (Culotta and Schmidt, 1988).

Operational Factors: To use this practice many dairy operations would need to install and operate additional lights.

Demonstration Status: This practice is primarily at the research stage and has not come into widespread use.

8.1.2 Reduced Water Use and Water Content of Waste

This section presents practices that reduce the water content in the waste stream. The production of a drier waste can be accomplished by three methods: (1) handling the waste in a dry form, (2) reducing the use of water at the AFO, or (3) separating the solid fraction of the waste from the liquid fraction. Most poultry operations currently handle their waste in a dry form, and this section does not apply to them.

Practice: Dry Scrape Systems and the Retrofit of Wet Flush Systems

Description: Scraper systems are a means of mechanically removing manure, and they can be used to push manure through collection gutters and alleys similar to those used in flush systems. For best results, scrapers should have a minimum depth of 4 inches in open gutters and 12 to 24 inches in underslat gutters (MWPS, 1993).

Retrofitting a wet flush system with a dry scrape system involves reconstructing the existing manure handling equipment within a livestock housing structure. A scraper blade replaces flowing water as the mechanism for removing manure from the floor of the structure.

In flush systems, large volumes of water flow down a sloped surface, scour manure from the concrete, and carry it to a manure storage facility. There are three basic types of flush systems: underslat gutters, narrow-open gutters, and wide-open gutters or alleys. Underslat gutters are used primarily in beef confinement buildings and swine facilities in which animals are housed on slats to prevent disease transmission as a result of animals coming into contact with feces. Narrow-open gutters are typically less than 4 feet wide and are used predominately in hog finishing buildings. Wide-open gutters or alleys are most often seen in dairy freestall barns, holding pens, and milking parlors. The water used in a flush system can be either fresh or recycled from a lagoon or holding basin (Fulhage et al., 1993; MWPS, 1993).

Application and Performance: Removing manure with a scraper is appropriate for semisolid and slurry manure, as well as drier solid manure. The flush system is an appropriate means of removal for both semisolid and slurry manure. Retrofitting a flush system to a scraper system appears to be most feasible in underslat gutters and wide alleys. A major concern to be addressed is the discharge area of the scraper. Existing collection gutters, pumps, and pipes used in a flush system will likely be inadequate for handling the undiluted manure product.

Replacing a flush system with a dry scrape system dramatically reduces the amount of water used in manure handling and also reduces the tonnage of manure by decreasing dilution with water. There are several options for storing manure from a scrape system, including prefabricated or formed storage tanks, from which contaminants are less likely to seep.

Retrofitting a flush system with a scrape system will not treat or reduce pathogens, nutrients, metals, solids, growth hormones, or antibiotics. The concentrations of these components will actually increase with the decrease in water dilution.

Advantages and Limitations: In a building with a scrape system, the manure removed from the livestock housing area is in slurry or semisolid form (depending on species) and no water need be added. Compared with a wet flush system, the resulting manure product has a greater nutrient density and increased potential for further treatment and transportation to an area where the manure product is needed as a fertilizer. A large lagoon is usually necessary for storing and treating flush waste and water; handling manure in a drier form, on the other hand, significantly decreases the volume and tonnage of the final organic product. Although this is an important advantage when it is necessary to transport manure to areas where there is an increase in available land base, it can be a disadvantage in that an irrigation system would not be able to transport the thicker slurry that results from the use of a scrape system.

The greater volume of contaminated water and waste created in a flush system generally dictates that storage in a large lagoon is required. There are more options for storing manure removed with a scrape system. These storage alternatives may be more suited to practices that reduce odors (e.g., storage tank covers), more appropriate for areas with karst terrain or high water tables, and more aesthetically desirable.

The drawbacks of using a scrape system rather than a flush system include an increased labor requirement because more mechanical components need maintenance, a higher capital outlay for installation, an increased requirement for ventilation, and less cleanliness. Using a flush system to remove manure results in a cleaner and drier surface with less residual manure and less in-house odor, thus creating a better environment for livestock. Furthermore, alleys can be flushed without restricting animal access. As mentioned above, the discharge area of the scraper is a concern. Existing pumps and pipes may be unable to handle the undiluted manure. Moreover, a completely new manure storage structure might be needed (Vanderholm and Melvin, 1990).

Operational Factors: Both the scrape and flush systems have disadvantages when used in open barns during winter months, but a scrape system is more likely to function properly at lower temperatures.

If alleys are straight with continuous curbs, alley scrapers can usually be installed, but alley lengths of up to 400 feet in dairy freestall barns may make installation of scraping systems impractical. Scrapers work best when they can be installed in pairs of alleys so the chain or cable can serve each and form a loop. It might be necessary to cut a grove into the concrete alley for the chain or cable to travel in. The decision of whether to cut a channel or let the chain rest on the pavement is best left to the manufacturer. It should be noted that maintenance requirements associated with the chain and cable will likely be high because of corrosion caused by continuous contact with manure. Hydraulic scrape units that operate on a bar and ratcheting blade are also available (Graves, 2000).

Demonstration Status: The use of scrape systems and the practice of retrofitting a flush system are not common in the livestock industry. Inquiries regarding the use of this practice have been made to manure management specialists, agricultural engineers, and manufacturers of scraper systems. Very few professionals indicated that they had any experience in the area or were aware of the practice being used. Those professionals willing to comment on the implications of retrofitting seemed to believe that it would be most feasible and advantageous on dairies (Graves, 2000; Jones, 2000; Lorimor, 2000; Shih, 2000).

Practice: Gravity Separation of Solids

Description: Gravity settling, separation, or sedimentation is a simple means of removing solids from liquid or slurry manure by taking advantage of gravitational forces. The engineering definition of a settling or sedimentation tank is any structure that is designed to retain process wastewater at a horizontal flow rate less than the vertical velocity (settling rate) of the target particles.

In agricultural applications, gravity settling is a primary clarification step to recover solids at a desired location where they can be managed easily, thereby preventing those solids from accumulating in a downstream structure where they would be difficult to manage. A wide range of gravity separation practices are used in agriculture, including sand and rock traps, picket dams, and gravity settling basins designed to retain 1 to 12 months' accumulation of solids.

Settling tanks can be cylindrical, rectangular, or square. Agricultural settling tanks have been made with wood, metal, concrete, and combinations of materials. Some are earthen structures. In agriculture, gravity separation is sometimes accomplished without a recognizable structure, including techniques such as a change in slope that allows particles to settle when the liquid velocity drops.

The critical design factor in sedimentation tanks is surface overflow rate, which is directly related to the settling velocity of particles in the wastewater (Loehr, 1977). Faster settling velocities allow for increased surface overflow rates, while slower settling velocities require decreased overflow rates to remove settleable particles. In "ideal" settling, the settling velocity (Vs) of a particle is equal to that particle's horizontal velocity (VH), where

$$VH = Q/DW$$

Q is the flow through the tank
D is the tank depth
W is the tank width

The American Society of Agricultural Engineers (ASAE, 1998) has defined several types of gravity separation techniques:

- Settling Channels: A continuous separation structure in which settling occurs over a defined distance in a relatively slow-moving manure flow. Baffles and porous dams may be used to aid separation by further slowing manure flow rates. Solids are removed mechanically once liquids are fully drained away.

- Settling Tank: A relatively short-term separation structure, smaller in size than a settling basin. The liquid is allowed to fully drain away for solids removal by mechanical means.
- Settling Basin: A relatively long-term separation structure, larger in size than a settling tank. Solids are collected by mechanical means once the liquids evaporate or have been drained away.

Application and Performance: Gravity separation is relatively common in the United States. Separation is used to reduce clogging of downstream treatment or handling facilities. Reduced clogging means improved lagoon function and better wastewater treatment. Most beef feedlots in the Midwest and Great Plains use gravity separation ponds to collect solids from rainfall runoff, thus improving the function of runoff collection ponds. Gravity separation basins are used across the country on hog farms to reduce solids accumulation in tanks or lagoons they discharge to. It is likely that more dairies with flush systems use gravity settling for solids recovery rather than mechanical separators to preserve lagoon capacity.

Table 8-2 shows the substantial range of treatment efficiencies for gravity settling of manure. The performance of a gravity separation basin depends on the design goal and ability of the operator to maintain the system in design condition. Performance will vary with animal type, animal feed, dilution water, flow rate, percent of capacity already filled with solids, temperature, and biological activity. The data ranges in Table 8-2 may be explained in part by the time span separating the studies. More recent studies show reduced solids recovery from swine manure. This may be partly due to the fact that animal diets have changed over the years, with feed more digestible and more finely ground these days. Further, feed is ground to different particle sizes that have different settling characteristics, thus potentially affecting separation basin performance. In addition, ruminants are fed materials that have different settling characteristics than those fed to nonruminants. Process variables such as overflow velocities are seldom reported in the literature, but they are important determinants of separation basin performance. Extra water from processing or precipitation and already settled material will increase the flow rate across a settling basin, reducing settling time and solids capture. In many agricultural settling basins, biological activity resuspends some settled materials which then pass through the separator. At best, one can conclude from these data that gravity settling can recover in swine wastes a larger percentage of total solids (TS), volatile solids (VS), and total nitrogen (TN) than another separation technique reviewed for the practice, mechanical solid-liquid separation, that follows in this chapter.

Table 8-2. Performance of Gravity Separation Techniques

Recovered in Separated Solids, Percent						
	TS	**VS**	**TN**	**P_2O_5**	**K**	**COD**
Swine (Moser et al., 1999)	39-65	45-65	23-50	17-50	16-28	25-55
Beef (Edwards et al.,1985; Lorimore et al., 1995) and Dairy (Barker and Young, 1985)	50-64	NA	32-84	20-80	18-34	NA

TS=Total solids; VS=volatile solids; TN=total nitrogen; P_2O_5=pyrophosphate; K=potassium, COD=chemical oxygen demand.

Because of short return times, pathogen reduction through settling is minimal; however, settling might reduce worm egg counts. No information is available on growth hormones in manure or on how settling might affect growth hormones that may be found in manure. Degradation of antibiotics usually hinders their detection in manure, and no information is available on the effect of settling on antibiotics in manure.

Taiganides (1972) measured 80 to 90 percent recovery of copper, iron, zinc, and phosphorus with settled swine solids. The study also reported that 60 to 75 percent of the sodium, potassium, and magnesium settled and was recovered.

Advantages and Limitations: The main advantage of gravity settling is the relatively low cost to remove solids from the waste stream. Recovering solids prevents the buildup of those solids in ditches, pipelines, tanks, ponds, and lagoons. Dairy solids consist mostly of fiber and can be composted and recycled as cow bedding material, or they can be composted and sold as a soil amendment. Swine solids are finely textured, hard to compost aerobically, and rapidly degraded to odoriferous material if handled improperly. Beef solids collected from lot runoff can become odoriferous if left in a separation basin, but they can be composted for sale to crop farms, nurseries, or soil products companies.

Collected solids are a more concentrated source of nutrients than the separated liquid, resulting in decreased hauling costs per ton of nutrient. The separated liquid has a reduced nutrient content and can be applied to a smaller acreage than the original material.

Disadvantages of solids separation include the need to clean out the separator, the potential odor emitted from the basin, the odor produced by solids removed from the basin, and attraction of insects and rodents to the separated solids. Additional costs are incurred when the solids and liquids from pig manure are managed separately.

Operational Factors: Solids separators do not function if they are frozen or experience horizontal flow rates higher than the solids settling rate. Solids tend to separate better at warmer temperatures.

Demonstration Status: Gravity separation is the most common solids separation technique in use in the United States.

Practice: Mechanical Solid-Liquid Separation

Description: Solids-liquid separation is used to recover solids prior to their entry into downstream liquid manure facilities. Solids recovery reduces organic loading and potential accumulation of solids and improves the pumping characteristics of animal manure. Mechanical separation equipment is used to reduce the space required for separation, to produce a consistent separated solid product amenable to daily handling, to produce a liquid product that is easily pumped for spreading, or to recover specific particle sizes for other uses such as bedding.

Mechanical separation equipment is readily available for animal wastes. Mechanical separators include static and vibrating screens, screw press separators, rotary strainers, vacuum filters, centrifugal separators, belt filter presses, and brushed screen/roller presses. Static screens are the most popular mechanical separators because they are inexpensive to buy, install, and operate. All other mechanical separation techniques are less common.

Static screens are usually mounted above grade on a stand to allow solids accumulation beneath. Barn effluent is typically pumped up to the screen, where the liquids pass through while the solids collect on the screen surface. Screens are typically inclined, causing accumulating solids to slide down from the screen toward collection. There are multiple configurations with different screen designs, screen materials, screen opening spacing, influent distribution, post-use washdown, and additional pressing of separated solids.

Vibrating screens are flat or funnel-shaped screens supported on springs and oscillated by an eccentric drive. The vibrations cause the solids to move from the screen for collection.

With screw presses, manure is pumped to the base of a turning open-flight auger that goes through a screen tube made of welded wire, wedge wire, perforated metal, or woven screen material. Solids collect on the screen, forming a matrix as the auger advances them. A tensioned opening restricts the flow of materials up the auger and out from the tube. The retained material is squeezed by the auger against the screen tube and tensioned opening until it overcomes the tension and exits. The matrix acts as a filter allowing the collection of finer particles than are collected by other types of screens. The auger wrings liquid from the separated solids by forcing material against the plug of material held by the tensioned opening and screen tube.

A rotary strainer is a slowly rotating, perforated cylinder mounted horizontally. Waste flows by gravity onto the cylinder at one end, where solids are scraped from the cylinder surface and moved to the exit end. Liquids pass through the screen for collection and removal (ASAE, 1998). Vacuum filters are horizontally mounted, rotating perforated cylinders with a cloth fiber cover. A vacuum is used to draw liquids from the wastewater. Wastewater flows onto the cylinder surface, liquids pass through the screen, and solids are scraped from the cloth at a separation point (ASAE, 1998).

A centrifugal separator, or centrifuge, is a rapidly rotating device that uses centrifugal force to separate manure liquids from solids. One type, a relatively low-speed design, uses a cylindrical or conical screen that can be installed vertically or horizontally. Manure is fed into one end, and solids are then contained by the screen, scraped from it, and then discharged from the opposite end. The liquid passes through the screen. A second type, a higher-speed decanter, uses a conical bowl in which centrifugal force causes the denser solids to migrate to the bowl exterior where they are collected. Less dense liquids are forced to the center for collection ASAE, 1998).

A belt press is a roller and belt device in which two concentrically running belts are used to squeeze the manure as it is deposited between the belts. The belts pass over a series of spring-loaded rollers where liquids are squeezed out or through the belt, and remaining solids are scraped off at a belt separation point (ASAE, 1998).

Brush screen presses are rectangular containers with four vertical sides and a bottom consisting of two half-cylindrical screens lying side by side to provide two stages of separation. Within each screen rotates a multiple-brush and roller assembly that sweeps the manure across the screen. Manure is pumped into one side of the separator. The liquids are forced through the screen by the brush/roller while the solids are retained by the screen and pushed from the separator on the opposite side (ASAE, 1998).

Application and Performance: Mechanical separation is used to reduce clogging of downstream treatment or handling facilities. The use of this practice to preserve lagoon capacity by separating solids is relatively common among dairies using flush manure collection. Reduced clogging means improved lagoon function and better wastewater treatment. Mechanical separation of solids from manure, however, is relatively rare because of the added costs.

Table 8-3 shows the range of treatment efficiencies for the mechanical separation of manure. These systems do not perform as well as gravity separation, but they produce a more consistent product delivered as a solid for easy collection. Most manufacturers and owners are less concerned about the percentage of recovery or the properties of the recovered material than they are about the total solids concentration of the separated solids. Performance will vary with animal type, animal feed, dilution water, flow rate, percent of capacity already full of solids, temperature, and biological activity. In general, pig manure has finer solids than cow manure, and recovery of pig manure constituents is in the low end of the ranges in Table 8-3, whereas cow manure constituent recovery is in the upper portion of the range.

Table 8-3. Summary of Expected Performance of Mechanical Separation Equipment

Separation Technique	Recovered in Separated Solids, Percent				
	TS	**VS**	**TN**	**P_2O_5**	**COD**
Stationary screen	10-25	10-25	5-15	10-20	5-20
Vibrating screen	10-20	10-20	10-20	8-15	10-20
Screw press	20-30	20-30	10-20	20-30	20-40
Centrifuge	40-60	40-60	20-30	25-70	30-70
Roller drum	20-30	20-30	10-20	10-15	10-25
Belt press/screen	40-60	40-60	30-35	15-20	30-40

Source: Moser et al., 1999.

Pathogen reduction through mechanical separation is negligible. No information is available on growth hormones in manure or on the effect of mechanical separation on growth hormones that may be found in manure. Degradation of antibiotics usually hinders their detection in manure, and no information is available on the effect of mechanical separation on antibiotics in manure.

No significant information was found on the effect of mechanical separation on heavy metal content of either the solids or the liquids. Work in gravity separation suggests that metals are associated with fine particle sizes that would pass with the liquids through mechanical separation.

Static (stationary) screens are most commonly used for separating solids from dilute solutions with solids concentrations of 5 percent or less. The more dilute the solution, the more likely that discrete particles will be collected on the screen because there is less particle-versus-particle interference. The dilute solution also washes finer particles from larger, retained particles and through the screen.

Vibrating screens are used for separating solids from dilute solutions with solids concentrations of 3 percent or less. Vibrating screens will generally process more flow per unit of surface area than static screens because the vibrating motion moves the solids from the screen. Vibrating screens are more sensitive than static screens to variations in solids content and wastewater flow (Loehr, 1977).

Static screens and vibrating screens usually collect 10 to 15 percent of the total solids from manure. An owner generally selects a screen that will not easily clog, or blind (i.e. one with larger screen spacing), instead of choosing an optimized screen and feed pump to avoid both screen blinding, when the slurry thickness changes, and the creation of a soggy solids pile.

Screw presses can handle thicker materials than most separators, and are used to separate manures that have between 0.5 and 12 percent total solids. Chastain et al. (1998) noted, however, that a screw press did not separate well unless the total solids content of the waste was above 5 percent. Because screw presses first allow the solids to form a matrix and catch fine solids, the percent solids recovery is generally greater than for other solids separators. The screw press is designed to produce drier solids (up to 35 percent). Solids recovery is dependent on the screen tube openings and the setting of the retaining tension. The higher the tension is set, the harder the screw squeezes the separated material, and the more solids are forced out through the screen. Tighter settings for drier solids may significantly affect the useful life of both auger and screen.

Belt presses are expensive, require a trained operator, operate best with chemical addition, and cannot process rocks and barn parts found in manure. With or without chemical addition, however, they can do a good job of separating 40 percent or more of the total solids. Nevertheless, the cost of belt presses, plus the extremely high cost of maintenance and the need for continuous operator presence, makes their use problematic.

The primary advantage of centrifugation over other separators appears to be in the reduction of total P, but centrifugation is also clearly more efficient than screening for removal of all constituents. Managed by trained operators, centrifuges will recover over 60 percent of the total solids. Nevertheless, the large capital cost, the need for trained operators, and the high maintenance costs have made this equipment impractical for farm use.

Advantages and Limitations: The main advantages of mechanical separation are the consistent level of solids removal from the waste stream and the delivery of separated solids at a recovery location. Recovering solids prevents the buildup of those solids in ditches, pipelines, tanks, ponds, and lagoons. Dairy solids, which consist mostly of fiber, can be composted and recycled as cow bedding material. Dairy solids have also been composted and sold as a soil amendment. Swine solids are finely textured, hard to compost aerobically, and rapidly degraded to odoriferous material if handled improperly.

Collected solids are a more concentrated source of nutrients than the separated liquid, resulting in decreased hauling costs per ton of nutrient. The separated liquid has a reduced nutrient content and can be applied to a smaller acreage than the original material.

Disadvantages of solids separation include operation and maintenance requirements, potential odor production from collection basins and separated solids, and attraction of insects and rodents to the separated solids. Additional costs are incurred when the solids and liquids in swine manure are managed separately.

Operational Factors: Mechanical solids separators do not function if the manure or the face of the machine is frozen, but they can operate under a wide variety of other conditions.

Demonstration Status: Mechanical solids separation is being used at thousands of dairies and perhaps several hundred hog farms. Regarding specific technologies, static screens are most commonly used, whereas vibrating screens and rotary strainers are seldom used on farms today. Vacuum filters are infrequently used on farms because inorganic materials such as rocks and metal bits tend to rip the filter fabric. High capital and operating costs have limited farm use of centrifugal separators. Brush screen presses may occasionally be found on farms, but the low throughput rate has limited its use. Screw presses are in use at a few hundred dairy farms, but at a very limited number of swine farms in the United States.

Practice: Two-Story Hog Buildings

Description: The two-story, High-Rise™ hog building design (Menke et al., 1996) integrates manure collection, storage, and treatment in a single, enclosed facility. The building is designed to pen approximately 1,000 head of hogs on the second floor of a two-story building, with a dry manure collection and storage system on the first (ground) level. The second floor features solid side walls and totally slatted floors. The manure falls through the slats to the first floor area, which is covered with 12 to 18 inches of a dry bulking agent such as sawdust, oat or wheat straw, corn fodder, or shredded newspaper. The design includes sliding doors on the ground level to allow for tractor and loader access.

The building's unique, two-fold ventilation system maintains superior air quality in the swine holding area and dries the manure in the storage area (Figure 8-1). Clean air is pulled from the ceiling through continuous baffle inlets and is directed down over the swine vertically (with no horizontal, pig-to-pig air movement). Air exits the swine holding area through the floor slats and is pulled horizontally to the outside of the first-floor pit area by 14 computer-controlled

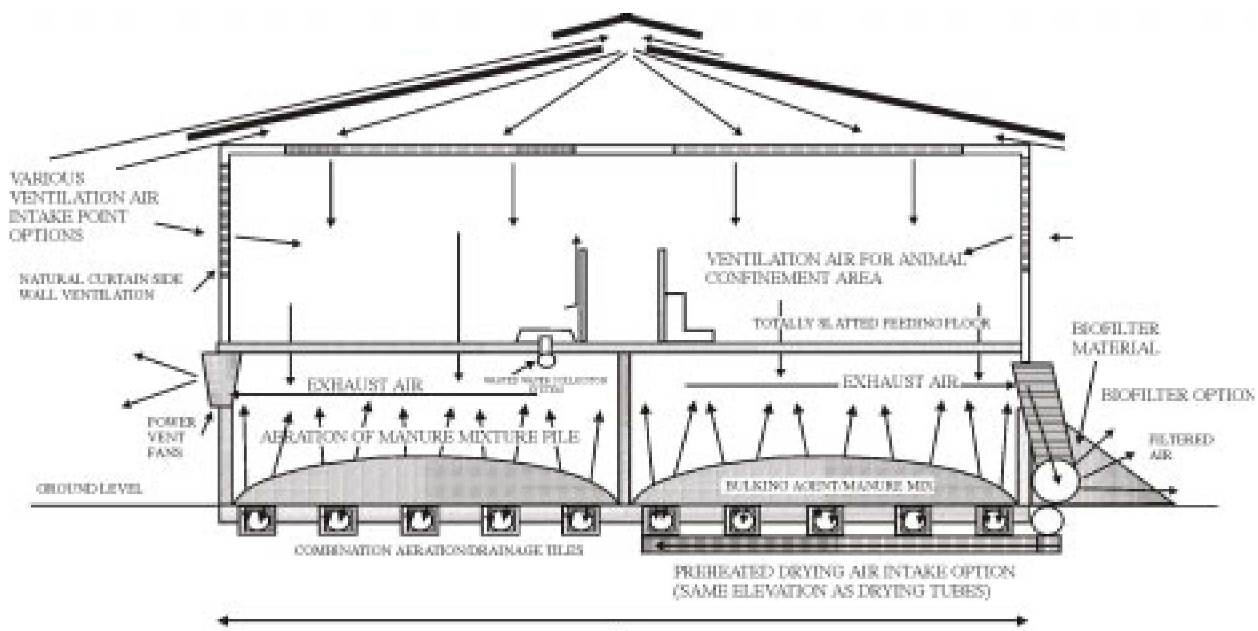


Figure 8-1. High-Rise Hog Building

ventilation fans mounted on the pit walls. This system prevents air from the manure pit from rising to the animal area. The second part of the ventilation system involves pumping air through the manure by floor aeration. PVC pipes with approximately 3,200 3/8-inch holes are installed before the concrete floor is poured. Two large fans on either end of the building force air through perforations in the concrete and into the composting mixture on the ground floor.

Application and Performance: Management practices, swine care, and feeding are much the same as with conventional confinement. The High Rise facility is distinctive because it incorporates dry manure handling and storage into a traditional confinement production scenario. The system dries the manure mixture and maintains an aerobic environment to facilitate the composting process. Drying and homogeneity of the mixture are also facilitated by mixing with a tractor and loader or skid-steer loader. Frequency of mixing varies from once per production cycle to biweekly, depending on the saturation of bedding. The semicomposted bedding mixture is removed once per year and can be further composted, land applied, or sold. A typical 1,000-head unit produces 500 tons of semicomposted product per year.

The High Rise facility is best suited for areas where there is limited local land base for manure application; sandy, porous soils; limited water supply; or an existing market for compost or partially composted material.

The aerobic decomposition that occurs within the pit results in a significant volume reduction in the manure. In fact, initial trials have shown that loading the pit with 12 to 18 inches (approximately 11 tons) of bedding results in only 2.5 to 3 feet of manure to be removed at the end of 1 year. This is estimated as a 22 percent reduction in manure volume and a 66 percent reduction in manure tonnage (Envirologic, 1999; Mescher, 1999). These figures are based on a final product with 63 percent moisture. When compared with liquid/slurry hog manure that is approximately 90 percent moisture, this presents a great advantage in areas where there is a lack of local land base and manure must be transported more than 3 to 4 miles to alternative areas for application. Manure with 63 percent moisture is considered to be in dry form and can be hauled in a semi truck with an open trailer rather than in a liquid tanker pulled by a tractor.

The aerobic decomposition and drying that reduce the volume and tonnage of the final organic product do not result in a reduction of the overall nutrient content. In fact, with the exception of N and sulfur (some of which volatilizes) nutrients will be more concentrated in the resulting semicomposted product. The semicomposted manure is four times more concentrated than liquid manure from treatment lagoons.

The High-Rise facility incorporates both manure treatment and storage in a completely aboveground handling system. In addition, the ground-level manure storage area is enclosed in poured concrete. This is especially advantageous in sites with porous soils or fragmented bedrock. Such locations are unfit or, at the least, potentially dangerous areas for earthen basin and lagoon construction due to concerns regarding ground water contamination. Furthermore, belowground concrete pits have an increased potential for ground water pollution if leaking occurs in a region with porous soils or fragmented bedrock. The aboveground concrete manure storage of the High-Rise building allows visual monitoring for leakage.

Information is not currently available on the reduction of pathogens, heavy metals, growth hormones, or antibiotics in the manure product as it is removed from the High-Rise facility. However, research on some of these topics is currently underway. Based on the composition of the product, temperature readings within the manure pack, and knowledge of the composting process, several speculations can be made. Destruction of pathogens in the composting process is a result of time and temperature. The higher the temperature within the manure pack, the less time it takes to eliminate pathogens. In general, the temperature within the manure pack needs to exceed the body temperature of the animal and pathogen destruction is most effective at 120 °F or higher. Temperature readings taken in the manure pack in the High-Rise facility ranged from only 45 to 78 °F (Keener, 1999). The predominant reason for the manure packs not reaching a high enough temperature is the continuous aeration provided. It is unlikely that there is a significant reduction of pathogens at this temperature. There may be some decrease in pathogen numbers due to the length of time (up to one year) the manure pack remains in the building. Further composting of the manure pack once it is removed from the High-Rise structure would allow the product to reach temperatures high enough for complete pathogen destruction.

The composting process has no effect on the quantity of heavy metals in the manure. Further, because of the decrease in volume and tonnage of the manure, heavy metals will be more concentrated. Composting does, however, influence the bioavailability of the metals, causing them to be less mobile. The extent to which the mobility of heavy metals is decreased in the semicomposted product removed from the High-Rise facility is unknown.

The degree to which growth hormones and antibiotics degrade during the composting process is unknown and is not widely studied.

Designers of the High-Rise facility claim a savings of 1.8 million gallons of water per 1,000 head of hogs annually when compared with a conventional pull-plug flush unit. This conservation results from using wet-dry feeders and eliminating the addition of water for manure removal and handling. A reduction in the amount of water used in the system results in less waste product to be handled.

Advantages and Limitations: As explained above, the dry manure handling system used in the High-Rise facility significantly decreases the volume and tonnage of the final organic product. This is an important advantage when transportation to areas where there is an increased land base for manure application is necessary. However, because the semicomposted product has greater concentrations of macronutrients, with the possible exception of N (which might volatilize), the number of acres needed to correctly apply the manure does not decrease. Nitrogen volatilization during the composting process creates the possibility of upsetting the nutrient balance in manure. For example, if manure was applied to land with the application rate based on the amount of N in the manure, P and potassium could be applied at rates 10 times the recommended rate. This problem is eliminated if application rates are based on the P content of manure. Additional commercial N application might be necessary depending on the crop being produced.

Data from an initial trial show that the manure product removed from the High-Rise facility has a fertilizer value of about $19 per ton at 60.7 percent moisture, with an organic matter content of 29.8 percent. Secondary studies show that the manure mixture is of adequate content for further composting, which is necessary to sell manure commercially. These factors create an increased opportunity to broker manure and possibly provide supplemental income to the swine production enterprise (Envirologic, 2000).

Observations and data resulting from the first year of study in the High-Rise structure indicate that there is a significant decrease in odor using the dry manure handling system. Ammonia measurements on the swine housing level averaged from 0 to 8 parts per million (ppm), with an overall mean of 4.3 ppm and spikes of up to 12 ppm in times of decreased ventilation (winter months). In a conventional confinement building with a deep, liquid pit, ammonia levels of 20 to 30 ppm are commonplace. Ammonia levels on the ground level of the High-Rise building vary inversely with building ventilation and have exceeded a short-term exposure rate of 50 ppm in the winter. It must be realized, however, that the basement level is not occupied during normal conditions. Large sliding doors are opened when the facility is cleaned to let in fresh air and facilitate the entry of a tractor/loader. Ammonia levels external to the outside exhaust fans averaged 23.3 ppm, but quickly dissipated (Keener et al., 1999).

No hydrogen sulfide gas was detected in the swine holding area. Levels on the first floor were minimal (National Hog Farmer, 2000). Decreased levels of these potentially toxic gases improve air quality and prevent excessive corrosion in the building.

Producers who plan to build a High-Rise facility can expect a 15 percent increase in capital outlay compared to a 1,000-head, tunnel ventilation finisher with an 8-foot-deep pit. Cost projections prepared for the company that manufactures the High-Rise building indicate that reduced cost for manure handling and transportation offsets the additional building cost (Envirologic, 2000). Solid manure handling is less automated than many liquid manure handling systems. Although solid systems have lower capital costs, labor costs are higher than those associated with liquid systems. Labor costs are expected to be less than traditional scrape and haul systems because the slatted floors eliminate the need to scrape animal areas frequently.

In addition to the increased capital requirement, the cost of utilities is also elevated. Additional energy is needed to power the many ventilation fans. Electricity usage averages roughly twice that of a naturally ventilated confinement barn. Accounting for all of these factors, the cost of production in a High-Rise facility is approximately $180 per pig. This is 28 to 30 percent greater than the cost of production in a confinement structure with a shallow pit, and 15 to 18 percent greater than in a more conventional deep pit (Mescher et al., 1999).

The ventilation system that pumps air over the swine holding area keeps the swine and slats dry, resulting in cleaner swine and fewer injuries. Also, there is no flow of air from pig to pig, which helps prevent airborne transmission of disease. The combination of decreased moisture and exceptional air quality leads to improved animal health and decreased medication costs.

Data from a single High-Rise facility show that animal performance was the same or better than that of conventional facilities with respect to average daily gain, days to market, feed conversion, mortality, and the number of culls. In fact, the decreased number of days to market translates into 0.2 to 0.3 more production cycles per year, creating potential to increase profits significantly. It is speculated that improvement in performance measures is due to better air quality (Envirologic, 2000).

Leachate from the manure mixture appears to be minimal if mixing is done on a regular basis. Rodents in the basement pit might become a problem if control measures are not taken.

Operational Factors: Artificial climate control and ventilation in the building make the High-Rise building appropriate in most climates . It is estimated that air in the building is exchanged every 10 to 15 seconds, providing an environment of uniform temperature and humidity throughout the building year-round. Over a 1-year span, the mean air temperature taken from several test areas within the building varied only ± 2 °F from the desired temperature. There were, however, differences of up to 10 °F between testing areas on the swine floor (Stowell et al., 1999). The building is equipped with a standard sprinkling system for use in hot summer months.

Demonstration Status: The High-Rise facility technology has been tested with finisher pigs since 1998 at a single research facility in Darke County, Ohio. The vendor has built four commercial grow-finish buildings since that time and they are currently in production in west central Ohio. The vendor is also developing prototypes for other phases of swine production using the same manure handling system.

Practice: Hoop Structures

Description: Hoop structures are low-cost, Quonset-shaped swine shelters with no form of artificial climate control. Wooden or concrete sidewalls 4 to 6 feet tall are covered with an ultraviolet and moisture-resistant, polyethylene fabric tarp supported by 12- to 16-gauge tubular steel hoops or steel truss arches placed 4 to 6 feet apart. Hoop structures with a diameter greater than 35 feet generally have trusses rather than the tubing used on narrower hoops. Some companies market hoops as wide as 75 feet. Tarps are affixed to the hoops using ropes or winches and nylon straps.

Generally, the majority of the floor area is earthen, with approximately one-third of the south end of the building concreted and used as a feeding area. The feeding area is designed with a slight slope (1 to 2 percent) to the outside of the building in case of a waterline break and is raised 12 to 19 inches above the earthen floor to keep the feeding area clear of bedding material. Approximately 150 to 200 finisher hogs or up to 60 head of sows are grouped together in one large, deep-bedded pen. The building should be designed so that the group housing area provides approximately 12 square feet of space per finisher pig, or 27 square feet per sow.

Hoop structures are considered a new and viable alternative for housing gestational sows and grow-finish pigs. Gestational housing systems being used in the United States are modeled after conventional Swedish style, deep-bedded gestation and breeding housing. In Sweden today, deep-bedded housing systems with individual feeding stalls are the conventional method of dry sow housing. There are feeding stalls for each sow, with connecting rear gates and individually opening front gates, a deep-bedded area for the group-housed sows, and bedded boar pens. The stalls are raised approximately 16 inches above the ground to accommodate the deep-bedding pack in the center.

In each production scenario, plentiful amounts of high quality bedding are applied to the earthen portion of the structure, creating a bed approximately 12 to 18 inches deep. The heavy bedding absorbs animal manure to produce a solid waste product. Additional bedding is added continuously throughout the production cycle. Fresh bedding keeps the bed surface clean and free of pathogens and sustains aerobic decomposition. Aerobic decomposition within the bedding pack generates heat and elevates the effective temperature in the unheated hoop structure, improving animal comfort in winter conditions.

Application and Performance: The hoop structure originated in the prairie provinces of Canada. Recently, interest in this type of structure has increased in Iowa and other states in the Midwest. Swine production in this type of facility is most prevalent for finishing operations, but is also used to house dry gestational sows. Other possible uses in swine production include gilt development, isolation facilities, housing for light pigs, breeding barns, farrowing, and segregated, early weaning swine development. A hoop structure is an appropriate alternative for moderately sized operations. An “all in, all out” production strategy must be used with finishing pigs.

The manure from hoop structures is removed as a solid with the bedding pack. The high volume of bedding used creates an increased volume of waste to be removed. Typically, a front-wheel assist tractor with a grapple fork attachment on the front-end loader is required to clean out the bedding pack. In a finishing production system, the bedding pack is removed at market time, usually two to three times per year. In gestational sow housing, slightly less bedding is required, and the bedding pack is typically removed one to four times a year depending on the stocking density and quality of bedding.

A limited amount of information is available on the manure characteristics, both inside the hoop and during consequent manure management activities. The manure content within the pack is highly variable. Dunging areas are quickly established when swine are introduced into the deep-bedded structure. These areas contain a majority of the nutrients within the pack. Results of an Iowa State University study are shown in Table 8-4. Samples were taken on a grid system at nine areas throughout the bedding pack (three samples along the west side of the building, three along the center, three along the east).

Table 8-4. Examples of Bedding Nutrients Concentrations

Bedding Nutrients by Location[a]				
Site	**Total Moisture (percent)**	**Total Nitrogen (lb/ton)**	**Phosphorus (lb/ton)**	**Potassium (lb/ton)**
West1	73.7	20	21	12
West2	75.2	22	22	12
West3	68.5	22	31	16
Center1	67.4	14	20	26
Center2	22.9	11	21	37
Center3	27.6	22	17	26
East1	68.5	29	24	29
East2	30.6	36	40	51
East3	73.5	16	13	15
Mean	56.4	21.3	23.2	24.8
Standard Deviation	22.3	7.6	7.6	13.0

[a] Adapted from Richard et al., 1997.

Temperatures throughout the bedding pack also varied greatly. Bedding temperature was highest in the sleeping/resting area where the moisture content is approximately 50 percent. Bedding temperatures were lowest in the wet dunging areas that contain 60 to 70 percent moisture. The lower temperatures were likely caused by anaerobic conditions that prevent oxidation of carbon and, therefore, reduce the amount of heat generated (Richard et al., 1997; and Richard and Smits, 1998).

Richard et al. and Richard and Smits (1997, 1998) also examined the loss of N in the hoop structure bedding pack. One-third of the N was lost while swine were housed in the structure. This loss was hypothesized to be caused largely by ammonia volatilization and possibly from nitrate leaching. An additional 10 percent reduction in N occurred as the bedding pack was removed from the hoop. This loss was also hypothesized as being a result of ammonia volatilization. Additional N was lost during the composting process, with the amount lost corresponding to the specific composting process demonstrated. In general, the composting process that resulted in the greatest reduction of volume also had the greatest N loss (Richard and Smits, 1998).

Nitrogen leaching potential was examined in yet another study at Iowa State University. The hoop facility used in this trial was located on hard-packed soil with a high clay-content. Following one production cycle, the surface NO_3-N was 5.5 times greater than the initial level. There was no significant change in NO_3-N at other depths ranging to 5 feet. Following a second production cycle, the NO_3-N levels at all depths to 5 feet increased three times compared with those taken following the initial production cycle (Richard et al., 1997). Nitrate was the only form of N tested.

The Medina Research Centre in Australia studied N and P accumulation in the soil beneath hoop structures. The hoop structures were constructed on Swan Coastal Plain sandy soils. Two trials were conducted in the same location approximately 6 weeks apart. In each trial there was no increase in the concentration of extractable P in the soil profile when compared with baseline data (Jeffery, 1996).

Advantages and Limitations: The quality of the work environment in a deep-bedded hoop structure is generally good. There is no liquid manure and therefore less odor than with conventional systems. The building structure and recommended orientation provide for a large volume of naturally ventilated air. Also, because the manure is solid, storage requirements are minimized.

The high degree of variability within the bedding pack makes it difficult to predict nutrient content. Some areas can have a high fertilizer value, whereas others have high carbon and low N content. The latter can lead to N immobilization and result in crop stress if applied during or immediately prior to the growing season. For these reasons, it is desirable to mix the bedding pack to achieve a higher degree of uniformity. Some mixing will occur during the removal and storage of the manure. Treatments that allow for additional mixing, such as composting in windrows, appear to offer considerable benefits. Initial studies at Iowa State University found that composting improved uniformity, and provided for a 14 to 23 percent reduction in moisture and a 24 to 45 percent reduction in volume (Richard and Smits, 1998). It should be noted that bedding from gestational sow facilities is typically drier than that from finishing facilities. The lack of moisture is likely to limit the extent of composting unless additional manure or moisture is added.

Trials comparing a conventional confinement system to hoop structures have been performed at Iowa State University. The swine raised in the hoop structure experienced similar performance. Specifically, there was a low level of swine mortality (2.6 to 2.7 percent), comparable and acceptable average daily gain, and a slightly poorer feed efficiency (8 to 10 percent) for swine raised in the winter months (Honeyman et al., 1999). Poor feed efficiency in winter months is due to an increased nutrient/energy requirement to maintain body heat. These findings supported an earlier study by the University of Manitoba that found swine finished in hoop structures to have excellent health, similar rates of gain, poorer feed efficiency in colder months (10 to 20 percent), low swine mortality, and similar days to market (Conner, 1993). Moreover, similar results were found in a South Dakota State University study. Several researchers have identified proper nutrition for swine raised in hoops as an area needing further research.

With respect to housing dry gestational sows, providing a lockable feeding area for each sow affords similar advantages to those of traditional gestation crates. Producers have the ability to keep feed intake even, eliminate competition for feed, administer treatments and medication effectively, lock sows in for cleaning and bedding, and sort and transfer sows for breeding or farrowing through the front gates. Furthermore, group housing stimulates estrus (the period of time within a female’s reproductive cycle in which she will stand to be bred), reduces stress to the sow, and alleviates many foot and leg problems common in sows. Fighting is minimized by the use of feeding stalls and introducing new sows at optimal times, such as farrowing. Concreting the deep-bedded section to prevent sows from rooting is an option, but it increases capital outlay (Honeyman et al.,1997).

Iowa State University has conducted demonstration trials on gestating sows in deep-bedded hoop structures. Conception rate, farrowing rate, number of swine born alive, and birth weight on groups gestated in the hoop structure were all excellent. The sow performance results indicate that hoop structures are an exceptional environment for gestating sows. It must be noted, however, that sow groups were not mixed and new sows were not introduced during the trial. With respect to breeding, hot weather is of greater concern than cold weather. Excessive high temperatures can be detrimental to breeding performance. Boars exposed to elevated effective temperatures will experience poor semen quality for a 6- to 8-week period that begins 2 to 3 weeks following exposure. Sows are more tolerant to high temperatures, except during the first 2 to 3 weeks of gestation and the final 2 weeks prior to farrowing. Litter size and birth weight can be severely altered during these periods (Honeyman et al., 1997).

Iowa State University has also conducted preliminary trials with farrow-to-finish production, early weaned pigs, and wean-to-finish production. These studies concluded that, although each may be a viable alternative, many details must still be worked out before they all become successful consistently.

The hoop system offers several benefits with respect to animal welfare and behavior. Honeyman et al. (1997) stated that one of the most extreme stresses in livestock production results when an animal is prevented from controlling various aspects of its environment. This lack of control is apparent in many of today's conventional production systems and is responsible for an unduly high level of stress that affects general health, reproduction, and welfare. Production in a deep-bedded hoop structure allows each animal to control its own microenvironment by burrowing down into the bedding, huddling, or lying on top. Deep-bedded hoops also allow swine to root through and ingest some bedding at will. This is especially advantageous in dry-sow gestational housing. The behavior serves two purposes. First, swine have an inherent drive to root. Being able to do so prevents frustration, boredom, and, hence, aggression. Second, consumption of bedding material quiets any hunger the pig may feel. Increased genetic evolution has led swine to have an increased drive to eat. Gestating sows are typically fed a limited amount of feed, satisfying what is estimated to be only 30 to 50 percent of their appetite. Stereotypic behavior is indicative of a suboptimal environment and will ultimately have implications on an animal's general health and production. No evidence of stereotypic behavior is cited in any of the deep-bedded system studies (Honeyman et al., 1997).

The initial capital outlay for hoop structures is about 30 percent less than the capital requirement associated with a typical double-curtain swine finishing building (Harmon and Honeyman, 1997). Additionally, hoop structures are highly versatile and have many alternative uses (e.g., equipment storage) if production capacity is not needed. Production in hoop structures requires a greater amount of feed and large volumes of high quality bedding, however. Bedding is the key to successful production in hoop structures. These differences make the cost of production comparable to that of a traditional confinement setting.

Hoop structures are easy to construct with on-farm labor. In Iowa State University trials, hoop structures show no visible signs of deterioration after 4 years (Honeyman, 1995). The average useful life of a hoop structure is estimated to be 10 years (Brumm, 1997).

The amount of bedding used in the studies averages 200 pounds per finisher pig in each production cycle, with a greater amount of bedding being used in the winter months. It is estimated that approximately 1,800 pounds of high quality bedding per gestational sow are needed each year (Halverson, 1998). The amount of labor is directly proportional to the amount of bedding and ranges from 0.3 to 0.6 hours per pig (Richard et al., 1997). A survey distributed to producers of finishing pigs in hoop structures and compiled by Iowa State University found actual labor requirements to average 0.25 hours per pig (Duffy and Honeyman, 1999). Labor requirements rely on many factors, including farm size, level of automation, and experience with the production system. Based on the trials conducted at each university, the labor requirement was considered to be reasonable and competitive with other finishing systems (Conner, 1993; Richard et al., 1997).

The large amount of bedding required in hoop structure production can limit its feasibility for some producers. Many types of bedding can be used. Corn stalks, oat straw, wheat straw, bean stalks, wood shavings, and shredded paper have all been used with some success, although shredded corn stalks are the most common. Selection of the appropriate bedding type is based on many factors. First, the availability of bedding must be considered. This is specific to geographical area but may also be limited by climate. An early snow or a wet fall could prevent stalk baling. Second, in several areas of the Midwest, federally mandated conservation plans on highly erodible land require residue to be left on the land. In such cases, harvesting corn and bean stalks may not be appropriate. Finally, bedding storage is an important consideration. Generally, bedding baled in the fall and used by the spring can be stored outdoors. Bedding needed for spring and summer use, however must be stored undercover in a well-drained area to avoid loss in quality and quantity.

Internal parasite control must be aggressive because swine are continually in contact with their feces. Several of the Iowa State University studies note that flies are a potential problem for hoop houses in warm months. Furthermore, rodent and bird problems may be difficult to control. Also, in the summer, incidental composting within the bedding pack can create unwelcome heat and may lessen the animals' comfort. It has not been determined whether there is severe potential for disease and parasite buildup in the soil beneath the hoop structure.

Operational Factors: Production in a hoop structure relies on bedding, intensive management, and keen husbandry for success. Climate control is a major factor in determining the feasibility of deep-bedded hoop structures. The recommended orientation of the buildings is north to south (depending on geographical area), to take advantage of the prevailing summer winds. Air enters the facility through spaces between the sidewall and the tarp and at the ends. Warm, moist air moves toward the top of the arch and is carried out the north end by natural currents. Various end structures are available that supply adjustable levels of ventilation. In the winter months, the north end is generally closed and the south is at least partially opened. If the ends are closed too tightly, high levels of humidity can become a problem. On average, the inside air temperature in the winter is only 5° to 8° F warmer than outside temperatures. This is different from the effective temperature which the swine can alter by burrowing into the deep bedding. In summer months, both ends are left open. Ultraviolet resistant tarp and sprinklers inside the structure help to control the temperature within the structure. Air temperature in the summer averages 2° to 4° F lower than outside temperature (Harmon and Xin, 1997). The length of the hoop structure also has an effect on air temperature because of the rate of air exchange. Wider and longer hoop structures often have ridge vents to improve ventilation.

Demonstration Status: Hoop structures have been used successfully in the United States for housing finishing pigs and dry gestational sows. Grow-finish production is the most common use for hoop structures in swine production. Recently, there has been an increased interest in this type of production system in the Midwest, including the states of Iowa, Illinois, Minnesota, Nebraska, and South Dakota. It is estimated that more than 1,500 hoop structures have been built for swine production in Iowa since 1996 (Honeyman, 1999). Furthermore, initial demonstrations have been conducted with early weaned pigs and in farrow-to-finish production. Hoop structures are being used to house swine in at least seven Canadian provinces. Currently, more than 400 hoop structures are used for swine finishing in Manitoba (Conner, 1994).

Practice: Rotational Grazing

Description: Intensive rotational grazing is known by many terms, including intensive grazing management, short duration grazing, savory grazing, controlled grazing management, and voisin grazing management (Murphy, 1998). This practice involves rotating grazing cattle (both beef and dairy) among several pasture subunits or paddocks to obtain maximum efficiency of the pasture land. Dairy cows managed under this system spend all of their time not associated with milking out on the paddocks during the grazing season and beef cattle spend all of their time out on the paddocks during the grazing season. Intensive rotational grazing is rarely if ever used at swine and poultry operations. Nonruminants such as swine and poultry are typically raised in confinement because of the large number of animals produced and the need for supplemental feed when they are raised on pastures.

Application and Performance: Rotational grazing is applicable to all beef and dairy operations that have sufficient land. During intensive rotational grazing, each paddock is grazed quickly (1 or 2 days) and then allowed to regrow, ungrazed, until ready for another grazing. The recovery period depends on the forage type, the forage growth rate, and the climate, and may vary from 10 to 60 days (USDA, 1997). This practice is labor- and land-intensive as cows must be moved daily to new paddocks. All paddocks used in this system require fencing and a sufficient water supply. Many operations using intensive rotational grazing move their fencing from one paddock to another and have a water system (i.e., pump and tank) installed in each predefined paddock area.

The number of required paddocks is determined by the grazing and recovery periods for the forage. For example, if a pasture-type paddock is grazed for 1 day and recovers for 21 days, 22 paddocks are needed (USDA, 1997). The total amount of land required depends on a number of factors including the dry matter content of the pasture forage, use of supplemental feed, and the number of head requiring grazing. Generally, this averages out to one or two head per acre of pasture land for both beef and dairy cattle (Hannawale, 2000). Successful intensive rotational grazing, however, requires thorough planning and constant monitoring. All paddocks should be monitored once a week. High-producing milk cows (those producing over 80 lbs/day) need a large forage allowance to maintain a high level of intake. Therefore, they need to graze in pastures that have sufficient available forage or be fed stored feed (USDA, 1997). It is also expected that beef cattle would need sufficient forage or stored feed to achieve expected weight gains.

The climate in many regions is not suitable for year round rotational grazing. Operations in these regions must maintain barns and/or dry lots for the cows when they are not being grazed or outwinter their cows. Outwintering is the practice of managing cows outside during the winter months. This is not a common practice because farmers must provide additional feed as cows expend more energy outside in the winter, provide windbreaks for cattle, conduct more frequent and diligent health checks on the cows, and keep the cows clean and dry so that they can stay warm (CIAS, 2000).

There are two basic management approaches to outwintering: rotation through paddocks and sacrifice paddocks. Some farms use a combination of these practices to manage their cows during the winter. During winter months, farmers may rotate cattle, hay, and round bale feeders throughout the paddocks. The main differences between this approach and standard rotational grazing practices are that the cows are not rotated as often and supplemental feed is provided to the animals. Deep snow, however, can cause problems for farmers rotating their animals in the winter because it limits the mobility of round bale feeders. The outwintering practice of "sacrifice paddocks" consists of managing animals in one pasture during the entire winter. There are several disadvantages and advantages associated with this practice. If the paddock surface is not frozen during the entire winter, compaction, plugging (tearing up of the soil), and puddling can occur. Due to the large amounts of manure deposited in these paddocks during the winter, the sacrificial paddocks must be renovated in the spring. This spring renovation may consist of dragging or scraping the paddocks to remove excess manure and then seeding to reestablish a vegetative cover. Some farmers place sacrifice paddocks strategically in areas where an undesirable plant grows or where they plan to reseed the pasture or cultivate for a crop (CIAS, 2000).

EPA conducted an analysis to estimate the manure reduction achievable with intensive rotational grazing at model beef and dairy operations (ERG, 2000a). Outwintering was not assumed to occur in this analysis. During the months that the cows from the model dairies and feedlots were assumed not to be on pasture, the amount of manure that must be managed is assumed to be equal to the amount produced at equal size confined dairy operations and beef feedlots. Table 8-5 presents the estimated range of months that intensive rotational grazing systems might be used at dairy farms and beef feedlots located in each of the five geographical regions included in this analysis.

Table 8-5. Amount of Time That Grazing Systems May Be Used at Dairy Farms and Beef Feedlots, by Geographic Region

Region	Annual Use of Grazing Systems (months)
Pacific	3 - 12
Central	3 -12
Midwest	3 - 6
Mid-Atlantic	3 - 9
South	9 - 12

It is estimated that approximately 15 percent of the manure generated by dairy cows is excreted in the milking center and 85 percent is excreted in the housing areas (i.e., barns, dry lots, pastures) (USDA NRCS, 1996). It is also estimated that 23 percent to 28 percent of the wastewater volume generated from a flushing dairy operation comes from the milking center and 72 percent to 77 percent (median of 75 percent) of the wastewater comes from flushing the barns (USEPA, 2000). All wastewater from a hose-and-scrape dairy system is generated at the milking center. Thus, dairies using intensive rotational grazing systems would manage 85 percent less solid manure and approximately 75 percent less wastewater (for flushing operations) than confined systems, during the months that the cows are on pasture.

All of the manure generated at beef feedlots using intensive rotational grazing systems would be excreted on the pasture during the months that the cows are grazing. No significant amounts of process wastewater are generated at beef feedlots. Thus, beef feedlots using intensive rotational grazing systems would manage 100 percent less solid waste during the months that the cows are on pasture.

Two model farm sizes were analyzed for dairy farms, assuming an average size of 454 (for medium-sized dairies) and 1,419 milking cows (for large-sized dairies). Both of these size groups are significantly larger than the 100 head or smaller operations expected to use intensive rotational grazing systems. Therefore, the specific model farm calculations are viewed as significantly overestimating the amount of collected manure and wastewater that could be reduced at typical intensive rotational grazing operations versus confined operations. For this reason, estimates on collected manure and wastewater reduction are presented on a per-head basis and model farm basis for the two dairy farm types (flushing, hose and scrape) included in EPA's Effluent Limitations Guidelines (ELG) analysis for each of the five geographical regions.

Three model farm sizes were analyzed for beef feedlots, assuming an average size of 844 (for medium-sized feedlots), 2,628 (for large-sized feedlots), and 43,805 beef slaughter steer (for very large feedlots). Due to the slow weight gain associated with grazing operations for beef cattle and required number of pasture acres, beef feedlots of these sizes are not expected to use intensive rotational grazing systems. However, estimates on collected manure reductions are presented on a per-head basis and model farm basis for the three sizes of beef feedlots included in EPA's ELG analysis for each of the five geographical regions.

Table 8-6 presents the expected reduction in collected manure and wastewater for flush and hose-and-scrape dairy operations, by head, and by region. Table 8-7 presents the expected reduction in collected manure and wastewater for dairy operations by model farm, and by region. Table 8-8 presents the expected reduction in collected manure for beef feedlots, by head, and by region. Table 8-9 presents the expected reduction in collected manure for beef feedlots by model farm, and by region.

Table 8-6. Expected Reduction in Collected Solid Manure and Wastewater at Dairies Using Intensive Rotational Grazing, per Head

Farm Type	Region	Manure Reduction (lb/yr/head)	Wastewater Reduction (gal/yr/head)
Flush	Pacific	10,200 - 41,500	9,000 - 36,500
	Central	10,200 - 41,500	9,000 - 36,500
	Midwest	10,200 - 20,500	9,000 - 18,000
	Mid-Atlantic	10,200 - 30,700	9,000 - 27,000
	South	30,700 - 41,500	27,000 - 36,500
Hose and Scrape	Pacific	10,200 - 41,500	0
	Central	10,200 - 41,500	0
	Midwest	10,200 - 20,500	0
	Mid-Atlantic	10,200 - 30,700	0
	South	30,700 - 41,500	0

Table 8-7. Expected Reduction in Collected Solid Manure and Wastewater at Dairies Using Intensive Rotational Grazing, per Model Farm

Farm Size (head)	Farm Type	Region	Manure Reduction (lb/yr/farm)	Wastewater Reduction (gal/yr/farm)
454	Flush	Pacific	4,630,800 - 18,841,000	4,086,000 - 16,571,000
		Central	4,630,800 - 18,841,000	4,086,000 - 16,571,000
		Midwest	4,630,800 - 9,307,000	4,086,000 - 8,172,000
		Mid-Atlantic	4,630,800 - 13,937,800	4,086,000 - 12,258,000
		South	13,937,800 - 18,841,000	12,258,000 -16,571,000
454	Hose & Scrape	Pacific	4,630,800 - 18,841,000	0
		Central	4,630,800 - 18,841,000	0
		Midwest	4,630,800 - 9,307,000	0
		Mid-Atlantic	4,630,800 - 13,937,800	0
		South	13,937,800 - 18,841,000	0
1,419	Flush	Pacific	14,473,800 - 58,888,500	12,771,000 - 51,793,500
		Central	14,473,800 - 58,888,500	12,771,000 - 51,793,500
		Midwest	14,473,800 - 29,089,500	12,771,000 - 25,542,000
		Mid-Atlantic	14,473,800 - 43,563,300	12,771,000 - 38,313,000
		South	43,563,300 - 58,888,500	38,313,000 - 51,793,500
1,419	Hose and Scrape	Pacific	14,473,800 - 58,888,500	0
		Central	14,473,800 - 58,888,500	0
		Midwest	14,473,800 - 29,089,500	0
		Mid-Atlantic	14,473,800 - 43,563,300	0
		South	43,563,300 - 58,888,500	0

Table 8-8. Expected Reduction in Collected Solid Manure at Beef Feedlots Using Intensive Rotational Grazing, per Head

Region	Manure Reduction (lb/yr/head)
Pacific	5,040 - 20,167
Central	5,040 - 20,167
Midwest	5,040 - 10,080
Mid-Atlantic	5,040 - 15,120
South	15,120 - 20,167

Table 8-9. Expected Reduction in Collected Solid Manure at Beef Feedlots Using Intensive Rotational Grazing, per Model Farm

Farm Size (head)	Region	Manure Reduction (lb/yr/farm)
844	Pacific	4,255,170 - 17,020,680
	Central	4,255,170 - 17,020,680
	Midwest	4,255,170 - 8,510,340
	Mid-Atlantic	4,255,170 - 12,765,510
	South	12,765,510 - 17,020,680
2,628	Pacific	13,249,500 - 52,998,000
	Central	13,249,500 - 52,998,000
	Midwest	13,249,500 - 26,499,000
	Mid-Atlantic	13,249,500 - 39,748,500
	South	39,748,500 - 52,998,000
43,805	Pacific	220,849,640 - 883,398,550
	Central	220,849,640 - 883,398,550
	Midwest	220,849,640 - 441,699,280
	Mid-Atlantic	220,849,640 - 662,548,910
	South	662,548,910 - 883,398,550

Advantages and Limitations: Compared with traditional grazing, intensive rotational grazing has been identified as environmentally friendly and, when managed correctly, is often considered better than conventional or continuous grazing. The benefits associated with intensive rotational grazing versus conventional grazing include:

- Higher live-weight gain per acre. Intensive rotational grazing systems result in high stocking density, which increases competition for feed between animals, forcing them to spend more time eating and less time wandering (AAC, 2000).

- Higher net economic return. Dairy farmers using pasture as a feed source will produce more feed value with intensive rotational grazing than with continuous grazing (CIAS, 2000). Competition also forces animals to be less selective when grazing. They will eat species of plants that they would ignore in other grazing systems. This reduces less desirable plant species in the pasture and produces a better economic return (AAC, 2000).

- Better land. Pasture land used in rotational grazing is often better maintained than typical pasture land. Intensive rotational grazing encourages grass growth and development of healthy sod, which in turn reduces erosion. Intensive rotational grazing in shoreline areas may help stabilize stream banks and could be used to maintain and improve riparian habitats (PPRC, 1996).

- Less manure handling. In continuous grazing systems, pastures require frequent maintenance to break up large clumps of manure. In a good rotational system, however, manure is more evenly distributed and will break up and disappear faster. Rotational grazing systems may still require manure maintenance near watering areas and paths to and from the paddock areas (Emmicx, 2000).

Grazing systems are not directly comparable with confined feeding operations, as one system can not readily switch to the other. However, assuming all things are equal, intensive rotational grazing systems might have some advantages over confined feeding operations:

- Reduced cost. Pasture stocking systems are typically less expensive to invest in than livestock facilities and farm equipment required to harvest crops. Feeding costs may also be lowered.

- Improved cow health. Dairy farmers practicing intensive rotational grazing typically have a lower cull rate than confined dairy farmers, because the cows have less hoof damage, and they are more closely observed by the farmer as they are moved from one paddock to another (USDA, 1997).

- Less manure handling. Intensive rotational grazing operations have less recoverable solid manure to manage than confined operations.

- Better rate of return. Research indicates that grazing systems are more economically flexible than the confinement systems. For example, farmers investing in a well-planned grazing operation will likely be able to recover most of their investment in assets if they leave farming in a few years. But farmers investing from scratch in a confinement operation would at best recover half their investments if they decide to leave farming (CIAS, 2000).

The disadvantages associated with intensive rotational grazing compared with either conventional grazing or confined dairy operations include:

- Limited applicability. Implementation of intensive rotational grazing systems is dependent upon available acreage, herd size, land resources (i.e., tillable versus steep or rocky), water availability, proximity of pasture area to milking center (for dairy operations), and feed storage capabilities. Typical confined dairy systems and beef feedlots are often not designed to allow cows easy access to the available cropland or pastureland. Large distances between the milking center and pastureland will increase the dairy cow's expended energy and, therefore, increase forage demands.

  In most of the country, limited growing seasons prevent many operations from implementing a year-round intensive rotational grazing system. Southern states such as Florida can place cows on pasture 12 months of the year, but the extreme heat presents other problems for cows exposed to the elements. Grazing operations in southern states typically install shade structures and increase water availability to cows, which in turn increases the costs and labor associated with intensive rotational grazing systems. Because most operations cannot provide year-round grazing, they still must maintain barns and dry lot areas for their cows when they are not grazing, and operations often prefer not to have to maintain two management systems.

- Reduced milk production levels. Studies indicate that dairy farmers using intensive rotational grazing have a lower milk production average than confined dairy farms (CIAS, 2000). Lower milk production can offset the benefit of lower feed costs, especially if rations are not properly balanced once pasture becomes the primary feed source during warm months.

- Reduced weight gain. Beef cattle managed in an intensive rotational grazing system would gain less weight per day than beef cattle managed on a feedlot unless they were supplied with extensive supplemental feed.

- Increased likelihood of infectious diseases. Some infectious diseases are more likely to occur in pastured animals due to direct or indirect transmission from wild animals or the presence of an infective organism in pasture soil or water (Hutchinson, 1998).

- Limited flexibility. Intensive rotational grazing systems have limited flexibility in planning how many animals can be pastured in any one paddock. Available forage in a paddock can vary from one cycle to another, because of weather and other conditions that affect forage growth rates. As a result, a paddock that was sized for a certain number of cows under adequate rainfall conditions will not be able to accommodate the same number of cows under drought conditions (USDA, 1997).

Operational Factors: As mentioned earlier, most dairy operations and beef feedlots cannot maintain year-round intensive rotational grazing systems. These systems are typically operated between 3 and 9 months of the year–with 12 months most likely in the southern states. Although outwintering is a possibility for year round grazing in more northern states, it is not a common practice.

Demonstration Status: Due to the labor, fencing, water, and land requirements of intensive rotational grazing, typically only small dairy operations (those with less than 100 head) use this practice (Hannawale, 2000; USDA NRCS, 2000; CIAS, 2000). Few beef feedlots practice intensive rotational grazing. Climate and associated growing seasons make it very difficult for operations to use an intensive rotational grazing system throughout the entire year.

Practice: Pasture-Based Systems at Swine Operations

Description: There are three main types of outdoor management systems at swine operations: pasture, open lots, and buildings with outside access. In pasture systems, crops are grown and the animals are allowed to forage for their own food. Open lots are generally nonvegetative areas where the animals are allowed to roam. These open lots are typically available to animals that are housed in buildings with outside access. The focus of this discussion is the pasture systems.

Application and Performance: This practice is applicable to any swine operation that has sufficient land. However, the practicality of the practice decreases with operation size. Wheaton and Rea (1999) found that the use of a good pasture containing such crops as alfalfa, clover, and grasses can support about 8 to 10 sows. Stocking rates, however, will depend upon soil fertility, quality of pasture, and time of year. The recommended stocking rates are (Wheaton and Rea, 1999):

- Sows with litters — 6 to 8 head per acre
- Pigs from weaning to 100 pounds — 15 to 30 head per acre
- Pigs from 100 pounds to market — 10 to 20 head per acre
- Gestating sows — 8 to 12 head per acre

Wheaton and Rea (1999) also found that pastured swine must receive two to three pounds of grain daily plus minerals and salt for proper weight gain. Adequate shade and water must also be provided to pastured swine. Swine can be very tough on pastures and soil. Therefore, it is recommended that producers rotate swine after each season and use the pasture for other animals or harvest hay for about 2 years before using it again for swine (Wheaton and Rea, 1999). All the waste produced by the animals while they are pastured is incorporated into the sod, and therefore requires minimal waste disposal.

Advantages and Limitations: A pasture-based system offers a number of advantages and disadvantages over confinement housing to swine producers. The advantages include (Wheaton and Rea, 1999):

- Lower feed costs on good pasture;
- Exercise and nutrients for breeding sows;
- Lower capital investment per production unit;
- Good use of land not suitable for machine harvest;
- Better isolation and disease control;
- Decreased waste management handling; and
- Decreased cannibalism.

The disadvantages include (Wheaton and Rea, 1999):

- Increased labor for animal handling, feeding, and watering;
- Increased risk of internal parasites;
- Increase labor for farrowing;
- Increase animal production time to reach desired market weight; and
- Lack of environmental controls.

Operational Factors: The increased labor costs associated with pasture-based swine operations are partially offset by decreased waste handling costs and reduced feed costs.

Demonstration Status: Data from the USDA's Animal and Plant Health Inspection Service - Veterinary Service indicate pasture-based systems are used at 7.6 percent of farrowing operations, 1.5 percent of nurseries, and 6.7 percent of finishing operations (USDA APHIS, 1995). The percentage of pigs raised on such operations is about five times less than the number of operations, indicating these operations are generally smaller than other types of swine operations. NAHMS confirmed this with additional analysis of the *Swine '95* data, and indicated 7 to 8 percent of swine farms with fewer than 750 total head use pasture systems, but less than 1 percent of swine operations larger than 750 head use pasture systems (USDA NAHMS, 1999).

Practice: Pasture-Based Systems at Poultry Operations

Description: Pastured poultry refers to broilers, layers, and turkeys that are raised on pasture and feed. There are three basic methods for raising poultry on pasture: pasture pens, free range, and day range (Lee, 2000). Pasture pens are bottomless pens that hold layers, broilers, or turkeys, and are moved daily or as needed to give the poultry fresh pasture. This is the most commonly used pasture poultry method at present. To accommodate layers, nest boxes are fixed to the side of the pen. Approximately 30 to 40 hens can be housed in one typical pasture pen. Free range generally means a fenced pasture surrounding the barn or poultry shelter, and day range is similar to free range except that the birds are sheltered at night from predators and weather.

Application and Performance: The use of pasture pens has been documented at operations with 1,000 birds but is believed to be used most commonly at operations with fewer than 1,000 birds. Lee (2000) also indicates that pastured poultry operations require up to twice the amount of feed as confined poultry does to achieve the same weight gain and/or production goal. All wastes produced while the birds are on pasture is incorporated into the sod, and therefore results in minimal waste requiring disposal.

Advantages and Limitations: Some of the advantages associated with pastured poultry versus confinement housing are:

- Pasture pens are easy and inexpensive to build;
- Controlled moves will harvest grass and help spread manure uniformly across the field;
- Perimeter fencing is not required;
- Diseases associated with confinement housing may be less likely to occur;
- Waste management handling is reduced; and
- Pasture-raised birds may have a higher market value (Lee, 2000).

The limitations associated with pastured poultry include the following:

- The small pens hold relatively few poultry, compared with their cost;
- Pens can trap heat, leading to heat stress;
- The roof height of the pens is too low for turkeys to stretch and raise their heads to full height;
- Pens may be difficult to move;
- Pens offer only minimal protection from weather; and
- Birds often have to bed down at night in manure-soaked grass (Lee, 2000).

Operational Factors: Pasture-based poultry operations require increased labor for animal handling, feeding, and watering (Lee, 2000). This increased labor is partially offset by a decrease in waste management.

Demonstration Status: No data could be found to indicate the number of pasture-based poultry operations. However, the use of pasture pens is rarely observed at operations with more than 1,000 birds. Thus few if any pastured poultry operations confine sufficient numbers of birds to be defined as CAFOs on the basis of operation size.

8.2 Manure/Waste Handling, Storage, and Treatment Technologies

Waste from animal feeding operations includes manure, bedding material, and animal carcasses. There are a variety of methods for handling, storing, and treating waste. Waste is handled in a solid form and through the use of water. As stated in earlier chapters, some facilities use water to move the waste away from the animals and then separate the solids from the liquids prior to storage, treatment, and disposal. Storage and treatment of waste is done in the both the solid and liquid/slurry forms.

8.2.1 Waste Handling Technologies and Practices

Different practices are used to handle or move liquid and solid wastes, and the choice of practices depends on the type of housing configuration. Housing configurations include total confinement, which is the most common and used almost exclusively in the poultry industry and at larger swine operations, open buildings with or without outside access, and lots or pastures with a hut or with no buildings.

Practice: Handling of Waste in Solid Form

Description: The use of hoop houses for swine and high-rise hog houses to handle manure in a dry form was discussed in section 8.1. In facilities with open lots, manure accumulates on the ground as a solid that can be diluted by rainfall (mostly for beef and dairy; swine and poultry are mostly totally confined) or by spillage from watering areas. Whether the lot is paved, partially paved, or unpaved, manure is typically handled as a solid or slurry and is scraped with tractor scrapers or front-end loaders and stored in a pile (see Figure 8-2). There are several options for separating solid manure from the animals at confinement facilities. Solid, unslatted floors, both paved and unpaved, can be hand-scraped or scraped with a tractor or front-end loader into a pile, pit, or other storage facility. Sloped floors further aid in manure collection as animal traffic works the manure downslope. Other facilities use uncovered alley or gutter systems combined with hand scraping, automatic scraping, or sloped floors to collect manure. Scraped manure from underslat gutters, alleys, or shallow pits can be held temporarily in a pit or a deep collection gutter at one end of the building, from which it can be applied to the land or transferred to a more permanent storage structure.

Application and Performance: Solid systems are best suited for open lot facilities, especially in areas that have a dry climate because exposed manure is less likely to be diluted by excess rainfall. The choice of solid or liquid handling systems, however, has been historically based on operator preference with respect to capital investment, labor requirements, and available equipment and facilities.

Advantages and Limitations: Solid handling systems offer both advantages and disadvantages to facility operators. For instance, solid systems use equipment that is already present at the facility, such as tractors and front-end loaders. Tractors and front-end loaders are flexible, have fewer mechanical problems, are less subject to corrosion, and work well on frozen manure, but they

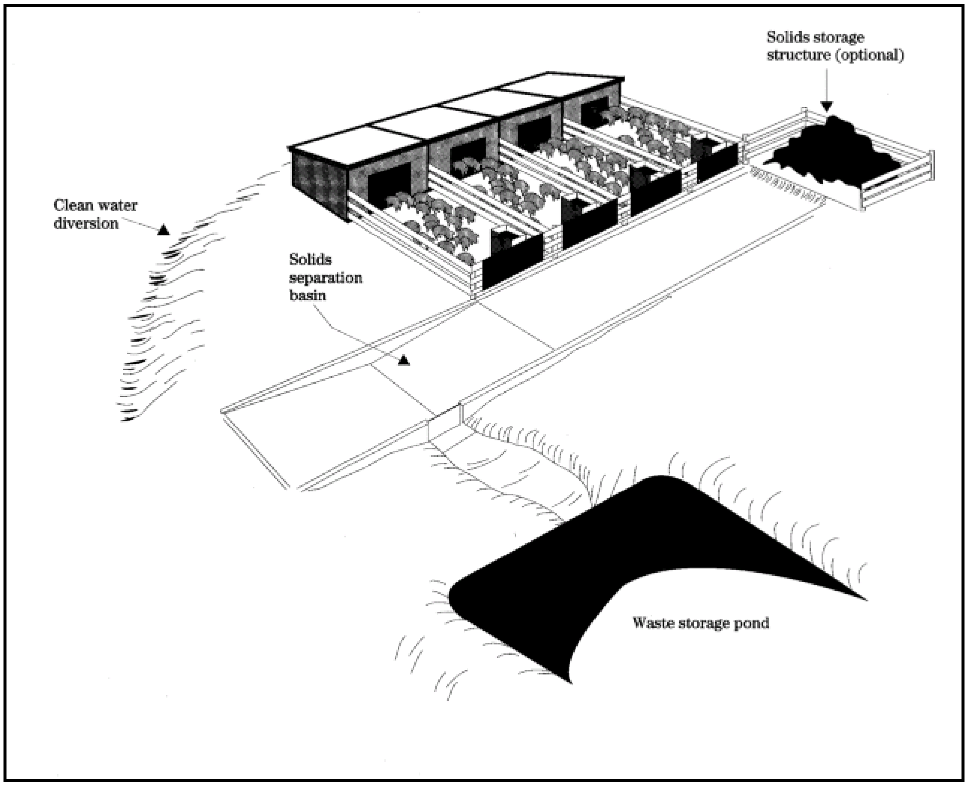


Figure 8-2. Manure Scraped and Handled as a Solid on a Paved Lot Operation (from USDA NRCS, 1996)

require more labor than automatic scrapers. Solid systems are not as automated as liquid systems; although they involve little or no capital investment and require less maintenance, they require much more labor than mechanical scraper systems or flushing systems. An advantage to solid systems is that the volume of manure handled is much less than the volume associated with liquid systems, which translates into smaller storage facility requirements. Bedding can be used without concern for pumping or agitating equipment problems (which are a concern for liquid handling systems).

Operational Factors: The extent of paving on an open lot determines the care with which manure is removed. Unpaved lots develop an impervious layer from bacterial activity and hoof action, and this layer protects against soil loss and percolation of liquids. Also, scraping of unpaved surfaces incorporates sand and soil into the manure, which can cause problems with storage or treatment of the manure. If scraped manure is to be stacked, it may be necessary to add an appreciable amount of bedding to attain a more solid consistency.

Demonstration Status: Solid handling systems are fairly common at smaller swine operations. According to *Swine '95* (USDA APHIS, 1996), removal of manure by hand is used most often in all types of operations (farrowing 38.2 percent, nursery 29.9 percent, and grower-finisher 27.2 percent). Mechanical scrapers and tractors are also used for solids handling (farrowing 12.0 percent, nursery 17.6 percent, and grower-finisher 24.9 percent).

Poultry waste is mostly handled as a dry litter, the exception being layer operations, particularly in the South region (USDA NAHMS, 2000a).

Manure is often handled in solid form at smaller dairy farms. According to *Dairy '96* (USDA APHIS, 1996A), gutter cleaners are used most often to remove manure from dairy cow housing areas (63.2 percent). Mechanical scrapers or tractors are frequently used to clean alleys (57.7 percent). A number of dairies store manure in solid form: 79.2 percent of dairies with fewer than 100 cows and 59.5 percent of dairies with 200 or more cows are reported to use some form of solid waste storage (USDA APHIS, 1996B).

Scraping is the most common method of collecting solid and semisolid manure from beef barns and open lots. Solids can be moved with a tractor scraper and front-end loader. Mechanical scrapers are typically used in the pit under barns with slotted floors. Scraping is common for medium and large feedlots. (Loudon, 1985)

Practice: Teardrop, V- and Y-Shaped Pits With Scraper

Description: Confinement facilities have several manure collection options for separating manure liquids from manure solids. Several underfloor gutter systems that are applicable only to swine will be discussed. No comparable manure collection systems that separate liquids and solids are known for other animal species.

The reason for separating swine manure into solids and liquids is to concentrate pollutants and nutrients. Kroodsma (1985) installed a plastic 0.78 mm filter net under the floor of a pig house in which eight pigs were fed by wet feeders so that no excess water fell into the manure. Solids fell onto the screen and liquids passed through. The results showed that the relatively undisturbed feces contained about 80 percent of the biological oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), phosphorus (P), calcium (Ca), magnesium (Mg), and copper (Cu). Sixty per cent of the total kjeldahl nitrogen (TKN) and forty percent of the potassium (K) were also retained in the filter net. Thus, if solids can be recovered relatively intact, parameters such as nutrients will be concentrated.

Two gutter configurations that may be useful for swine operations are Y-shaped and V-shaped gutters under slatted floors (Tengman, et al., undated draft). The sloping sides of the gutters facilitate retention of solids and allow liquids to drain to the center collection area. Scrapers pull the solids to one end of the barn for solids handling, while liquids flow with gravity in the opposite direction for management in a liquid manure system.

V-shaped gutters are easier to build than Y-shaped gutters and may be easier to clean. Manure movement in v-shaped gutters is not substantially different than in y-shaped gutters. The sideslope of Y- or V-shaped gutters should be 1:1 for farrowing operations and 3/4:1 for nurseries. A slope of 1:240 to 1:480 is recommended for the liquid gutter (Tengman, et al., undated draft).

Manure that is scraped from underslat gutters, alleys, or shallow pits can be held temporarily in a pit or a deep collection gutter at one end of the building, from which it can be applied to the land or transferred to a more permanent storage structure.

Application and Performance: The choice of a manure handling system is based primarily on operator preference with respect to capital investment, labor requirements, and available equipment and facilities. Demonstration of the economic viability or the value of concentrating nutrients using the Y-shaped gutter and V-shaped gutter is apparently lacking. No performance data was found from full-scale demonstration of the segregation of constituents, including pathogens, metals, growth hormones, and antibiotics.

Advantages and Limitations: The advantage in using a Y-shaped or V-shaped scrape collection system would be the concentration of nutrients in the solids. Nutrients concentrated in solid form are cheaper to haul than in slurry form because water, which would increase the weight and volume, is not added. Disadvantages include reduced air quality in hog buildings over manure solids smeared on the collection slope, repair of cable scrapers in small spaces under slatted floors with hogs present, the need for the operator to manage both a compost or solids stacking operation with solids handling equipment and a liquid storage and application system with liquid handling equipment.

Operational Factors: Climate, temperature, and rainfall generally do not affect scraper systems in hog barns. If scraped manure solids are to be stacked or composted, it may be necessary to add an appreciable amount of bedding to attain a more solid consistency.

Demonstration Status: Underslat manure scrape and gutter systems to direct manure liquids and solids to different handling systems have been developed, but they are not commonly used.

Practice: Handling of Waste in Liquid Form

Description: Liquid handling systems are the alternative to scraping and hauling manure. They are especially common in confinement housing operations because it is easier to install automated systems inside new or existing structures and it is more difficult to maneuver tractors or front-end loaders for scraping in small pens and tight corners. Excreted manure can be collected in shallow, narrow, open gutters or alleys, or it can collect under slats in gutters or pits for periodic flushing to a more permanent storage or treatment facility. The manure can also be directly applied to land without extended storage or treatment.

Slotted floors are an efficient method for removing manure from animal areas. Floors tend to be typically partially slotted over a pit or gutter. Feeding and resting areas are located on solid floors, and watering areas are placed over slotted floors. Manure is worked through the slats by hoof action and is stored beneath the slats until it is pumped or flushed to a lagoon. Fresh water can be used for flushing or water from a secondary lagoon can be recycled as flush water. An example of a slotted floor system is shown in Figure 8-3.

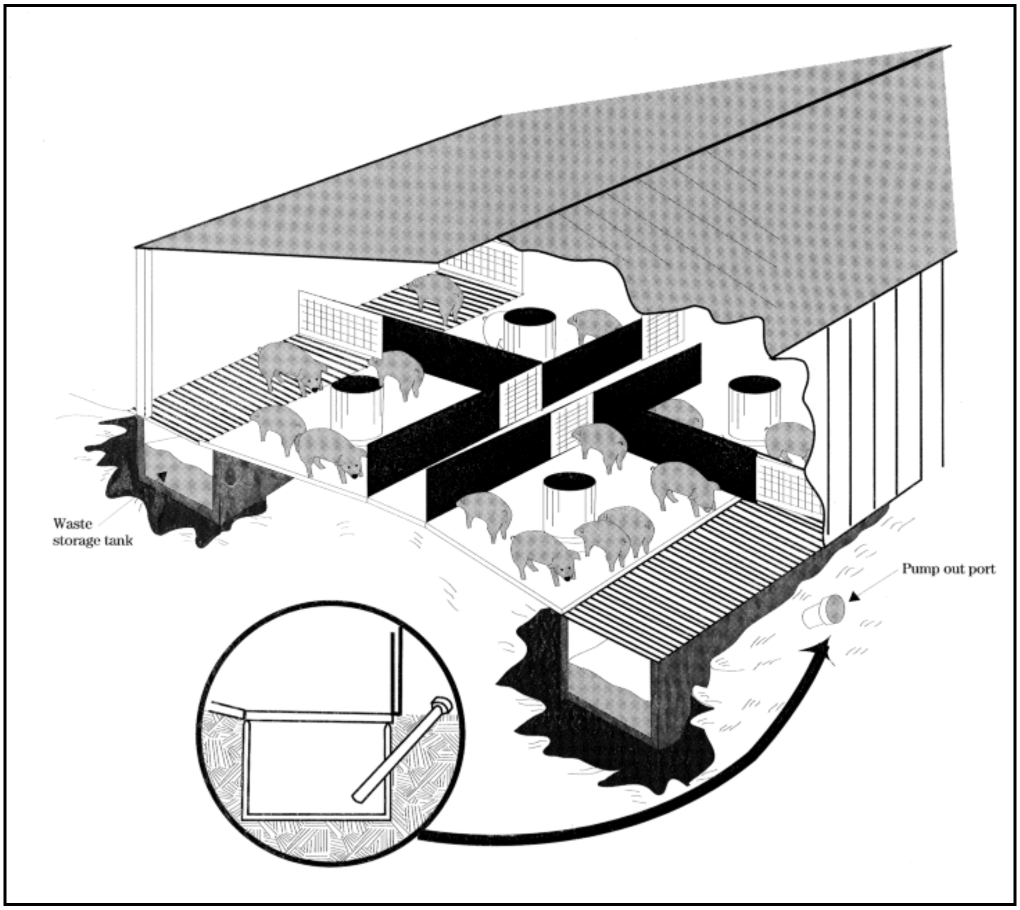


Figure 8-3. Fed hogs in confined area with concrete floor and tank storage liquid manure handling (from USDA NRCS, 1996).

Application and Performance: Liquid manure systems are most frequently used for large animal facilities, where the automation of waste management systems is very important. They may also be preferred where water is abundant or when rainfall on open lots causes considerable dilution of manure solids. Liquid systems are especially appropriate when spray irrigation of nutrient-laden waters is the preferred method for fertilizing and watering crops.

Advantages and Limitations: Flushing systems with liquid manure handling are less labor-intensive and more automated than solid handling systems, but the volume of manure and water to be stored, treated, and disposed of is greater. Flushing systems require large volumes of water to be pumped and stored in a sump until discharged by gravity flow or pumped to a lagoon. Consequently, where water is a valuable commodity, liquid systems might not be economical. This limitation can be offset by recycling flush water from treatment lagoons. Equipment needed for liquid systems, including sumps, pumps, agitators, choppers, and sprayers, brings with it high capital, operating, and maintenance costs, although savings may be seen in decreased labor costs. Manure consistency is very important in liquid handling systems because the equipment can be damaged by fibrous material (bedding), sand, or other foreign materials. Periodic cleanout of solids is necessary to maintain the capacity and proper functioning of storage structures and handling equipment.

Operational Factors: Slats can be made of wood, concrete, steel, aluminum, or plastic. Concrete is the most sturdy material, is the least corrodible, and handles the weight of larger animals, but it requires extra supports and the initial costs are higher than the costs of other materials. Wood is the least expensive material, but it can be chipped by the animals and needs to be replaced at least every 2 to 4 years. Plain steel and aluminum slats are subject to corrosion, but they can be galvanized or coated with paint or plastic to extend their life. Plastic slats, metal grates, expanded metal mesh, and stainless steel slotted planks are appropriate for swine farrowing and nursery operations that house smaller pigs. Openings between slats should be greater than 3/4 inch, up to 1 3/4 inches for swine operations.

Demonstration Status: The *Swine '95* report (USDA APHIS, 1996) demonstrates that liquid systems, although not the most common type on a facility-by-facility basis, are still used fairly frequently. Flushing under slats accounts for 5.3 percent of farrowing, 9.4 percent of nursery, and 2.4 percent of grower-finisher operations, whereas flushing with open gutter systems accounts for 3.0, 2.1, and 3.4 percent of each operation type, respectively. Liquid handling systems are becoming increasingly popular as larger operations become more prevalent, necessitating automated systems for manure handling.

Poultry waste is mostly handled as a dry litter, the exception being layer operations, particularly those in the South region. Approximately 40 percent of the laying operations in the South use a flush system with a lagoon (USDA NAHMS, 2000a).

Dairy '96 (USDA APHIS, 1996A) reports that a small number of dairy farms, 2.8 percent, use water to remove manure from alleys. However, over 90 percent of operations with 200 or more cows are reported to use liquid manure storage systems (USDA APHIS, 1996B). According to the NAHMS survey results (Garber, 1999), approximately 50% of all facilities with greater than 500 mature dairy cows employ flushing as a means of cleaning the housing area.

A flushing system dilutes manure from beef feedlots with water to allow for automated handling. The system uses a large volume of water to flush manure down a sloped gutter to storage, where the liquid waste can be transferred to a storage lagoon or basin. This system is not common for large beef feedlots; however, this type of system is widely used at veal operations (Loudon, 1985). Based on EPA site visits, about 67 percent of veal operations flush manure to liquid lagoon storage systems.

Practice: Berms and Storm Water Diversions

Description: "Clean" storm water runoff from land surrounding livestock facilities can be diverted from barns, open animal concentration areas, and waste storage or treatment facilities to prevent mixing with wastewater. This is accomplished through earthen perimeter controls and roof runoff management techniques.

Earthen perimeter controls usually consist of a berm, dike, or channel constructed along the perimeter of a site. Simply defined, an earthen perimeter control is a ridge of compacted soil, often accompanied by a ditch or swale with a vegetated lining, located at the top or base of a sloping area. Depending on their location and the topography of the landscape, earthen perimeter controls can achieve one of three main goals: preventing surface runoff from entering a site, diverting manure-laden runoff created on site to off-site waste trapping devices, and intercepting "clean" storm water runoff and transporting it away from lagoons or belowground tanks. Therefore, diversions are used to protect areas from runoff and divert water from areas where it is in excess to locations where it can be stored, used, or released. Thus, it prevents the mixing of "clean" storm water with manure-laden wastewater, reducing the volume of wast water to be treated.

Roof runoff management techniques such as gutters and downspouts direct rainfall from roofs away from areas with concentrated manure. Because these devices prevent storm water from mixing with contaminated water, they also reduce the volume of wastewater to be treated.

Application and Performance: Earthen perimeter controls or diversions are applicable where it is desirable to divert flows away from barns, open animal concentration areas, and waste storage or treatment facilities. They can be erected at the top of a sloping area or in the middle of a slope to divert storm water runoff around a feeding or manure storage site. However, unvegetated, earthen channels should not be used in regions of high precipitation because of potential erosion problems.

The design capacity of a channel is calculated using Manning's equation and is based on precipitation, slope, wetted perimeter, water cross-sectional area, and surface roughness. Water velocity is also a consideration in designing diversions to minimize erosion. Other types of diversions that can be used for runoff control include grassed waterways, which are natural or constructed channels that provide stable runoff conveyance, and lined waterways or outlets, which are lined channels or outlets reinforced with erosion-resistant linings of concrete, stone, or other permanent materials to provide additional stability.

Advantages and Limitations: When properly placed and maintained, earthen perimeter controls are effective for controlling the velocity and direction of storm water runoff. Used by themselves, they do not have any ability to remove pollutants and thus must be used in combination with an appropriate sediment or waste trapping device at the outfall of the diversion channel. With these diversion techniques, storm water runoff is prevented from mixing with contaminated manure-laden wastewater and thus the volume of water for treatment is decreased;.however, the concentrated runoff in the channel or ditch has increased erosion potential. To such erosion, diversion dikes must be directed to sediment trapping devices where erosion sediment can settle out of the runoff before being discharged. In addition, if a diversion dike crosses a vehicle roadway or entrance, its effectiveness may be reduced. Wherever possible, diversion dikes should be designed to avoid crossing vehicle pathways.

Operational Factors: The siting of earthen perimeter controls depends on the topography of the area surrounding a specific site. When determining the appropriate size and design of these diversion channels, the shape of the surrounding landscape and drainage patterns should be considered. Also, the amount of runoff to be diverted, the velocity of runoff in the diversion, and the erodibility of soils on the slope and within the diversion channel or swale are essential design considerations.

Both diversion channels and roof management devices must be maintained to remain effective. If vegetation is allowed to grow in diversions, the roughness increases and the channel velocity decreases which can cause channel overflow. Therefore, vegetation should be periodically mowed. In addition, the dike should be maintained at the original height, and any decrease in height due to settling or erosion should be remedied.

Roof management devices such as gutters and downspouts must be cleaned and inspected regularly to prevent clogging and to ensure its effectiveness.

Demonstration Status: The use of earthen perimeter techniques such as berms, diversions, and channels and the use of roof management techniques to divert storm water away from barns, open animal concentration areas, and waste storage or treatment facilities are well-accepted practices that prevent “clean” wastewater from mixing with manure-laden wastewater, thus reducing the volume of wastewater to be treated.

8.2.2 Waste Storage Technologies and Practices

The USDA NRCS recommends that storage structures be designed to handle the volume of manure produced between emptying events. The minimum storage period is based on the timing required for environmentally safe waste utilization considering climate, crops, soil, equipment, and local, state, and federal regulations. The design storage volume for liquid manure should account for manure, wastewater, precipitation and runoff (if uncovered), and other wastes that will accumulate during the storage period, such as residual solids that are not removed when liquids are pumped. Other general considerations are inlet designs, outlets or pumping access, and safety (such as fencing, odor and gas control, reinforcement against earth movements and hydrostatic pressure, use of a cover, and amount of freeboard).

Practice: Anaerobic Lagoons

Description: Anaerobic lagoons are earthen basins that provide storage for animal wastes while decomposing and liquefying manure solids. Anaerobic processes degrade high biochemical oxygen demand (BOD) wastes into stable end products without the use of free oxygen. Anaerobic lagoons are designed based on volatile solids loading rates (VSLR). Volatile solids are the wastes that will decompose. The volume of the lagoon consists of the following (see Figure 8-4):

1. Minimum Treatment Volume—The total daily volatile solids from all waste sources divided by the volatile solids loading rate for a particular region. The minimum treatment volume is based on the volatile solids loading rate, which varies with temperature and therefore with geographic location. Recommended volatile solids loading rates in the United States vary from 3 to 7 pounds per 1,000 ft^3 per day.

2. Sludge Volume—Volume of accumulated sludge between cleanouts. A fraction of the manure solids settles to the bottom of the lagoon and accumulates as sludge. The amount of sludge accumulation depends on the type and amount of animal waste.

3. Manure and Wastewater Volume—The volume of manure and wastewater transferred from feedlot operational facilities to the lagoon during the storage period. Lagoons are typically designed to store from 90 to 365 days of manure and wastewater.

4. Net Precipitation—Precipitation minus the evaporation during the storage period.

5. Design Storm—Typically a 25-year, 24-hour storm event.

6. Freeboard—A minimum of 1 foot of freeboard. Freeboard is the extra depth added to the pond as a safety factor.

7. Runoff—The runoff volume from lagoon berms. In general, lagoons should not receive runoff because runoff can shock the lagoon with an overload of volatile solids. Some runoff will enter the lagoons from the berms surrounding them.

Anaerobic lagoons should be at least 6 to 10 feet deep, although 8- to 20-foot depths are typical. Deeper lagoons require a smaller surface area, and they more thoroughly mix lagoon contents as a result of rising gas bubbles and minimize odors. Lagoons are typically constructed by excavating a pit and building berms around the perimeter. The berms are constructed with an extra 5 percent in height to allow for settling. The sides of the lagoon should be sloped with a 2:1 or 3:1 (horizontal:vertical) ratio. Lagoons can be designed as single-stage or multiple-stage (usually two stages). Two-stage lagoons require greater total volume but produce a higher quality lagoon effluent.

Lagoon covers can be used to control odor and collect biogas produced from the natural decomposition of manure. Covers are usually made of a synthetic material, and are designed to float on the surface of the lagoon. Often, because of the large size of the lagoon, the cover is constructed in multiple modules. Each module has flotation devices at the corners to help support the cover, and is tied down at the edge of the pond or lagoon. Covers typically have drains constructed in them to allow rainwater to drain through to the lagoon.

Lagoons are sometimes used in combination with a solids separator, typically for dairy waste. Solids separators help control the buildup of nondegradable material such as straw or other bedding materials. These materials can form a crust on the surface of the lagoon, which decreases its activity.

Application and Performance: Anaerobic lagoons provide effective biological treatment of animal wastes. Anaerobic lagoons can handle high pollutant loads while minimizing manure odors. Nondegradable solids settle to the bottom as sludge, which is periodically removed. The liquid is applied to cropland as fertilizer or irrigation water or is transported off site. Properly managed lagoons will have a musty odor. Anaerobic processes decompose faster than aerobic processes, providing effective treatment of wastes with high BOD, such as animal waste. Anaerobic lagoons are larger than storage ponds because additional volume is needed to provide biological treatment; however, since a constant oxygen concentration is not required, anaerobic lagoons are generally smaller than aerobic lagoons.

Lagoons reduce the concentrations of both N and P in the liquid effluent. Phosphorus settles to the bottom of the lagoon and is removed with the lagoon sludge. Approximately 60 percent of the influent N is lost through volatilization to ammonia (Fulhage, Van Horn). Microbial activity converts the organic N to ammonia N. Ammonia N can be further reduced to elemental nitrogen (N_2) and released into the atmosphere. Lagoon effluent can be used for land application or flushing of animal barns, or can be transported off site. The sludge can also be applied to land provided the soil is not saturated with nutrients. Information on the reduction of BOD, pathogens, and metals in lagoons is not available. Reductions in chemical oxygen demand, total solids, volatile solids, total N, P, and potassium are presented in Table 8-10.

Table 8-10. Anaerobic Unit Process Performance

Anaerobic Treatment	**HRT**	**COD**	**TS**	**VS**	**TN**	**P**	**K**
	days	Percent Reduction					
Pull plug pits	4-30	—	0-30	0-30	0-20	0-20	0-15
Underfloor pit storage	30-180	—	30-40	20-30	5-20	5-15	5-15
Open top tank	30-180	—	—	—	25-30	10-20	10-20
Open pond	30-180	—	—	—	70-80	50-65	40-50
Heated digester effluent prior to storage	12-20	35-70	25-50	40-70	0	0	0
Covered first cell of two cell lagoon	30-90	70-90	75-95	80-90	25-35	50-80	30-50
One-cell lagoon	>365	70-90	75-95	75-85	60-80	50-70	30-50
Two-cell lagoon	210+	90-95	80-95	90-98	50-80	85-90	30-50
HRT=hydraulic retention time; COD=chemical oxygen demand; TS=total solids; VS=volatile solids; TN=total nitrogen; P=phosphorus; K= potassium; — =data not available.							

Source: Moser and Martin, 1999

Advantages and Limitations: Anaerobic lagoons offer several advantages over other methods of storage and treatment. Anaerobic lagoons can handle high pollutant loads and provide a large volume for long-term storage. They stabilize manure wastes and reduce N content through biological degradation. Lagoons allow manure to be handled as a liquid, which reduces labor costs. If lagoons are located at a lower elevation than the animal barns, gravity can be used to transport the waste to the lagoon, which further reduces labor. Mild climates are most suitable for lagoons; cold weather reduces the biological activity of the microorganisms that degrade the wastes. Lagoons can experience spring and fall turnover, in which the more odorous bottom material rises to the surface. Foul odors can also result if biological activity is reduced or if there is a sudden change in temperature or pollutant loading rate.

Operational Factors: To avoid ground water and soil contamination, several factors must be considered. The lagoon should be located on soils with low to moderate permeability or on soils that can form a seal through sedimentation and biological action (NRCS). Impervious barriers or liners are used to reduce seepage through the lagoon bottom and sides and are described in the following practice.

Lagoon inlets should be designed from materials that resist erosion, plugging, and freezing. Vegetation around the pond should be maintained to help stabilize embankments.

Lagoons must be properly maintained for effective treatment. The minimum treatment volume of the lagoon must be maintained. Lagoons work best when the influent flow is a steady, gradual flow rather than a large slug flow. The pH of the lagoon should be monitored. The optimum pH for lagoon treatment is about 6.5, which maximizes the activity level of the bacteria. Lime can be added to the lagoon to increase pH to this level. Also, since the rate of volatile solids decomposition is a function of temperature, the acceptable volatile solids loading rate varies with climate. The loading rate should be monitored to ensure that it is appropriate to the region in which the lagoon is located.

Demonstration Status: Anaerobic lagoons without covers are used at 20.9 percent of all grower-finisher swine operations. Of these, swine operations with 10,000 or more head use uncovered lagoons most frequently (81.8 percent) (USDA APHIS, 1996). Lagoons are used on egg-laying farms in warmer climates. Beef facilities typically use storage ponds rather than lagoons. NAHMS estimates that 1.1 percent of dairies with more than 200 head use anaerobic lagoons with a cover and 46.7 percent use anaerobic lagoons without a cover (USDA APHIS, 1996b). The use of lined lagoons is dependent on site-specific conditions.

Practice: Lagoon Liners

Description: Lagoon liners are impervious barriers used to reduce seepage through the lagoon bottom and sides.

Application and Performance: Soil that is at least 10 percent clay can be compacted with a sheepsfoot roller to create a suitable impervious barrier. If the soil is not at least 10 percent clay, a liner or soil amendment should be used. There are also site conditions that may require seepage

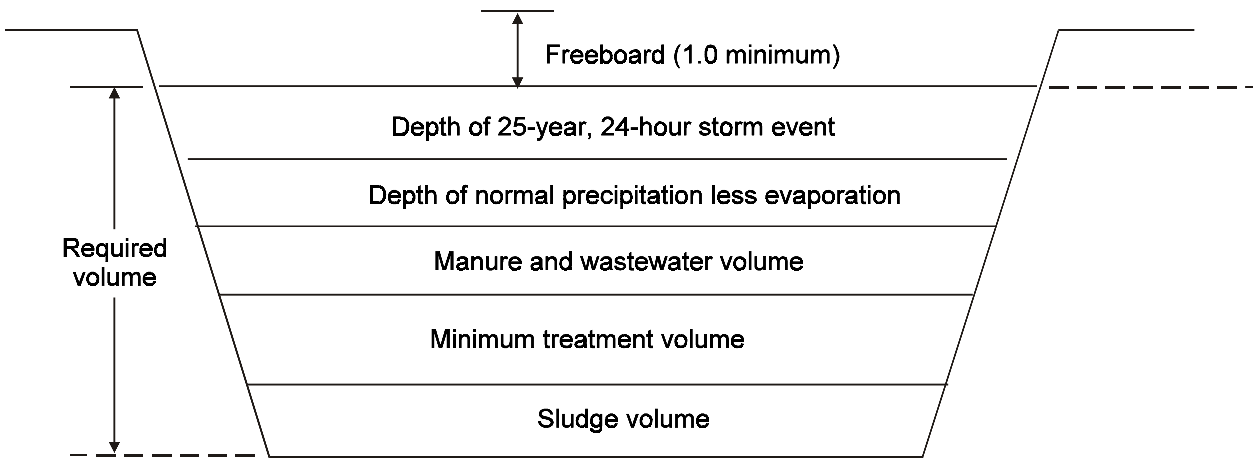


Figure 8-4. Cross Section of Anaerobic Lagoons
(Source: USDA NRCS, 1998)

reduction beyond what is provided by compacting the natural soil. These conditions may include a shallow underlying aquifer, an underlying aquifer that is ecologically important or used as a domestic water source, or highly permeable underlying bedrock or soil. There are three options available to provide additional seepage reduction. First, the soil can be mixed with bentonite or a soil dispersant and then compacted. Clay can be imported from another area and compacted along the bottom and side walls. Last, concrete or synthetic materials such as geomembranes or geosynthetic clay liners can be used.

Advantages and Limitations: Concrete and synthetic liners are usually the most expensive.

Operational Factors: The method chosen to line the lagoon depends on the type of soil, site geography and location, available materials, and economics.

Demonstration Status: The use of lined lagoons depends on site-specific conditions.

Practice: Storage Ponds

Description: Waste storage ponds are earthen basins used to store wastes temporarily, including runoff, solids (e.g. manure), and wastewater. The total volume of the pond consists of the following (see Figure 8-5):

1. Sludge Volume—Volume of accumulated sludge between cleanouts. A fraction of the manure solids settles to the bottom of the pond and accumulates as sludge. The amount of sludge accumulation depends on the type and amount of animal waste.

2. Manure and Wastewater Volume—The volume of manure and wastewater from feedlot operational facilities transferred to the pond during the storage period. Ponds are typically designed to store from 90 to 270 days of manure and wastewater. The percentage of solids in the influent will depend on animal type and the waste management system.

3. Runoff—The runoff from the sites (usually the drylot area at animal feeding operations).

4. Net Precipitation—Precipitation minus the evaporation for the storage period.

5. Design Storm—Typically a 25-year, 24-hour storm event.

6. Freeboard—A minimum of 1 foot of freeboard. Freeboard is the extra depth added to the pond as a safety factor.

Ponds are typically rectangular in shape and are constructed by excavating a pit and building berms around the perimeter. The berms are constructed with an extra 5 percent in height to allow for settling. The sides of the pond are typically sloped with a 1.5:1 or 3:1 (horizontal:vertical) ratio.

Ponds are typically used in combination with a solids separator. Solids separators help control buildup of material such as straw or other bedding materials on the surface of the pond.

Pond covers can be used to control odor and collect biogas produced from the natural degradation of manure. Covers are usually made of a synthetic material, and are designed to float on the surface of the impoundment. Often, because of the large size of the pond, the cover is constructed in multiple modules. Each module has flotation devices at the corners to help support the cover, and is tied down at the edge of the pond. Covers typically have drains constructed in them to allow rainwater to drain through to the pond.

Application and Performance: Waste storage ponds are frequently used at animal feeding operations to contain wastewater and runoff from contaminated areas. Manure, process water, and runoff are routed to these storage ponds, where the mixture is held until it can be used for

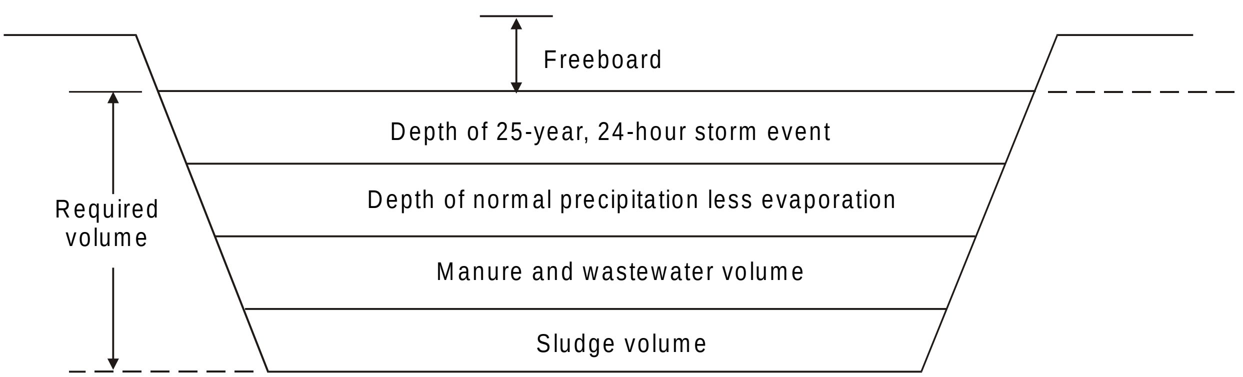


Figure 8-5. Cross Section of Waste Storage Pond (Source: USDA 1996)

irrigation or transported off site. Solids settle to the bottom as sludge, which is periodically removed. The liquid is applied to cropland as fertilizer or irrigation water, or is transported off site.

Storage ponds hold wastewater and manure and are not intended to actively treat the waste. Because they do not require additional volume for treatment, storage ponds are smaller in size than treatment lagoons.

Ponds reduce the concentrations of both N and P in the liquid effluent. Phosphorus settles to the bottom of the pond and is removed with the sludge. Influent N is reduced through volatilization to ammonia. Pond effluent can be used for land application or flushing animal barns, or it can be transported off site. The sludge can also be applied to the land provided the soil is not saturated with P.

Advantages and Limitations: Storage ponds provide a large volume for long-term waste storage and allow manure to be handled as a liquid. If ponds are located at a lower elevation than the animal barns, gravity can be used to transport the waste to the pond, which minimizes labor. Although ponds are an effective means of storing waste, no treatment is provided. Because ponds are open to the air, odor can be a problem.

Operational Factors: To avoid ground water and soil contamination, several factors must be taken into consideration. Impervious barriers or liners are used to reduce seepage through the pond bottom and sides. Soil that is at least 10 percent clay can be compacted with a sheepsfoot roller to create a suitable impervious barrier. If the soil is not at least 10 percent clay, a liner or soil amendment should be used. There are also site conditions that may require seepage reduction beyond what is provided by compacting the natural soil. Conditions may include a shallow underlying aquifer, an underlying aquifer that is ecologically important or used as a domestic water source, or highly permeable underlying bedrock or soil. There are three options available to provide additional seepage reduction. First, the soil can be mixed with bentonite or a soil dispersant and then compacted. Clay can be imported from another area and compacted along the bottom and side walls. Last, concrete or synthetic materials such as geomembranes or geosynthetic clay liners can be used. Concrete and synthetic liners are usually the most expensive. The method chosen to line the pond depends on the type of soil, site geography and location, available materials, and economics.

Pond inlets should be designed from materials that resist erosion, plugging, and freezing. Vegetation around the pond should be maintained to help stabilize embankments.

Demonstration Status: Ponds are a common method of waste storage for swine, beef, and dairy facilities and are used on poultry farms in warmer climates. Beef feedlots tend to use storage ponds for collection of runoff from the drylots. EPA estimates that 50 percent of the medium-size (300-1000 head) beef feedlots in all regions and 100 percent of the large-size (>1,000 head) beef feedlots in all regions have a storage pond for runoff. NAHMS estimates 27.8 percent of dairies use earthen storage basins (USDA APHIS, 1999). The use of lined ponds depends on site-specific conditions.

Practice: Pit Storage

Description: Manure pits are a common method for storing animal wastes. They can be located inside the building underneath slats or solid floors, or outside and separated from the building. Typical storage periods range from 5 to 12 months, after which manure is removed from the pit and transferred to a treatment system or applied to land. There are several design options for pit storage. For example, shallow pits under slats provide temporary storage and require more frequent manure removal to longer-term storage or for land application. Pit recharge systems, which are common in the Midwest, involve regularly draining the pit contents to a lagoon and recharging the pit with fresh or recycled water. The regular dissolution of solids keeps the pits free of excessive buildup while providing temporary storage for manure. Pit recharge systems typically have level floors with an average depth of 12 inches of recharge water, 12 inches allowed for waste accumulation, and 12 inches of air space between the pit surface and the slatted floor.

Application and Performance: Because agitating and pumping equipment does not handle solid or fibrous materials well, manure with greater than 15 percent solids will require dilution. Chopper-type agitators may be needed to break up bedding or other fibrous materials that might be present in the pit.

Advantages and Limitations: Below-floor storage systems provide ease of collection and minimize volume while maximizing fertilizer value, but they may cause a buildup of odors and gases and can be difficult to agitate and pump out. Remote storage avoids odor and gas buildup in animal housing areas and provide options for methane production and solids separation, but entails additional costs for transfer from the housing facilities to storage.

Operational Factors: Pits must have access for pumping equipment, and outside pits must be covered or fenced to prevent accidental entry into the pit. They should be designed to withstand anticipated hydrostatic, earth, and live loads as well as uplifting in high-water-table areas. Before the pit is filled with manure, water is typically added to prevent solids from sticking to the pit floor. Depths range from 3 to 4 inches under slatted floors and 6 to 12 inches if manure is scraped and hauled to the pit. Sand should not be used as a bedding material because it is incompatible with pumping systems. The pits should always be free of nails, lumber, or other foreign material that can damage equipment.

Demonstration Status: Pit holding is mostly done at swine operations. *Swine '95* (USDA-APHIS, 1996) reports that pit holding accounts for 25.5, 33.7, and 23.2 percent of farrowing, nursery, and grower-finisher operations, respectively.

Below-floor slurry or deep pit storage is reported in *Dairy '96* (USDA APHIS, 1996b) at 7.9 percent of all dairy operations. Based on EPA site visits, about 33 percent of veal operations are believed to utilize pit storage systems. Beef feedlots do not typically utilize pit storage.

Practice*: *Belowground or Aboveground Storage Tanks

Description: Belowground and aboveground storage tanks are used as an alternative to under-building pit storage and earthen basins. Both aboveground and belowground tanks are commonly constructed of concrete stave, reinforced monolithic concrete, lap or butt joint coated steel, or spiral wound coated steel with concrete floors. Current assembly practices for aboveground storage facilities are primarily circular silo types and round concrete designs, but the structures may also be rectangular. Belowground storage can be located totally or partially below grade. All storage tanks must be engineered to withstand operational constraints, including internal and external hydrostatic pressure, flotation and drainage, live loads from equipment, and loads from covers and supports. Belowground tanks should be surrounded by fences or guardrails to prevent people, livestock, or equipment from accidently entering the tank.

When located directly adjacent to the animal housing facility, belowground tanks are easily filled by scraping directly into the tank. In those situations where the storage tank is not adjacent to the animal housing facility, a collection pit or sump is necessary for loading. In these systems a large piston or pneumatic manure pump forces waste through a large-diameter underground pipe. Aboveground tanks at a lower grade than the livestock housing facility can often be gravity-fed through a similar underground pipe. The tank can be loaded from the top or bottom. Bottom loading in aboveground tanks is most appropriate for manure that forms a surface crust, such as cattle manure. The inlet pipe is usually located 1 to 3 feet above the bottom of the tank to prevent blockages from solids. An advantage to bottom loading is that it pushes solids away from the inlet pipe and distributes them more evenly. Top loading is suitable and most common for manures that do not crust (i.e., liquid swine manure); however, top loading in an aboveground system requires that manure be pumped against gravity. Figure 8-6 shows a typical aboveground storage tank.

Application and Performance: Aboveground or belowground tanks are suitable for operations handling slurry (semisolid) or liquid manure. This generally excludes open-lot waste which is inconsistent in composition and has a higher percentage of solids. Furthermore, because of the high cost of storage volume, prefabricated storage tanks are generally used to contain only waste, but not runoff, from the livestock facility.

Belowground and aboveground storage tanks are appropriate and preferred alternatives in situations where the production site has karst terrain, space constraints, or aesthetics issues associated with earthen basins. Storing manure in prefabricated or formed storage tanks is especially advantageous on sites with porous soils or fragmented bedrock. Such locations may be unfit for earthen basins and lagoons out of concern that seepage and ground water contamination may occur. Construction of formed storage tanks often includes installation of a liner beneath the concrete to prevent seepage. Aboveground formed storage facilities allow visual monitoring for leaking. Aboveground tanks may exhibit unsightly leaks at seams, bolt holes, or joints, but these are usually quickly sealed with manure. In these storage systems the joint between the foundation and sidewall is the greatest concern. Leaching and ground water contamination can occur if the tank is not sealed properly.

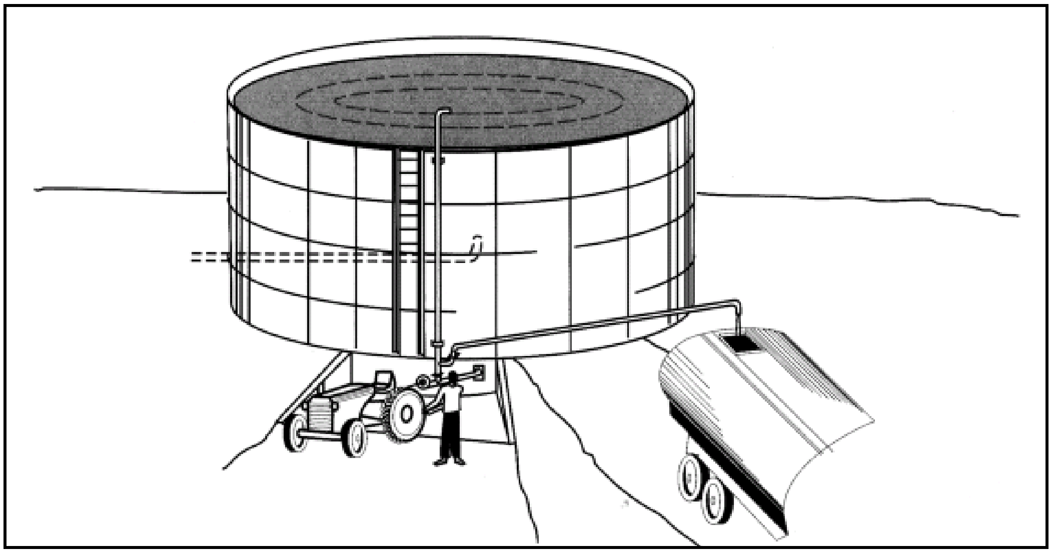


Figure 8-6. Aboveground Waste Storage Tank (from USDA NRCS, 1996).

Proper operational practices to maintain adequate storage tank capacity between land applications are critical. The holding volume of a storage tank consists of five fractions: residual volume, manure/waste storage volume (bedding, wasted feed, water added for manure handling), wash water volume, net rainfall and evaporation change, and freeboard capacity.

In general, large amounts of water are not added during the handling of manure that is stored in an aboveground or belowground storage tank. Installation costs usually dictate that capacity be limited to manure storage requirements. Thus, water conservation is often practiced by facilities that use aboveground or belowground storage tanks. For these facilities, recycling of wastewater is not an option because the manure is generally in slurry form with more than 4 percent solids.

Aboveground and belowground storage tanks are simply storage facilities, and they do not facilitate treatment of the manure. Thus, there is little to no effect on the reduction of nutrients, pathogens, solids, heavy metals, growth hormones, or antibiotics. Nitrogen in liquid manure is predominately in the inorganic form. This allows for some ammonia volatilization into the atmosphere and a reduction in the total amount of N.

Advantages and Limitations: When these systems are used, manure agitation is necessary before the contents of the storage structure are pumped into a tanker wagon for land application. Agitation ensures uniform consistency of manure and prevents the buildup of solids, thus maintaining the storage capacity of the tank. Agitation results in a more even distribution of nutrients in the manure prior to land application. It can be accomplished with high-horsepower, propeller-type agitators or by recirculating with a high-capacity pump. The length of time the manure needs to be agitated depends on the size of the storage tank, the volume of manure it contains, the percent of solids in the manure, and the type of agitator. Manure with up to 15 percent solids can be agitated and pumped. Because of the potential for agitation and pumping problems, only small amounts of chopped bedding are recommended for use in systems using storage tanks. Some types of agitators have choppers to reduce the particle size of bedding and solids. Dilution with additional water may be necessary to reduce agitation problems. One design variation places the pump in a sump outside the tank, using it for both agitation and pumpouts.

Manure in a storage tank undergoes some anaerobic decomposition, releasing odorous and potentially toxic gases, such as ammonia and hydrogen sulfide. Methane is also produced. Covers can be installed to interrupt the flow of gases up from the liquid surface into the atmosphere. Types of covers range from polyethylene, concrete, or geotextile to biocovers such as chopped straw. Various covers have been shown to reduce odors by up to 90 percent. Furthermore, particular types of covers can be used as methane reservoirs to collect and contain gases from the digestion process for disposal by flaring or converting to electrical power. Moreover, certain covers can prevent rainwater dilution and accumulation of airborne silts and debris. Finally, it is generally accepted that some types of covers control N volatilization into the atmosphere and maintain the N content of the manure.

The installation costs associated with prefabricated storage tanks are high when compared with other liquid manure-handling systems. Glass-lined steel tanks are typically associated with the highest cost. The useful life of the tanks depends on the specific manufacturer and the operator's maintenance practices. Once they have been installed, aboveground and belowground storage tanks have a low labor requirement, especially when designed as a gravity feed system (Purdue Research Foundation, 1994).

Operational Factors: Specific storage structure designs will vary by state because of climate and regulatory requirements. Pumping manure during freezing conditions can be a problem unless all pipes are installed below the freezing level in the ground. Design considerations in these systems include check valves if bottom loading is used, pumping power with respect to the maximum head, and pipe friction from the pump to the storage.

Demonstration Status: Belowground and aboveground storage tanks are in use nationwide in swine, poultry, and dairy operations. They are appropriate for use in all slurry-based manure handling systems, including those with shallow-pit flush systems, belt or scrape designs, or open-gutter flush systems.

Practice: Solid Poultry Manure Storage in Dedicated Structures

Description: In the broiler and turkey segments of the poultry industry, specially designed pole-type structures are typically used for the temporary storage of solid poultry manure; however, horizontal (bunker) silo-type structures are also used. Manure produced in "high-rise" houses for caged laying hens does not require a separate storage facility if handled as a solid.

A typical pole-type storage structure is 18 to 20 feet high and 40 feet wide. The length depends on the storage capacity desired but is usually a minimum of 40 feet. The structure will have a floor of either compacted soil or concrete, the latter being more desirable but much more expensive. The floor elevation should be at a height above grade that is adequate to prevent any surface runoff from entering the structure. A properly sited structure will be oriented parallel to

the direction of the prevailing wind. Equipment access will be through the lee side, which will have no wall. The other three sides of the structure will have walls extending from the floor to a height of 6 to 8 feet. Experience has shown that a higher wall on the windward side of the building excludes precipitation more effectively. Walls may be constructed using pressure-treated lumber or reinforced concrete. Wooden trusses covered with steel sheets are most commonly used for roofing, although plywood roof decking covered with composition shingles is also an option. Manure is usually stacked to a height of 5 to 8 feet. Figure 8-7 shows three types of permanently covered solid manure storage structures.
Horizontal silo-type storage structures are also used for the temporary storage of solid poultry manure. These storage structures can be constructed using either post-and-plank or reinforced concrete walls on three sides. Equipment access will be through the lee side which will have no wall. Concrete walls can be poured in place or made with prefabricated sections that are manufactured for horizontal silo construction. Wall height can be from as low as 3 to 4 feet to as high as 8 to 10 feet if prefabricated concrete sections are used. Usually, there is a concrete floor.

Again, floor elevation should be sufficiently above grade to prevent surface runoff from entering the structure. With this type of storage structure, 6-mil or heavier plastic is typically used to cover the stored manure, but tarpaulins have also been used. As with horizontal silos, old tires are commonly used to secure the cover, although ropes or cables can also be used. Manure is usually stacked to a height of 5 to 8 feet.

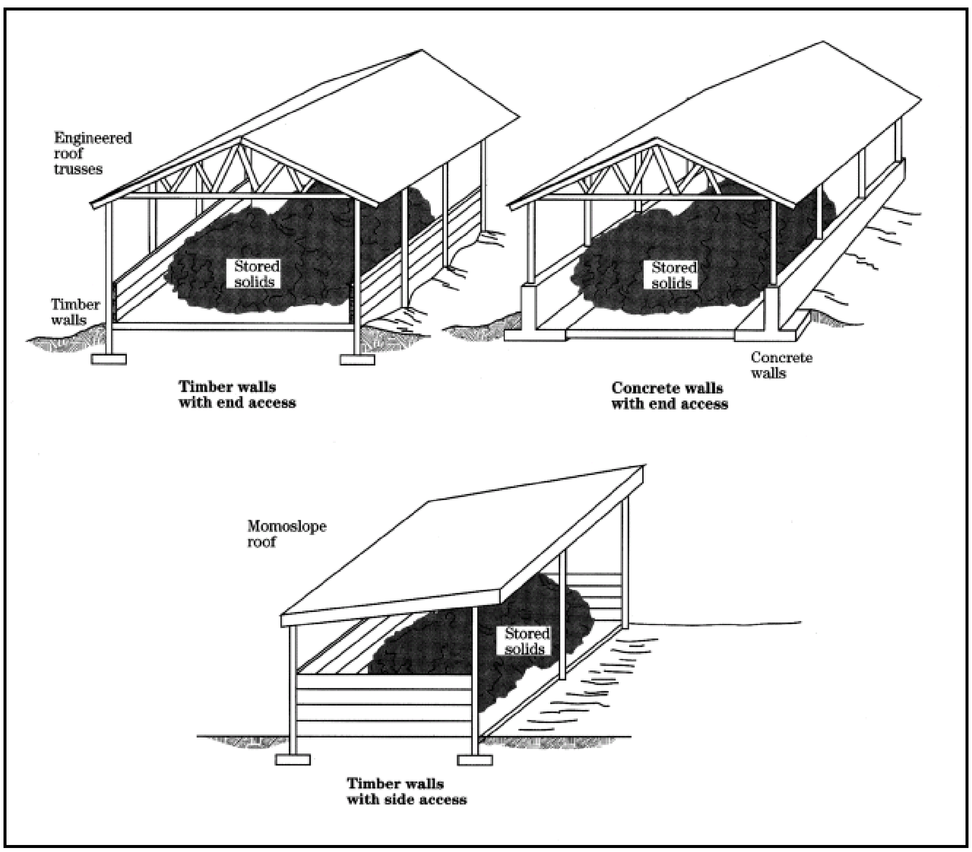


Figure 8-7. Roofed Solid Manure Storage (from USDA NRCS, 1996).

In the broiler industry, total cleanouts of production facilities occur only after a minimum of 1 year of production. A total cleanout frequency of 2 to 3 years is not uncommon. Total cleanouts may be more frequent for brood chambers, but the frequency depends on the cost and availability of bedding material, the incidence of disease, the concentration of gaseous ammonia within the production facility, and the policy of the integrator. Caked manure, also known as crust, is removed after every flock, typically a period of 49 days for 4- to 5-pound broilers. Usually, storage structures are designed only for the storage of this caked manure because most broiler growers view the cost of a structure large enough to store manure and litter from a total cleanout as prohibitively high. Because caked manure production varies with the type of bedding material, type of watering system, and climatic conditions, storage requirements may vary from farm to farm. Also, cake production increases with bedding age. Local experience is usually relied upon to estimate storage requirements.

In the turkey industry, total cleanouts of brooder facilities occur after every flock to control disease, but grow-out facilities typically are totally cleaned out only once a year. Again, most turkey growers consider the cost of storage of the manure and bedding from a total cleanout of grow- out facilities to be prohibitively high. Therefore, structures are typically sized only for the storage of manure and bedding from brooder houses.

Application and Performance: The temporary storage of solid poultry manure in a dedicated structure is applicable to all poultry operations at which birds are maintained on a bedding material. Thus, this practice is applicable to all broiler and turkey operations and the small fraction of egg-producing operations that do not house birds in cages. The combination of manure and bedding generated in these operations has a moisture content of less than 50 percent, usually 25 to 35 percent, and is handled as a solid. This practice is not necessary for caged laying hens in high-rise housing because the production facility has a manure storage capacity of 1 or more years.

When sized and managed correctly, storage of solid poultry manure in a dedicated structure will allow for the most efficient use of plant nutrients in the manure for crop production. This eliminates the potential for contamination of surface and ground waters resulting from open stacking of manure or spreading during the fall, winter, and early spring and after crop establishment, when there is no potential for crop uptake. When the stored manure is effectively protected from precipitation, odor and fly problems are minimal. Odor can be a problem, however, when the manure is removed from the storage structure and spread on cropland.

The storage of caked broiler litter and turkey brooder house manure and bedding reduces the potential impact of these materials on surface and ground water quality; however, a substantial fraction of the manure and bedding produced by these segments of the poultry industry is not stored because the associated cost is viewed as prohibitive. The material resulting from the total cleanout of broiler houses and turkey grow-out facilities is often stored temporarily in open piles or spread at inappropriate times of the year. Thus, storage, as currently practiced, probably is not as effective in reducing water quality impacts as is presently thought.

Advantages and Limitations: A correctly sized and managed storage structure allows application to cropland when nutrients will be most efficiently used, thus minimizing negative impacts on surface and ground waters as noted above. If application to cropland is not a disposal alternative, storage can facilitate off-site disposal other than application to cropland.

The principal disadvantage of storing solid poultry manure in a dedicated structure is the cost of the structure and additional material handling costs. Currently, sources of government assistance are available (e.g., cost-share funds available from local soil and water conservation districts) to partially offset construction costs and encourage the adoption of this practice.

Operational Factors: Spontaneous combustion in stored poultry manure has been a problem and has led to the recommendation that stacking height be limited to 5 to 8 feet to avoid excessive compaction. Fires in solid poultry manure storage structures, like silo fires, are extremely difficult to extinguish and often lead to the total loss of the structure.

Demonstration Status: Permanent covered structures for storage of solid manure are used extensively in the broiler and turkey segments of the poultry industry. In a 1996 survey of broiler growers on the Delmarva Peninsula, 232 of 562 respondents indicated that they used a permanent storage structure (Michel et al., 1996).

Practice: Concrete Pads

Description: Concrete pads are used as semi-impermeable surfaces upon which to place waste. The waste pile is often open to the environment, but it can be covered with a roof or plastic sheeting to minimize exposure to the elements. Pads are often sloped to a central location to allow for drainage of rainwater and runoff.

The design for concrete pads varies according to the type of waste it receives (wet or dry) Waste that includes settled solids from a settling basin or solids separator has a high moisture content. In this case, the concrete pad typically has at least two bucking walls to contain the waste and to facilitate the loading and unloading of waste onto the pile. The design height of the waste pile does not exceed about 4 feet, because of the semi-liquid state of the waste. For operations with drier waste, the concrete pad typically does not have bucking walls, and the maximum height of the manure pile is 15 feet, because the manure is drier and can be stacked more easily.

Figure 8-8 illustrates the design of a concrete pad (MWPS,1993; USDA NRCS, 1996). Concrete pads are between 4 and 6 inches thick and are made of reinforced concrete to support the weight of a loading truck. The concrete pad is underlain by 4 inches of sand and 6 inches of gravel. The pad is sloped to divert storm water runoff from the pile to the on-site waste management facility, such as a lagoon or a pond. Bucking walls, made of reinforced concrete, are 8 inches thick and 3 to 4 feet tall.

Application and Performance: Concrete pads are used at animal feeding operations to provide a surface on which to store solid and semi-solid wastes that would otherwise be stockpiled directly on the feedlot surface. Manure scraped from dry lots and housing facilities and solids separated from the waste stream in a solids separator can be stored on a concrete pad.

The pads provide a centralized location for the operation to accumulate excess manure for later use on site (e.g. bedding, land application) or transportation off site. A centralized location for stockpiling the waste also allows the operation to better control storm water runoff (and associated pollutants). Rainwater that comes into contact with the waste is collected on the

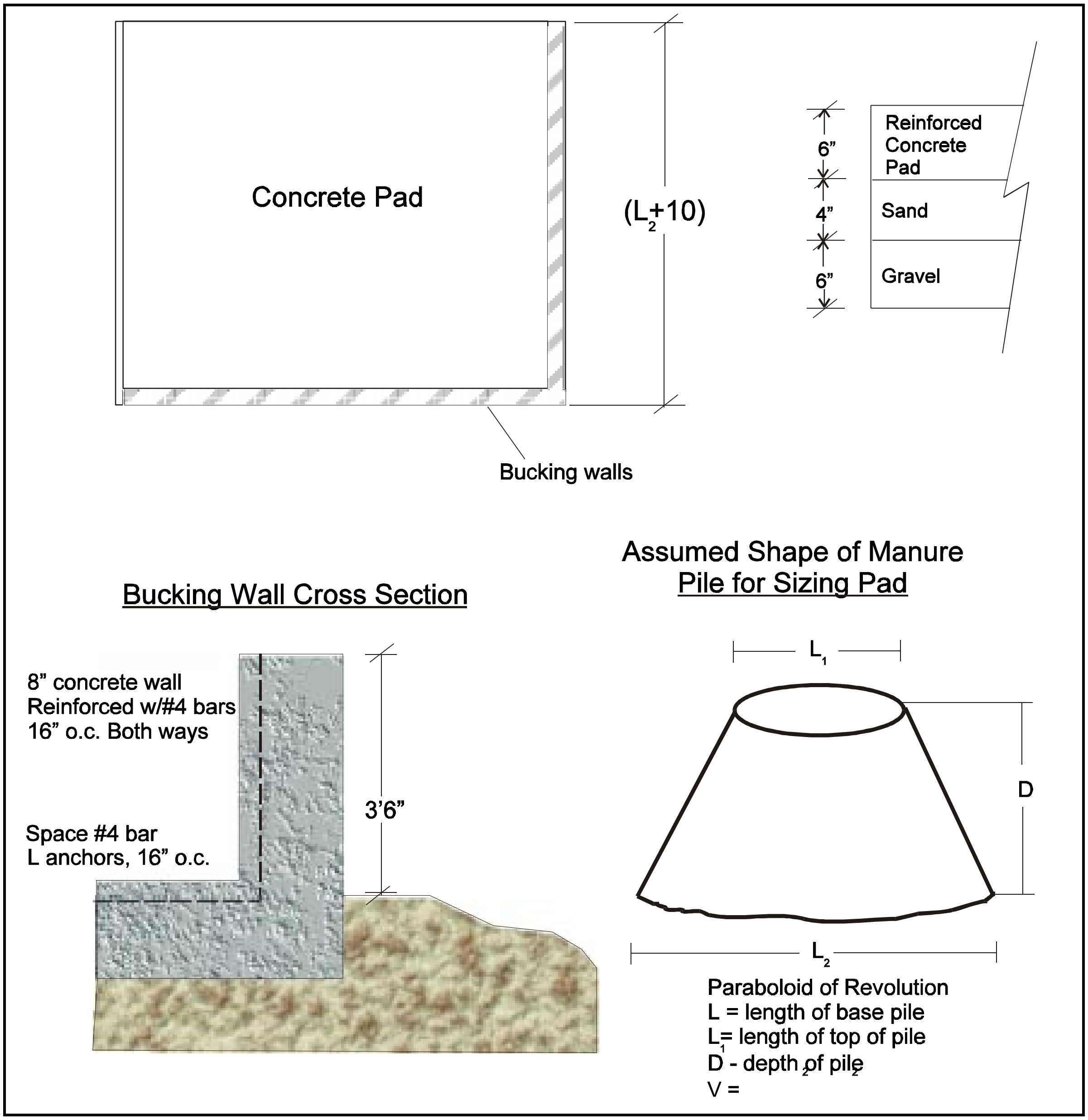


Figure 8-8 Concrete Pad Design

concrete pad and is directed to a pond or lagoon and is thereby prevented from being released on the feedlot. The pad also provides an impermeable base that minimizes or prohibits seepage of rainfall, leaching pollutants or nutrients from the waste and infiltrating into the soil beneath it. The waste is not treated once it is on the concrete pad; the pad serves as a pollution prevention measure. However, with regular handling of the waste, the N loads in the waste will be released into the atmosphere through volatilization, and both N and P may be contained in runoff from the pile after storm events. Pathogen content, metals, growth hormones, and antibiotics loads are not expected to decrease significantly on the concrete pad unless the pile ages considerably.

Advantages and Limitations: An advantage to using a concrete pad for storage is to control runoff and prevent waste from contaminating the surrounding environment. When rainwater or precipitation comes into contact with the pile, the water may percolate through the pile, carrying pollutants along the way. The water may exit the pile as runoff and carry pollutants to surface waters or seep into the ground. The concrete pad and bucking walls minimize this potential seepage into and runoff onto the ground around the pile.

Depending on the duration of storage required, however, these pads can take up a very large area. An operation may not have sufficient area to install a concrete pad large enough to store waste in one place. It can also be expensive to construct a concrete pad large enough to accommodate the amount of waste that would accumulate over an appropriate storage time.

Waste stored on a concrete pad will still need to be further managed, either by land application or by transportation off site. There may be some odors from the pile on a concrete pad, but no more than would be expected from any manure stored in a pile.

Operational Factors: Operations that frequently transport their waste will require less storage volume than operations that have less frequent hauling schedules. Operations requiring less storage capacity will require a smaller pad area, resulting in lower capital costs.

Demonstration Status: Concrete pads are used relatively infrequently in the livestock industry. They are more commonly used in dairies than in poultry, beef or swine operations, because dairy waste is semi solid and bucking walls are needed to contain the waste effectively, given the higher moisture content. Waste from swine operations is generally too wet to stack on a pad, and beef and poultry waste is usually piled directly on the feedlot.

8.2.3 Waste Treatment Technologies and Practices

8.2.3.1 Treatment of Animal Wastes and Wastewater

Some treatment systems store waste as well as change the chemical or physical characteristics of the waste. Anaerobic lagoons are the most common form of treatment for animal feeding operations. Other technologies use oxidation to break down organic matter. These include aerated lagoons and oxidation ditches for liquids and composting for solids.

Practice: Anaerobic Digesters for Methane Production and Recovery

Description: An anaerobic digester is a vessel that is sized both to receive a daily volume of organic waste and to grow and maintain a steady-state population of methane bacteria to degrade that waste. Methane bacteria are slow growing, environmentally sensitive bacteria that grow without oxygen and require a pH greater than 6.5 to convert organic acids into biogas over time. Anaerobic digestion can be simplified and grouped into two steps. The first step is easy to recognize because the decomposition products are volatile organic acids that have disagreeable odors. During the second step, methane bacteria consume the products of the first step and produce biogas—a mixture of carbon dioxide and methane—a usable fuel by-product. A properly operating digester will produce a gas with minimal odor because methane bacteria from the second step reach a population large enough to rapidly consume the products of the first step. There are three basic temperature regimes for anaerobic digestion: psychrophilic, mesophilic, and thermophilic. Psychrophilic, or low-temperature, digestion is the natural decomposition path for manures at temperatures found in lagoons. These temperatures vary from about 38 to 85 °F (3 to 29 °C). The hydraulic retention time (HRT) required for stable operation varies from 90 days at low temperatures to 30 days at higher temperatures. Methane production will vary seasonally with the variation in lagoon temperature.

Maintaining a constant elevated temperature enhances methane production. Mesophilic digestion cultivates bacteria that have peak activity between 90 and 105 °F (32 to 40 °C). Mesophilic digesters operate at a retention period of 12 to 20 days. Thermophilic digesters promote bacteria that grow at between 135 to 155 °F (57 to 68 °C); these digesters operate with a retention time of 6 to 12 days.

Although there are many types of anaerobic digesters, only covered lagoons operating at ambient temperatures, complete-mix digesters, and plug-flow digesters can be considered commercially available, because they are the only ones that have been implemented successfully at 10 or more sites.

A cover can be floated on the surface of a properly sized anaerobic lagoon to recover methane. Ideally, the cover is floated on the primary lagoon of a two-cell lagoon system, with the primary lagoon maintained as a constant volume treatment lagoon and the second cell used to provide storage of treated effluent until the effluent can be properly applied to land. The lagoons are not heated, and the lagoon temperature and biogas production vary with ambient temperatures. Coarse solids, such as hay and silage fibers in cow manure, must be separated in a pretreatment step and kept from the lagoon. If dairy solids are not separated, they will float to the top and form a crust. The crust will thicken, reducing biogas production and eventually filling the lagoon.

A complete-mix digester is a biological treatment unit that anaerobically decomposes animal manures using controlled temperature, constant volume, and mixing. These digesters can accommodate the widest variety of wastes. Complete-mix digesters are usually aboveground, heated, insulated, round tanks; however, the complete-mix design has also been adapted to function in a heated, mixed, covered earthen basin. Mixing can be accomplished with gas recirculation, mechanical propellers, or liquid circulation. In Europe, some mixed digesters are operated at thermophilic temperatures; however, most of these are regional digesters that are built and operated by digester professionals. A complete-mix digester can be designed to maximize biogas production as an energy source or to optimize volatile solids (VS) reduction with less regard for surplus energy. Either process is part of a manure management system, and supplemental effluent storage is required.

Plug-flow digesters are heated, unmixed, rectangular tanks. New waste is pumped into one end of the digester, thereby displacing an equal portion of older material horizontally through the digester and pushing the oldest material out through the opposite end. Lusk (1998) refers to a slurry-loop digester as a separate digester category, but this system, which is built in the shape of a horseshoe, functions by displacement in the same manner as a plug-flow digester.

Biogas formed in a digester bubbles to the surface and may be collected by a fixed rigid top, a flexible inflatable top, or a floating cover, depending on the type of digester. Biogas from a stable digester is saturated and contains 60 to 80 percent methane, with the balance as carbon dioxide and trace amounts of hydrogen sulfide (1,800 to 5,000 ppm H_2S). A collection system directs the virtually odorless biogas to gas handling components. Biogas may be filtered for mercaptan and moisture removal before being pumped or compressed to operating pressure and then metered to equipment for use. Biogas that is pressurized and metered can be used as fuel for heating, adsorption cooling, electrical generation, or cogeneration.

Application and Performance: Properly designed anaerobic lagoons are used to produce biogas from dilute wastes with less than 2 percent total solids (98 percent moisture), including flushed dairy manure, dairy parlor washwater, and flushed hog manure. Complete-mix digesters can be used to decompose animal manures with 3 to 10 percent total solids. Plug-flow digesters are used to digest thick wastes (11 to 13 percent total solids) from ruminant animals, including dairy and beef animals. The plug-flow system operates best with scrape-collected, fresh dairy manure that contains low levels of dirt, gravel, stones, or straw.

Anaerobic digestion is one of the few manure treatment options that reduce the environmental impact of manure and produce a commodity—energy—that can be used or sold continuously. Digesters are used to stabilize manures to produce methane, while at the same time reducing odors.

Approximately 35 percent of the volatile solids from dairy manure and 60 percent of the volatile solids from swine or beef manure can be converted to biogas and removed from the manure liquid.

Table 8-11 summarizes the performance expected from anaerobic digesters. Anaerobic digesters will reduce biological oxygen demand (BOD) and total suspended solids (TSS) by 80 to 90 percent, and virtually eliminates odor. The digester will have minimal effect on the nutrient content of the digested manure passing through plug-flow or complete-mix digesters. Half or

Table 8-11. Anaerobic Unit Process Performance

Digester type	Percentage Reduction						
	HRT (days)	**COD**	**TS**	**VS**	**TN**	**P**	**K**
Complete-mix	12-20	35-70	25-50	40-70	0	0	0
Plug-flow	18-22	35-70	20-45	25-40	0	0	0
Covered first cell of two-cell lagoon	30-90	70-90	75-95	80-90	25-35	50-80	30-50

Source: Moser and Martin, 1999.

more of the organic N (Org-N) is converted into ammonia (NH_3-N). In lagoons, the concentrations of nutrients are reduced through settling, volatilization, and precipitation. With a cover in place, ammonia volatilization losses are eliminated, leaving only settling and precipitation as pathways for N loss. A small amount of the P and K will settle as sludge in most digesters.

The reductions of P, K, or other nonvolatile elements reported in the literature for covered lagoons are not really reductions at all. The material settles and accumulates in the lagoon, awaiting later management. Vanderholm (1975) reported P losses of up to 58 percent. Bortone et al. (1992) suggest that P accumulation in anaerobic lagoons may be due to high pH driving phosphate precipitation as $Ca(PO_4)_2$ and $Mg(PO_4)_2$. This is consistent with and supported by P mass losses documented in most lagoon studies. Water-soluble cations, such as sodium, potassium, and ammonium N, tended to be distributed evenly throughout the lagoon. Humenik et al. (1972) found that 92 to 93 percent of the copper and zinc in anaerobic swine lagoon influent was removed and assumed to be settled and accumulated in sludge.

Pathogen reduction is greater than 99 percent in mesophilic and thermophilic digesters with a 20-day HRT. Digesters are also very effective in reducing weed seeds.

Advantages and Limitations: Some advantages of anaerobic digestion include the opportunity to reduce energy bills, produce a stabilized manure, recover a salable digested solid by-product, reduce odor and fly breeding, and produce a protein-rich feed from the digested slurry.

The energy from biogas can be used on site as a fuel or sold to a local utility company. On-site uses include the heating of the digester itself, fuel for boilers or electric generators, hot water production, and refrigeration. The equipment listed in Table 8-12 can use biogas in lieu of low-pressure natural gas or propane.

Table 8-12. Biogas Use Options

Electrical generator	electricity for use or sale, heat recovery optional
Refrigeration compressors	cooling, heat recovery optional
Irrigation pumps	pumping, heat recovery optional
Hot water boiler	for space heat, hot water for process and cleanup
Hot air furnace	for space heat
Direct fire room heater	for space heat
Adsorption chiller	for cold water production, heat recovery optional

Dairy waste digesters partially decompose fibrous solids to a uniform particle size that is easily separated with a mechanical separator. The recovered solids are valuable for reuse as cow bedding or can be sold as a bagged or wholesale soil product.

Limitations include the costs associated with building and operating the digester. Furthermore, nutrient concentrations in the semisolid anaerobic digestion product are not reduced substantially unless they are then stored for several months. Therefore, the amount of land needed for land application of manure is greater than that needed for uncovered lagoons and other treatment practices.

Operational Factors: The successful operation of a properly designed digester is dependent upon two variables: feed rate and temperature. All other operational issues are related to ancillary equipment maintenance. Once a properly designed digester is operating, it will usually continue to function unless management oversight is lacking. Reactor capacity is maintained through periodic removal of settled solids and grit.

A sudden drop in biogas production or pH (from accumulation of organic acids) will indicate digester upset. Factors that decrease the efficiency of microbial processes and might result in digester upset include a change in temperature or feed rations, a change in manure loading rates, or the addition of large quantities of bacterial toxins. A normal ratio of alkalinity to volatile acids during a stable or steady-state anaerobic decomposition is 10:1. The known operating range is 4:1 to 20:1. (Metcalf and Eddy, 1979). An increase in volatile acids resulting in an alkalinity to volatile acid ratio of 5:1 indicates the onset of failure of methane-producing anaerobic digestion (unbalanced decomposition) (Chynoweth, 1998).

The level of hydrogen sulfide in the produced biogas can be controlled through either scrubbing or managed operation of equipment. Scrubbing is necessary for some gas uses but is generally expensive and maintenance intensive.

Demonstration Status: Anaerobic lagoons with covers were used at 1.8 percent of grower/finisher operations in 1995 (USDA APHIS, 1999). Approximately 30 pig lagoons have been covered in the United States for odor control or methane recovery (RCM, 1999). The oldest continuously operating covered swine waste lagoon is at Roy Sharp's Royal Farms in Tulare, California. This system, which was installed in 1981, has been producing electricity with the recovered methane since 1983. Not all covered lagoon projects have beneficial uses for recovered methane; some farms either flare or release the gas.

The oldest complete-mix pig manure digester in the United States was built in 1972. Approximately 10 units are in operation today, 6 of which were built within the last 4 years. Many digesters are not operational, typically because the farm is no longer in the pig business. At least 16 operating plug-flow and slurry-loop digesters are currently operating in the United States (Lusk, 1998; RCM, 2000).

Practice: Single-Cell Lagoon With Biogas Generation

Description: In this practice, a cover is floated on the surface of a properly sized anaerobic lagoon to recover biogas (70 percent methane and 30 percent carbon dioxide). Anaerobic lagoons can produce biogas from any type of animal manure. The most successful arrangement consists of two lagoons connected in series to separate biological treatment for biogas production and storage for land application. A variable-volume, one-cell lagoon designed for both treatment and storage can be covered for biogas recovery; however, a single-cell lagoon cover presents design challenges due to the varying level of the lagoon surface.

In the early 1960s, the floating cover industry expanded beyond covering water reservoirs into floating covers for industrial wastewater lagoons. Covering industrial organic wastewater lagoons began as an odor control technique. Within the discovery that economic quantities of biogas could be recovered, cover systems were refined to collect and direct biogas back to the factory producing the organic waste. Lagoon design was optimized to provide both good BOD/COD reduction and a supply of usable biogas. Today, hundreds of industrial anaerobic lagoons have floating covers that optimize anaerobic digestion, control odor, and recover biogas. The industries that use such covers include pork processors and rendering plants in the United States. Lessons learned in the development of floating covers are incorporated into today's designs for animal waste facilities.

Psychrophilic, or low-temperature, digestion is the natural decomposition path for manures at the temperatures found in lagoons. These temperatures vary from about 38 to 85 °F (3 to 29 °C). The retention time required for stable operation varies from 120 days at low temperatures to 30 days at the higher temperatures. Methane production varies seasonally with lagoon temperature. More methane is produced from warmer lagoons than from colder lagoons.

The Natural Resources Conservation Service (1998) developed NRCS Interim Practice Standard 360, Covered Anaerobic Lagoon, to guide floating cover design, installation, and operation. Many types of materials have been used to cover agricultural lagoons. Floating covers are not limited in dimension. A floating cover allows for some gas storage. Cover materials must have a bulk density near that of water and must be UV-resistant, hydrophobic, tear- and puncture-resistant, and nontoxic to aquatic aerobes and anaerobes.

Several types of material are used to construct floating covers, including high-density polyethylene, XR-5, polypropylene, and hypalon. Material is selected based on material properties (such as UV resistance), price, availability, installation, and service. Installation teams with appropriate equipment travel and install covers.

Biogas formed in a digester bubbles to the surface and is collected and directed by the cover to a gas use. Biogas from a stable covered lagoon is virtually odorless and saturated. It contains 70 to 85 percent methane; the balance is carbon dioxide and trace amounts of hydrogen sulfide (1,000 to 3,000 ppm H_2S). Biogas can be harmful if inhaled directly, corrosive to equipment, and potentially explosive in a confined space when mixed with air. When properly managed, the off-gas is as safe as any other fuel (e.g., propane) used on the farm. Safety concerns are more completely addressed in the *Handbook of Biogas Utilization* (Ross, 1996).

Biogas may be filtered for mercaptan and moisture removal. Biogas is usually pumped or compressed to operating pressure and then metered to the gas use equipment. Biogas can be used as fuel for heating, electrical generation, or cogeneration. Alternatively, it can simply be flared for odor control.

Application and Performance: Covered lagoons are used to recover biogas and control. Covers can be installed to completely cover the lagoon and capture clean rainwater. The uncontaminated rainwater can be safely pumped off, reducing the volume of lagoon liquid to be managed later.

Off-gases collected by an impermeable cover on an anaerobic manure facility are neither explosive nor combustible until mixed with air in proper proportions to support combustion. No reports of any explosions of biogas systems at animal production facilities were found.

Table 8-13 summarizes the performance expected from covered lagoons. Anaerobic digestion in a covered lagoon will reduce BOD and TSS by 80 to 90 percent. Odor is virtually eliminated. The concentrations of nutrients are reduced through settling and precipitation in lagoons. Ammonia volatilization losses are virtually eliminated with a cover in place, leaving only settling and precipitation as pathways for N loss.

During anaerobic digestion, microbial activity converts half or more of the organic N (Org-N) to soluble ammonia (NH_3-N). Cheng (1999) found that 30 percent of the total Kjeldahl N (TKN, which includes ammonia and organic N) entering the covered first cell of a two-cell lagoon was retained in that cell, probably as organic N in slowly degradable organics in the sludge. A similar loss due to settling could be expected in a covered single-cell lagoon. A covered single-cell lagoon will not lose NH_3-N to the atmosphere; however NH_3-N will be volatilized from the uncovered second cell of a two-cell lagoon. Cheng (1999) also reported that approximately 50 percent of the influent TKN was subsequently lost from the uncovered second cell of the system.

Reported reductions of P, K, or other nonvolatile elements through a covered lagoon are not really reductions at all. The material settles and accumulates in the lagoon awaiting later management. This is consistent with and supported by P mass losses documented in most lagoon studies. Humenik et al. (1972) found that 92 to 93 percent of the copper and zinc in anaerobic swine lagoon influent was removed and assumed to be settled and accumulated in sludge.

Table 8-13. Anaerobic Unit Process Performance

		Percentage Reduction					
Digester type	HRT Days	COD	TS	VS	TN	P	K
Covered lagoon	30 – 90	70-90	75-95	80-90	25-35	50-80	30-50

Source: Moser, 1999.

Cheng (1999) found pathogen reduction through a North Carolina covered lagoon to be 2 to 3 orders of magnitude. J. Martin (1999) determined that relationships between temperature and the time required for a one $\log_{10}$ reduction in densities of pathogens were consistently exponential in form. Although there is substantial variation between organisms regarding the time required for a one $\log_{10}$ reduction in density at ambient temperatures, this work suggests that variation in die-off rates among species decreases markedly as temperature increases. For example, the predicted time required for a one $\log_{10}$ reduction in fecal streptococcus density decreases from 63.7 days at 15 °C to 0.2 day at 50 °C. For *S. aureus*, the decrease is from 10.6 days at 15 °C to 0.1 day at 50 °C. Thus, for both storage and treatment at ambient temperature, an extended period of time is predicted for any significant reduction. A single-cell covered lagoon has a longer residence time than the covered first cell of a two-cell lagoon and should therefore have a greater reduction of pathogens. However, during pumpout of a single-cell lagoon, fresh influent can be short-circuited to the pumpout, carrying pathogens with it, whereas the covered first cell of a two-cell lagoon produces a consistent pathogen reduction without short-circuiting because the first cell's pathogen destroying retention time is not affected when the second cell is pumped down.

Advantages and Limitations: The advantages of covered anaerobic lagoons are the reduction of lagoon odor, exclusion of rainfall from the lagoon, recovery of usable energy, reduction of ammonia volatilization, and reduction of methane emissions. There are also significant labor savings involved in handling manure as a liquid and being able to apply lagoon waters to the land through irrigation. Solids are broken down through microbial activity, and organic matter is stabilized when anaerobic digestion is complete, reducing the potential for production of noxious by-products. A bank-anchored cover prevents the growth of weeds where the cover is placed. Finally, treated lagoon water can be recycled for flush water in confinement houses, resulting in cost savings in areas where water is scarce.

Limitations of covered anaerobic lagoons include the cost of installing a cover, which in 1999 varied from $0.37 to $1.65 per square foot (Martin, 1999), and the occasional need for cover maintenance such as rip repair, and rainfall pump-off. The lagoons themselves can be large, depending on the size of the hog operation, and can require a significant amount of cover material. Spills and leaks to surface and ground water can occur if the lagoon capacity is exceeded, or if structural damage occurs to berms, seals, or liners. The treatment capacity of most lagoons is diminished by sludge accumulation, and sludge has to be removed and managed.

Operational Factors: Lagoons should be located on soils of low permeability or soils that seal through biological action or sedimentation, and proper liners should be used to avoid contamination of ground water. Proper sizing and management are necessary to effectively operate a covered anaerobic lagoon and maintain biogas production. The minimum covered lagoon capacity should include treatment volume, sludge storage, freeboard, and, if necessary, storage for seasonal rainfall and a 25-year, 24-hour rainfall event.

Temperature is a key factor in planning the treatment capacity of a covered lagoon. The lagoons are not heated, and the lagoon temperature and biogas production vary with ambient temperatures. Warm climates require smaller lagoons and have less variation in seasonal gas production. Colder temperatures will reduce winter methane production. To compensate for reduced temperatures, loading rates are decreased and hydraulic retention time is increased. A larger lagoon requires a larger, more costly cover than a smaller lagoon in a warmer climate.

The floating cover must be designed and operated in such a way as to keep it from billowing in windy conditions. Coarse solids, such as hay and silage fibers in cow manure, must be separated in a pretreatment step and kept from the lagoon. If dairy solids are not separated, they float and form a crust. The crust will thicken, reducing biogas production and eventually filling the lagoon.

Proper lagoon inspection and maintenance are necessary to ensure that lagoon liners and covers are not harmed by agitating and pumping, berms and embankments are stable, and the required freeboard and rainfall storage are provided. Sampling and analysis of the lagoon water are suggested to determine its nutrient content and appropriate land application rates.

Anaerobic lagoons accumulate sludge over time, diminishing treatment capacity. Lagoons must be cleaned out once every 5 to 15 years, and the sludge can be applied to land other than the spray fields receiving the lagoon liquid. Because crop P requirements are less than those for N, it takes more land to apply the sludge from lagoon cleanout than to apply liquid wastewater.

Demonstration Status: Floating-cover technology is well developed and readily available. Covering lagoons for odor control has been demonstrated in all sectors of the animal production industry. The installation of floating covers specifically for methane recovery is a less common, but well-known practice. There are at least 10 covered lagoon systems with biogas collection and combustion in the pig and dairy industries (Lusk, 1998; RCM, 2000).

Practice: Aerobic Treatment of Liquids

Description: Conventional aerobic digestion is a process used frequently at small municipal and industrial wastewater treatment plants for biosolids stabilization. It is a suspended growth process operating at ambient temperature in the stationary or endogenous respiration phase of the microbial growth curve. In the stationary phase, the exogenous supply of energy is inadequate to support any net microbial growth. Endogenous respiration occurs when the exogenous supply of energy also is inadequate to satisfy cell maintenance requirements, and a net decrease in microbial mass occurs. Operating parameters include a relatively long period of aeration, ranging from severa daysl to more than 30 days, depending on the degree of stabilization desired. Given the relatively long period of aeration, activated sludge recycling is not necessary and hydraulic detention and solids retention times are equal in continuous-flow systems. This is a major difference between aerobic digestion and the various variants of the activated sludge process, including extended aeration (see "Secondary Biological Treatment" below). When aerobic digestion is used for biosolids stabilization, either the fill-and-draw or the continuous mode of operation can be used. With the fill-and-draw mode of operation, an option is to periodically cease aeration temporarily to allow settling and then decant the clarified liquid before resuming aeration. This approach also allows the reactor to be used as a biosolids thickener.

With conventional aerobic digestion, substantial reductions in total and volatile solids, biochemical and chemical oxygen demand, and organic N can be realized. Total N reduction can also be substantial, with either ammonia stripping or nitrification-denitrification serving as the primary mechanism, depending on the dissolved oxygen concentration of the mixed liquor. Actual process performance depends on a number of variables, including solids retention time, temperature, and adequacy of oxygen transfer and mixing.

An aeration basin typically is used for the aerobic digestion of municipal and industrial wastewater biosolids. In contrast, several reactor types, including oxidation ditches and mechanically aerated lagoons, as well as aeration basins, have been used for the aerobic digestion of animal manures. Under commercial conditions, the oxidation ditch has been the most commonly used because it can be located in the animal housing unit under cages for laying hens or under slatted floors for swine. This eliminates the need for transport of manure to the treatment system.

It should be noted that since the oxidation ditch was originally developed to employ the activated sludge process used in municipal wastewater treatment, the term "activated sludge" has been used incorrectly on occasion to describe the aerobic digestion of swine, poultry, and other animal wastes. Aerobic digestion, not the activated sludge process, is employed in oxidation ditches, mechanically aerated lagoons, and aeration basins. Table 8-14 presents technologies that use aerobic digestion or the activated sludge process.

Application and Performance: Conventional aerobic digestion is an option for all swine and poultry operations where manure is handled as a liquid or slurry, and it can be used with flushing systems using either mixed liquor or clarified effluent as flush water. With proper process design and operation, a 75 to 85 percent reduction in 5-day biochemical oxygen demand (BOD_5) appears achievable, with a concurrent 45 to 55 percent reduction in chemical oxygen demand (COD), and a 20 to 40 percent reduction in total solids (TS) (Martin, 1999). In addition, a 70 to 80 percent reduction of the N in both poultry and swine wastes via nitrification-denitrification also appears possible. Total P is not reduced, but the soluble fraction may increase. As with aerobic digestion

Table 8-14. Operational Characteristics of Aerobic Digestion and Activated Sludge Processes

Process Modification	Flow Model	Aeration System	BOD Removal Efficiency (percent)	Remarks
Conventional	Plug flow	Diffused-air, mechanical aerators	85-95	Use for low-strength domestic wastes. Process is susceptible to shock loads.
Complete mix	Continuous-flow stirred-tank reactor	Diffused-air, mechanical aerators	85-95	Use for general application. Process is resistant to shock loads, but is susceptible to filamentous growths.
Step feed	Plug flow	Diffused air	85-95	Use for general application for a wide range of wastes.
Modified aeration	Plug flow	Diffused air	60-75	Use for intermediate degree of treatment where cell tissue in the effluent is not objectionable.
Contact stabilization	Plug flow	Diffused-air, mechanical aerators	80-90	Use for expansion of existing systems and package plants.
Extended aeration	Plug flow	Diffused-air, mechanical aerators	75-95	Use for small communities, package plants, and where nitrified element is required. Process is flexible.
High-rate aeration	Continuous-flow stirred-tank reactor	Mechanical aerators	75-90	Use for general applications with turbine aerators to transfer oxygen and control floc size.
Kraus process	Plug flow	Diffused air	85-95	Use for low-N, high-strength wastes.
High-purity oxygen	Continuous-flow stirred-tank reactors in series	Mechanical aerators (sparger turbines)	85-95	Use for general application with high-strength waste and where on-site space is limited. Process is resistant to slug loads.
Oxidation ditch	Plug flow	Mechanical aerators (horizontal axis type)	75-95	Use for small communities or where large area of land is available. Process is flexible.
Sequencing batch reactor	Intermittent-flow stirred-tank reactor	Diffused air	85-95	Use for small communities where land is limited. Process is flexible and can remove N and P.
Deep-shaft reactor	Plug flow	Diffused air	85-95	Use for general application with high-strength wastes. Process is resistant to slug loads.
Single-stage nitrification	Continuous-flow stirred-tank reactors or plug flow	Mechanical aerators, diffused-air	85-95	Use for general application for N control where inhibitory industrial wastes are not present.
Separate stage nitrification	Continuous-flow stirred-tank reactors or plug flow	Mechanical aerators, diffused-air	85-95	Use for upgrading existing systems, where N standards are stringent, or where inhibitory industrial wastes are present and can be removed in earlier stages.

Source: Metcalf and Eddy, 1991.

of biosolids, some reduction in pathogen densities may also occur depending on process temperature.

Advantages and Limitations: In addition to the potential for substantial reductions in oxygen-demanding organics and N, one of the principal advantages of aerobic digestion of poultry and swine manures is the potential for a high degree of odor control. Another advantage is the elimination of fly and other vermin problems.

Limitations include high energy requirements for aeration and mixing (e.g., pumps, blowers, or mixers for mechanical aeration). In addition, aerobic lagoons without mechanical aeration are generally shallow, requiring a very large land area to meet oxygen demands. The absence of a reduction in the volume of waste requiring ultimate disposal is another limitation. In certain situations, waste volume will be increased significantly. For example, use of an undercage oxidation ditch versus a high-rise type system to manage the waste from laying hens will increase substantially the waste volume requiring ultimate disposal. Also, management, maintenance, and repair requirements for aerobic digestion systems can be significant. For example, liquids and solids must be separated in a pretreatment step when aerated lagoons are used.

Operational Factors: Establishing and maintaining an adequate microbial population in aerobic digestion reactors is critical to ensure optimal process performance. Failure to do so will lead to excessive foam production, which has suffocated of animals on slatted floors above in-building oxidation ditches. Failure to remove slowly biodegradable solids on a regular basis to maintain a mixed liquor total solids concentration of about 1 percent in fill-and-draw systems will lead to a substantial reduction in oxygen transfer efficiency and mixing. This results in reduced treatment efficiency and the potential for generation of noxious odors and release of poisonous gases, particularly hydrogen sulfide. Because ambient temperature determines process temperature, seasonal variation in process performance occurs.

Demonstration Status: Aerobic digestion has not been adapted to any significant degree by the poultry, dairy, or swine industries, although a number of research and demonstration scale studies were conducted in the late 1960s and early 1970s. Problems related to process and facilities design, together with the significant increase in electricity costs in the early to mid-1970s, led to a loss of interest in this animal waste treatment alternative. It is possible that no aerobic digestion systems for animal wastes are currently in operation in the poultry and swine industries.

Lagoons are the most popular method of treatment for livestock manure. Aerobic lagoons are commonly used for secondary treatment and storage of anaerobic lagoon wastes. Despite the advantages, however, aerobic lagoons are considered uneconomical for livestock manure treatment.

Practice: Autoheated Aerobic Digestion

Description: Autoheated aerobic digestion uses heat released during the microbial oxidation of organic matter to raise process temperature above ambient levels. This is accomplished by minimizing both sensible and evaporative heat losses through the use of insulated reactors and aeration systems with high-efficiency oxygen transfer. Mesophilic temperatures, 86 ºF (30 ºC) or higher, typically can be maintained even in cold climates, and thermophilic temperatures as high as 131 to 149 ºF (55 to 65 ºC) can be attained. Both ammonia stripping and nitrification-denitrification can be mechanisms of N loss at mesophilic temperatures; nitrification-denitrification is typically the principal mechanism if the aeration rate is adequate to support nitrification. Because both *Nitrosomas* and *Nitrobacter*, the bacteria that convert ammonium ions into nitrate, are mesophiles, N loss at thermophilic temperatures is limited to ammonia stripping. Typically, autoheated digestion reactors are operated as draw-and-fill reactors to minimize influent short-circuiting, especially when maximizing pathogen reduction is a treatment objective.

Application and Performance: Autoheated aerobic digestion is appropriate for all livestock and poultry operations where manure is handled as a slurry that has a minimum total solids concentration of at least 1 to 2 percent, wet basis. At lower influent total solids concentrations, such as those characteristic of flushing systems, achieving process temperatures significantly above ambient levels is problematic because of an insufficient biological heat production potential relative to sensible and evaporative heat losses. As influent total solids concentration increases, the potential for achieving thermophilic temperatures also increases. Influent total solids concentrations of between 3 and 5 percent are necessary to attain thermophilic temperatures.

With proper process design and operation, the previously discussed reductions in biochemical oxygen demand (BOD_5), chemical oxygen demand, total solids, and total N that can be realized with conventional aerobic digestion also can be realized with autoheated aerobic digestion (Martin, 1999a). Autoheated aerobic digestion can also provide significant reductions in pathogen densities in a relatively short 1- to 2-day period of treatment. Reductions realized are a function of process temperature. At a process temperature of 122 °F (50 °C) or greater, a minimum of at least a one log_{10} reduction in the density of most pathogens is highly probable, with two to three log_{10} reductions likely (Martin, 1999b).

Advantages and Limitations: With respect to waste stabilization and odor control, the potential benefits of conventional and autoheated aerobic digestion are comparable. The principal advantages of autoheated aerobic digestion relative to conventional aerobic digestion from a process performance perspective are (1) higher reaction rates that translate into shorter detention times to attain a given degree of stabilization and (2) more rapid reduction in densities of pathogens. The time required to achieve comparable reductions in BOD_5, chemical oxygen demand, total solids, and total N is much shorter in autoheated than in conventional aerobic digestion. With autoheated aerobic digestion, these reductions occur within 1 to 3 days at thermophilic temperatures, whereas 15 days or more are required with conventional aerobic digestion at ambient temperatures. This translates directly into smaller reactor volume requirements.

The ability to provide rapid and substantial (at least a one log_{10}) reductions in pathogen densities is one of the more attractive characteristics of autoheated aerobic digestion. This ability has been demonstrated in several studies of autoheated aerobic digestion of biosolids from municipal wastewater treatment, including a study by Martin et al. (1990).

The high energy requirements for aeration and mixing are limitations of autoheated aerobic digestion. In addition, waste volume is not reduced through the treatment process. However, the requirement of a less dilute influent waste stream, as compared with conventional aerobic digestion, for example, to provide the necessary biological heat production potential translates into reduced ultimate disposal requirements.

Operational Factors: A foam layer covering the mixed liquor in autoheated aerobic digestion reactors is a common characteristic and serves to reduce both sensible and evaporative heat losses. It is necessary to control the depth of this foam layer to ensure that an overflow of foam from the reactor does not occur. Typically, mechanical foam cutters are used. Although autoheated aerobic digestion is less sensitive to fluctuations in ambient temperature than are other treatment processes, such as conventional aerobic digestion, some reduction in treatment efficiency can occur, especially during extended periods of extremely cold weather.

Demonstration Status: The feasibility of using autoheated aerobic digestion to stabilize swine manure has been demonstrated in several studies (Martin, 1999b). Feasibility also has been demonstrated in several studies with cattle manure, including studies by Terwilliger and Crauer (1975) and Cummings and Jewell (1977); however, there does not appear to have been any comparable demonstration of feasibility with poultry wastes. Given the similarities in the composition of swine and poultry wastes, it is highly probable that autoheated aerobic digestion of poultry wastes is also technically feasible. Although no data are available, it is probable that this waste treatment technology is not currently being used in any segment of animal agriculture, primarily because of the associated energy cost.

Practice: Secondary Biological Treatment

Description: The activated sludge process is a widely used technology for treating wastewater that has high organic content. The process was first used in the early 1900s and has since gained popularity for treatment of municipal and industrial wastewater. Many versions of this process are in use today, but the fundamental principles are similar. Basically, the activated sludge process treats organic wastes by maintaining an activated mass of microorganisms that aerobically decomposes and stabilizes the waste.

Primary clarification or solids settling is the first step in the activated sludge process. Next, the organic waste is introduced into a reactor. Maintained in suspension in the reactor is a biological culture that converts the waste through oxidation and synthesis. The aerobic environment in the reactor is achieved using diffused or mechanical aeration, which also maintains a completely mixed state. After a specified period, known as the hydraulic retention time (HRT), the mixture in the reactor is passed to a settling tank. A portion of the solids from the settling tank is recycled to the reactor to maintain a balance of microorganisms. Periodically, solids from the settling tank are "wasted" or discharged to maintain a specific concentration of microorganisms in the system. The solids are discharged according to a calculated solids retention time (SRT), which is based on the influent characteristics and the desired effluent quality. The overflow from the settling tank is discharged from the system.

Application and Performance: The activated sludge process is very flexible and can be used to treat almost any type of biological waste. It can be adapted to provide high levels of treatment under a wide range of operating conditions. Properly designed, installed, and operated activated sludge systems can reduce the potential pollution impact of feedlot waste because this technology has been shown to reduce carbon-, N-, and P-rich compounds.

In the activated sludge process, N is treated biologically through nitrification-denitrification. The supply of air facilitates nitrification, which is the oxidation of ammonia to nitrite and then nitrate. Denitrification takes place in an anoxic environment, in which the bacteria reduce the nitrate to nitrogen gas (N_2), which is released into the atmosphere. The activated sludge process can nitrify and denitrify in single- and double-stage systems.

Phosphorus is removed biologically when an anaerobic zone is followed by an aerobic zone, causing the microorganisms to absorb P at an above-normal rate. The activated sludge technology most effective for removing P is the sequencing batch reactor (see "Sequencing Batch Reactors," below).

N and P can both be removed in the same system. The SBR is also most effective for targeting removal of both N and P because of its ability to alternate aerobic and anaerobic conditions to control precisely the level of treatment.

Advantages and Limitations: An advantage of the activated sludge process is that it removes pollutants, particularly nutrients, from the liquid portion of the waste. Nutrient removal can allow more feedlot wastewater to be applied to land without overloading it with N and P. Furthermore, concentrating the nutrients in a sludge portion can potentially reduce transportation volumes and costs of shipping excess waste.

A disadvantage of an activated sludge system compared with an anaerobic lagoon is the relatively high capital and operating costs and the complexity of the control system. In addition, because pollutants will remain in the sludge, stabilization and pathogen reduction are necessary before disposing of it.

Because the activated sludge process does not reduce pathogens sufficiently, another way to reduce pathogens in both the liquid and solid portions of a waste may be appropriate prior to discharge or land application. The liquid effluent from an activated sludge system can be disinfected by using chlorination, ultraviolet radiation, or ozonation, which are the final steps in many municipal treatment systems.

Operational Factors: Many parameters can affect the performance of an activated sludge system. Organic loading must be monitored carefully to ensure that the microorganisms can be sustained in proper concentrations to produce a desired effluent quality. The principal factors in the control of the activated sludge process are:

- Maintaining dissolved oxygen levels in the aeration tank (reactor);
- Regulating the amount of recycled activated sludge from the settling tank to the reactor; and
- Controlling the waste-activated sludge concentration in the reactor.

Ambient temperature can also affect treatment efficiency of an activated sludge system. Temperature influences the metabolic activities of the microbial population, gas-transfer rates, and settling characteristics of biological solids. In cold climates, a larger reactor volume may be necessary to achieve treatment goals because nitrification rates decrease significantly at lower temperatures.

Demonstration Status: Although activated sludge technologies have not been demonstrated on a full-scale basis in the animal feedlot industry, the process may treat such waste effectively. Studies have been performed on dairy and swine waste to determine the level of treatment achievable in an SBR (see "Sequencing Batch Reactors," below). The SBR is simpler, more flexible, and perhaps more cost-effective than other activated sludge options for use in the feedlots industry.

Practice: Sequencing Batch Reactors

Description: A sequencing batch reactor (SBR) is an activated sludge treatment system in which the processes are carried out sequentially in the same tank (reactor). The SBR system may consist of one reactor, or more than one reactor operated in parallel. The activated sludge process treats organic wastes by maintaining an aerobic bacterial culture, which decomposes and stabilizes the waste. An SBR has five basic phases of operation, which are described below.

<u>Fill Phase</u>: During the fill phase, influent enters the reactor and mechanical mixing begins. The mixing action resuspends the settled biomass from the bottom of the reactor, creating a completely mixed condition and an anoxic environment. As wastewater continues entering the reactor, oxygen may also be delivered, converting the environment from anoxic to aerobic. Depending on the desired effluent quality, the oxygen supply can be operated in an "on/off" cycle, thus alternating the aerobic and anoxic conditions and accomplishing nitrification and denitrification.

<u>React Phase</u>: During the react phase, wastewater no longer enters the reactor. Influent to the system is instead either stored for later treatment in a single-reactor system or diverted to another reactor to begin treatment in a system with multiple reactors. Mechanical mixing continues throughout this phase. The oxygen supply may be operated in a cyclical manner, as described in the fill phase, to accomplish additional denitrification if necessary. Activated sludge systems, such as SBRs, depend upon developing and sustaining a mixed culture of bacteria and other microbes (i.e., the biomass) to accomplish the treatment objectives.

Settle Phase: During the settle phase, the oxygen supply system and mechanical mixer do not operate. This phase provides a quiescent environment in the reactor and allows gravity solids separation to occur, much like in a conventional clarifier.

Draw Phase: Following the treatment of a batch, it is necessary to remove from the reactor the same volume of water that was added during the fill phase. After a sufficient settling phase, the liquid near the top of the reactor is decanted to a predetermined level and discharged or recycled.

Idle Phase: The idle phase is a time period between batches during which the system does not operate. The duration of this unnecessary phase depends on the hydraulic aspects of the reactor. However, as a result of biological degradation and accumulation of inert materials from the wastewater, solids must be discharged from the reactor periodically to maintain a desirable level of mixed liquor suspended solids. This "sludge wasting" is done during the idle phase, or immediately following the draw phase.

Application and Performance: SBR technology could be applied to reduce the potential pollution impact of liquid manure waste from dairies because this technology has been shown to reduce carbon-, N-, and P-rich compounds. Removing these pollutants from the liquid portion of the waste could allow for greater hydraulic application to lands without exceeding crop nutrient needs. Concentrating the nutrients in the sludge portion could potentially reduce transportation volumes and cost of shipping excess waste. Although a proven technology for treatment of nutrients in municipal wastewater, available data does not exist showing SBRs to be effective in pathogen reduction.

Given the processes it employs, SBR treatment may allow treated dairy wastewater to be either applied to land or discharged to a stream if a sufficient level of treatment can be achieved. Further, the sludge from the wasting procedure could be applied to land, composted, or sent off site for disposal. Aqua-Aerobic Systems of Rockford, Illinois, (Aqua-Aerobics, 2000) estimates a sludge production rate of approximately 1.3 pounds of waste activated sludge per pound of BOD_5 entering the system. The use of SBRs to treat dairy waste has been studied in the laboratory at both Cornell University and the University of California at Davis. Both studies have shown SBR technology to be effective in reducing pollutants in the liquid portion of dairy waste, although neither report included specific information on sludge characteristics or P removals (Johnson and Montemagno, 1999; Zhang et al., 1999).

In the Cornell study, diluted dairy manure was treated in bench-scale reactors (Johnson and Montemagno, 1999). Experiments were conducted to determine the operating strategy best suited for the diluted dairy manure. The study resulted in removals of 98 percent of ammonia (NH_3), 95 percent of chemical oxygen demand (COD), 40 percent of nitrate/nitrite (NO_3/NO_2), and 91 percent of inorganic N.

The University of California at Davis studied how SBR performance was affected by hydraulic retention time (HRT), solids retention time (SRT), organic loading, and influent characteristics of dairy wastewater (Zhang et al., 1999). The highest removal efficiencies from the liquid portion of the waste were for an influent COD concentration of 20,000 milligrams per liter (a COD concentration of 10,000 mg/L was also studied) and an HRT of 3 days (HRTs of 1 to 3 days were studied). With these parameters, laboratory personnel observed removal efficiencies of 85.1 percent for NH_3 and 86.7 percent for COD.

In addition, studies on SBR treatment of swine waste in Canada and of veal waste in Europehave demonstrated high removal rates of COD, N, and P (Reeves, 1999).

Advantages and Limitations: Technology currently used at dairies includes solids settling basins followed by treatment and storage of waste in an anaerobic lagoon. Lagoon effluent and solids are applied to cropland in accordance with their nutrient content, and excess water or solids are then transported off site. The SBR could replace treatment in an anaerobic lagoon, but there would still be a need for solids separation in advance of SBR treatment, as well as a pond or tank to equalize the wastewater flow. In fact, Aqua-Aerobics (2000) has indicated that solids removal and dilution of the raw slurry would be necessary to make treatment in the SBR. Following the SBR, it is possible that some type of effluent storage would be required for periods when direct irrigation is not possible or necessary.

Use of an SBR is expected to be advantageous at dairies that apply a portion of their waste to land. The reduced level of nutrients in the liquid portion would allow for application of a greater volume of liquid waste, thereby reducing the volume of waste that must be transported off site and possibly eliminating liquid waste transport. An SBR is also beneficial in the handling of the solids portion of the waste because no periodic dredging is required as is the case with anaerobic lagoons. Disadvantages of an SBR system are the relatively high capital and operating costs, as well as the need to manage the nutrients that remain in the sludge.

Because the activated sludge process is not a generally accepted method of pathogen reduction, another means of reducing pathogens in both the liquid and solid portions of the dairy waste may be appropriate. Disinfection of the liquid effluent from the SBR could be accomplished through use of chlorination, ultraviolet radiation, or ozonation which are used as the final step in many municipal treatment systems. Composting has also been demonstrated as a means of reducing pathogens in organic solid waste and could be implemented for use with the SBR sludge.

Operational Factors: The five phases of SBR operation may be used in a variety of combinations in order to optimize treatment to address specific influent characteristics and effluent goals. N in the activated sludge process is treated biologically through the nitrification-denitrification process. The nitrification-denitrification process in the SBR is controlled through the timing and cyclical pattern of aeration during the react phase. The supply of air causes nitrification, which is the oxidation of ammonia to nitrite and then nitrate. To accomplish denitrification, the air supply is shut off, creating an anoxic environment in which the bacteria ultimately reduce the nitrate to nitrogen gas (N_2), which is released to the atmosphere. The cycle can be repeated to achieve additional levels of denitrification. Some portion of the N in the influent to the SBR may also volatilize prior to treatment, and a portion may also be taken up by microorganisms that are present in the waste activated sludge (Zhang et al., 1999).

P is removed when an anaerobic zone (or phase) is followed by an aerobic zone, causing the microorganisms to take up P at an above-normal rate. The waste activated sludge containing the microorganisms is periodically "wasted" as described above. As such, the bulk of the P will be concentrated ultimately in the sludge portion with a minimal amount remaining in the liquid effluent.

N and P can both be removed in the same system. This dual removal is accomplished by beginning the fill phase without aeration, which creates an anoxic condition allowing for some denitrification as well as release of P from the cell mass to the liquid medium. there follows a period of aerated mixing, which will continue into the react phase, allowing for nitrification and uptake of P. The settle phase, in which no aeration occurs, is extended sufficiently to allow for additional denitrification. Again, these phases can be repeated or executed for varying durations in order to accomplish specific treatment goals.

Demonstration Status: Although the SBR technology has not been demonstrated on a full-scale basis in the dairy industry, SBRs are currently being evaluated for use at dairies because they generate a high volume of wastewater. Dairy wastewater treated in the SBR includes a combination of parlor and barn flush/hose water and runoff.

Cornell University is currently studying two pilot-scale SBR systems to further investigate the treatability of dairy waste (Johnson and Montemagno, 1999). No results from the pilot-scale study are yet available, although preliminary results for nutrient removal have been favorable and a full-scale system is being planned.

Practice: Solids Buildup in the Covered First Cell of a Two-Cell Lagoon

Description: This section addresses sludge accumulation, removal, and management in the first cell of a two-cell lagoon. The first cell may or may not be covered for methane recovery. Some sludge will be carried from the first cell to the second cell; however, the quantity is not significant compared with potential accumulations in the first cell. No quantitative information was found regarding the differences in the rate of accumulation of sludge in the first cell versus accumulation in a single-cell lagoon. The removal and management of sludge from the first cell of a two-cell lagoon will be the same as described for sludge cleaning from a single cell lagoon.

For the purpose of this section, sludge is material settled on the bottom of a lagoon receiving waste from any animal; it has a total solids content greater than 10 percent, generally has a high angle of repose when dewatered, and will not readily flow to a pump. Sludge includes organic material not decomposed by lagoon bacteria, and inorganic material such as sand and precipitates. Sludge accumulation can eventually fill a lagoon.

Accumulated sludge is removed to restore lagoon treatment and storage capacities. Two general methods of sludge removal, slurry and solid, are described below. When managed as a slurry, sludge is resuspended with agitation and pumped to tankers or irrigation guns for land application. Slurry management is desirable when the sludge mixture can be pumped to an irrigation gun or hauled a short distance. Sludge removed from covered lagoons is removed as a slurry.

Sludge managed as a solid is excavated from the lagoon or pumped from the bottom as slurry to a drying area. Solid sludge is cheaper to haul than slurry because water, which increases the weight and volume, is not added. Solid sludge can be spread with conventional manure spreaders or dumped on fields and spread out and disced into the soil. In drier areas of the country, a lagoon may be withdrawn from service as a parallel lagoon is restored to service. The lagoon liquids are pumped off to field application and the sludge is allowed to dry. After 4 to 12 months, excavators, backhoes or bulldozers scrape, push, pull, or lift the material into trucks or wagons for hauling and spreading. Some lagoons are designed to be desludged by dragline bucket excavators while still in operation. Draglines work along the banks of these long, narrow lagoons, excavating sludge and either dropping it into trucks for hauling or depositing it on the lagoon embankment to dry for later hauling.

Application and Performance: Lagoon cleanout is applicable to all two-cell lagoons, regardless of location. Reported reductions of P, K, and other nonvolatile elements through a lagoon are not really reductions at all because these materials settle. Nitrogen is considered volatile in the ammonia form, but some organic N associated with heavier and nondegradable organics also settles into the lagoon sludge and stays, resulting in a high-organic N fraction of total Kjeldahl N (TKN) in settled solids. The settled materials accumulate in the lagoon awaiting later disposal. Compared with lagoon liquids, lagoon sludges have higher concentrations of all pollutants that are not completely soluble. All reported data suggest that the sludge is more stable than raw manure based on its reduced volatile solids/total solids ratio (VS/TS). Volatile solids are a portion of the total solids that can be biologically destroyed, and as they are destroyed, the VS/TS ratio declines.

As anaerobic digestion of manure changes the solution chemistry in a lagoon, materials such as ammonia and P form precipitates with Ca and Mg. Fulhage and Hoehne (1999) and Bicudo et al. (1999) both report concentrations of Ca, Mg, P, and K in lagoon sludge at 10 to 30 times that found in raw manure. Fulhage and Hoehne also reported that Cu and Zn settle and concentrate to 40 to 100 times the concentration found in lagoon liquid.

Martin (1999), in a review and analysis of factors affecting pathogen destruction, found that time and temperature controlled the die-off rate of pathogens. Sludge that has been in a lagoon for 10 years is expected to have very low concentrations of pathogens, and those would be associated with the most recent 90 to 180 days of settling.

Advantages and Limitations: The advantage of lagoon cleanout is that removal of sludge restores the volume of a first-cell lagoon that is necessary for design treatment capacity. One of the limitations is that sludge disposal is ignored in most nutrient management plans. Sludge is a concentrated, nutrient-rich material. The nutrients in the sludge, if applied to the same cropland historically receiving lagoon liquids, could easily exceed the planned application rate of nutrients. Phosphorus and other relatively insoluble nutrients are more concentrated than N in sludge and become the basis of planning proper use of the sludge.

Ideally, sludge will be managed as a high-value fertilizer in the year it is applied. As the sludge has a higher nutrient and, hence, cash value than liquid manure, hauling to remote farms and fields to replace commercial fertilizer application is possible and desirable. Proper management of applied sludge will result in successful crops and minimal loss of nutrients to surface or ground waters.

The cover is a limiting factor in covered lagoon cleanout. At least a portion of the cover is removed to allow equipment access. Removing a complete cover is usually not practical. Lacking complete access, covered lagoon cleanouts will not remove all of the sludge present. Therefore, more frequent cleanouts would be expected. Most covered lagoons have been developed with cleanout intervals of 10-15 years.

Operational Factors: The USDA allows for sludge accumulation by incorporating a sludge accumulation volume (SAV) in its lagoon design calculations. Table 8-15 shows USDA's ratios of sludge accumulated per pound of total solids (TS) added to the lagoon. The higher the rate of sludge accumulation assumed in a design, the larger the lagoon volume required. There are no published data to compare sludge accumulation in the first cell of a two-cell lagoon versus accumulation in a single-cell lagoon. Anecdotal observations suggest that a first cell does not accumulate sludge faster than a single-cell lagoon as long as the first cell is sized to contain all of the treatment volume and sludge accumulation volume (SAV). In theory, a constant volume first cell should accumulate less sludge over time than a single-cell lagoon because the constant volume lagoon has a consistently higher microbial concentration than a single-cell lagoon. The higher concentration should result in the ability to consume new manure organic solids before they can settle to become sludge. Also in theory, a covered first cell would accumulate less sludge due to higher biological activity because a covered lagoon is a few degrees warmer than an uncovered lagoon.

Table 8-15. Lagoon Sludge Accumulation Ratios (USDA NRCS 1996)

Animal Type	Sludge Accumulation Ratio
Layers	0.0295 ft^3/lb TS
Pullets	0.0455 ft^3/lb TS
Swine	0.0485 ft^3/lb TS
Dairy cattle	0.0729 ft^3/lb TS

Information from various studies suggests that the USDA values may overestimate actual sludge accumulation rates. Table 8-16 shows a range of long-term sludge accumulation rates reported by various researchers. Field studies by both Fulhage and Hoehne (1999) and Bicudo et al. (1999) show lower accumulation rates than developed by Barth and Kroes (1985) and USDA NRCS (1996).

Table 8-16. Lagoon Sludge Accumulation Rates Estimated for Pig Manure

Source	Sludge Accumulation Rate
Fulhage (1990)	0.002 m^3/kg LAW*
Bicudo (1999)	0.003 m^3/kg LAW*
Barth (1985)	0.008 m^3/kg LAW*
USDA (1992)**	0.012 m^3/kg LAW*

* LAW = live animal weight ** as calculated by Bicudo et al. (1999).

It is important to note that the accumulation rate of sludge is influenced by lagoon design, influent characteristics, site factors, and management factors. Lagoon design factors such as lagoon volume, surface fetch, and lagoon depth increase or decrease potential lagoon mixing. More lagoon mixing encourages greater solids destruction by increasing the opportunity for bacteria to encounter and degrade solids. Influent factors, including animal type and feed, determine the biodegradability of manure solids. Highly degradable manure solids are more completely destroyed, thus accumulating as sludge to a lesser degree. Site temperature and incident rainfall impact the biological performance of the lagoon. High temperature increases biological activity and solids destruction. High rainfall can fill the lagoon and reduce retention time, thus slowing biological destruction of solids. Management factors also affect sludge accumulation. Increasing animal population, adding materials such as straw or sand used for animal bedding, or adding process water will reduce the ability of a lagoon to destroy solids and, therefore, increase the rate of sludge accumulation. Properly managed solids separators can reduce the quantity of solids reaching the lagoon, hence reducing sludge accumulation

Demonstration Status: First-cell cleanouts are common and have occurred since two-cell lagoons have been used. In many areas of the country, there are companies that specialize in lagoon cleaning.

Practice: Solids Buildup in an Uncovered Lagoon

Description: For the purpose of this section, sludge is material settled on the bottom of a lagoon receiving waste from any animal; it has a total solids content greater than 10 percent, generally has a high angle of repose when dewatered, and will not readily flow to a pump. This definition is intended to distinguish sludge from a less concentrated layer of solids above the sludge surface that can be drawn off with conventional pumping. All lagoons accumulate settleable materials in a sludge layer on the bottom of the lagoon. Sludge includes organic material not decomposed by lagoon bacteria and inorganic material such as sand and precipitates. Over time the sludge accumulation decreases the active treatment volume of a lagoon and negatively impacts the lagoon performance. Reduced treatment performance increases the rate of sludge accumulation. Sludge accumulations can eventually fill a lagoon.

Accumulated sludge is removed to restore lagoon treatment and storage capacities. Two general methods of sludge removal, slurry and solid, are described below.

When managed as a slurry, sludge is resuspended with agitation and pumped to tankers or irrigation guns for land application. Slurry management is desirable when the sludge mixture can be pumped to an irrigation gun or hauled a short distance.

Sludge managed as a solid is excavated from the lagoon. Solid sludge is cheaper to haul than slurry because water, which increases the weight and volume, is not added. Solid sludge can be spread with conventional manure spreaders or dumped on fields and spread out and disced into the soil. In drier areas of the country, a lagoon may be withdrawn from service when a parallel lagoon is restored to service. The lagoon liquids are pumped off to field application, and the sludge is allowed to dry. After 4 to 12 months, excavators, backhoes, or bulldozers scrape, push, pull, or lift the material into trucks or wagons for hauling and spreading. Some lagoons are designed to be desludged by dragline bucket excavators while still in operation. Draglines work along the banks of these long, narrow lagoons, excavating sludge and either dropping it into trucks for hauling or depositing it on the lagoon embankment to dry for later hauling.

Application and Performance: Lagoon cleanout is applicable to all operations that have lagoons, regardless of location. Reported reductions of P, K, and other nonvolatile elements through a lagoon are not really reductions at all. The material settles and accumulates in the lagoon, awaiting later disposal. Compared with lagoon liquids, lagoon sludges have higher concentrations of all pollutants that are not completely soluble. All reported data suggest that the sludge is more stable than raw manure based on its reduced volatile solids to total solids ratio (VS/TS). Volatile solids are a portion of the total solids that can be biologically destroyed, and as they are destroyed, the VS/TS ratio declines. Some organic N associated with heavier and nondegradable organics also settles into the lagoon sludge and stays, resulting in a high-organic N fraction of total Kjeldahl N (TKN) in settled solids.

As anaerobic digestion of manure changes the solution chemistry in a lagoon, materials such as ammonia and P form precipitates with Ca and Mg. Both Fulhage and Hoehne (1999) and Bicudo et al. (1999) report concentrations of Ca, Mg, P, and K in lagoon sludge at 10 to 30 times that found in raw manure. Fulhage and Hoehne also reported that Cu and Zn settle and concentrate to 40 to 100 times the concentration found in lagoon liquid.

Martin (1999), in a review and analysis of factors affecting pathogen destruction, found that time and temperature controlled the die-off rate of pathogens. Sludge that has been in a lagoon for 10 years is expected to have very low concentrations of pathogens, and those would be associated with the most recent 90 to 180 days of settling.

Advantages and Limitations: The advantage of lagoon cleanout is that removal of sludge restores the volume of a lagoon that is necessary for design treatment and storage capacities. One of the limitations is that sludge disposal is ignored in most nutrient management plans. Sludge is a concentrated, nutrient-rich material. The nutrients in the sludge, if applied to the same cropland historically receiving lagoon liquids, could easily exceed the planned application rate of nutrients. Phosphorus and other relatively insoluble nutrients are more concentrated than N in sludge and become the basis of planning proper use and disposal of the sludge.

Ideally, sludge will be managed as a high value fertilizer in the year it is applied. As the sludge has a higher nutrient and, hence, cash value than liquid manure, hauling to remote farms and fields to replace commercial fertilizer application is possible and desirable. Proper management of applied sludge will result in successful crops and minimal loss of nutrients to surface or ground waters.

Operational Factors: The USDA allows for sludge accumulation by incorporating a sludge accumulation volume (SAV) in its lagoon design calculations. Table 8-15 shows USDA's ratios of sludge accumulated per pound of total solids (TS) added to the lagoon. The higher the rate of sludge accumulation assumed in a design, the larger the lagoon volume required.

Information from various studies suggests that the USDA values may overestimate actual sludge accumulation rates. Table 8-16 shows a range of long-term sludge accumulation rates reported by various researchers. Field studies by both Fulhage and Hoehne (1999) and Bicudo et al. (1999) show lower accumulation rates than were developed by Barth and Kroes (1985) and USDA NRCS (1996).

It is important to note that the accumulation rate of sludge is influenced by lagoon design, influent characteristics, site factors, and management factors. Lagoon design factors such as lagoon volume, surface fetch, and lagoon depth increase or decrease potential lagoon mixing. More lagoon mixing encourages greater solids destruction by increasing the opportunity for bacteria to encounter and degrade solids. Influent factors, including animal type and feed, determine the biodegradability of manure solids. Highly degradable manure solids are more completely destroyed, thus accumulating as sludge to a lesser degree. Site temperature and incident rainfall impact the biological performance of the lagoon. High temperature increases biological activity and solids destruction. High rainfall can fill the lagoon and reduce retention time, thus slowing biological destruction of solids. Management factors also affect sludge accumulation. Increasing the animal population, the addition of materials such as straw or sand used for animal bedding, or the addition of process water will reduce the ability of a lagoon to destroy solids and increase the rate of sludge accumulation. Properly managed solids separators can reduce the quantity of solids reaching the lagoon, thereby reducing sludge accumulation. Mixing a lagoon before land application will suspend some of the sludge solids, causing them to be pumped out sooner rather than later.

Demonstration Status: Lagoon cleanouts are common and have occurred since lagoons have been used. Companies that specialize in lagoon cleaning are found in many areas of the country.

Practice: Trickling Filters

Description: Trickling filters are currently being evaluated for use at animal feeding operations (AFOs) to address the high concentrations of organic pollutants in AFO wastewater. The technology is a type of fixed-growth aerobic biological treatment process. Wastewater enters the circular reactor and is spread over media that support biological growth. The media are typically crushed rock, plastic-sheet packing, or plastic packing of various shapes. Wastewater contaminants are removed biologically.

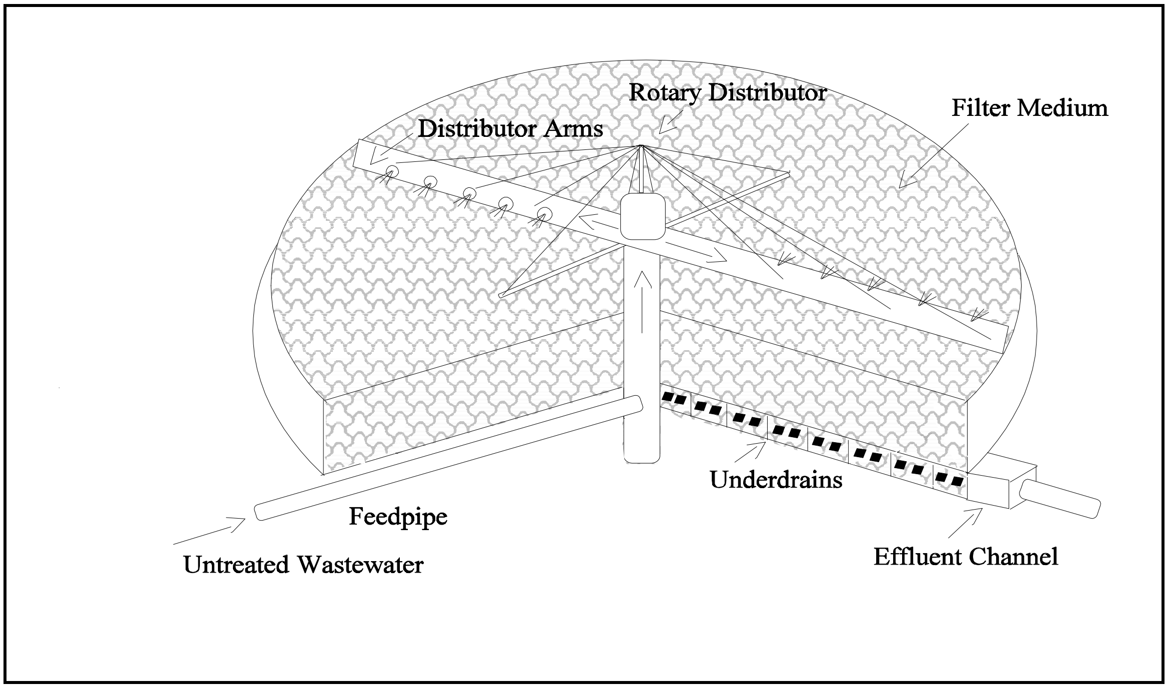


Figure 8-9. Trickling Filter

The top surface of the media bed is exposed to sunlight, is in an aerobic state, contains microorganisms that are in a rapid growth phase, and is typically covered with algae. The lower portion of the bed is in an anaerobic state and contains microorganisms that are in a state of starvation (i.e., microorganism death exceeds the rate of reproduction). The biofilm covering the filter medium is aerobic to a depth of only 0.1 to 0.2 millimeters; the microbial film beneath the surface biofilm is anaerobic. As wastewater flows over the microbial film, organic matter is metabolized and absorbed by the film. Continuous air flow is necessary throughout the media bed to prevent complete anaerobic conditions (Viessman, 1993).

Components of a trickling filter include a rotary distributor, underdrain system, and filter medium. Untreated wastewater enters the filter through a feedpipe and flows out onto the filter media via distributor nozzles, which are located throughout the distributor. The distributor spreads the wastewater at a uniform hydraulic load per unit area on the surface of the bed. The underdrain system, typically consisting of vitrified clay blocks, carries away the treated effluent. The clay blocks have entrance holes that lead to drainage channels and permit the circulation of air through the media bed. Figure 8-9 below shows a cutaway of a typical trickling filter.
Rock media beds can be up to 200 feet in diameter and 3 to 8 feet deep, with rock sizes ranging from 1 to 4 inches. Plastic media beds are narrower and deeper, ranging from 14 to 40 feet deep (Viessman, 1993). These systems look more like towers than conventional rock-media systems. It is also common to have single-stage or two-stage systems for N removal. A two-stage system allows for greater flexibility because each stage can be operated independently and optimized accordingly. Flow capacity of trickling filters can range between 200 and 26,000 gallons per day; however, units can be installed in parallel to handle larger flows (AWT Environment).

Application and Performance: Traditionally, the trickling filter medium has been crushed rock or stone; however, this type of media occupies most of the volume in a filter bed, reducing the void spaces for air passage and limiting surface area for biological growth. Many trickling filters now use a chemical-resistant plastic medium because it has a greater surface area and a large percentage of free space. These synthesized media forms offer several advantages over naturally available materials, particularly in terms of surface contact area, void space, packing density, and construction flexibility (Viessman, 1993).

Although stone-media trickling filters are not as common, they are still used in shallow filters. BOD loads, expressed in terms of pounds of BOD applied per unit of volume per day, are typically 25 to 45 pounds per 1,000 ft^3 per day for single-stage stone filters and 45 to 65 pounds per 1,000 ft^3 per day/day for two-stage stone filters (based on the total media volume of both filters). The recommended hydraulic load ranges from 0.16 gallons per minute per ft^2 to 0.48 gallons per minute per ft^2 (Viessman, 1993).

Other shallow filters use random packing (e.g., small plastic cylinders, 3.5 x 3.5 inches), with a specific surface area of 31 to 40 ft^2/ft^3 and a void space of 91 to 94 percent. Deep filters use corrugated PVC plastic sheets that are 2 feet wide, 4 feet long, and 2 feet deep stacked on top of each other in a crisscross pattern. The specific surface area ranges from 26 to 43 ft^2/ft^3 and a void space of approximately 95 percent. The BOD loads for plastic media towers are usually 50 pounds per 1,000 ft^3 per day or greater with surface hydraulic loadings of 1 gpm/ft^2 or greater (Viessman, 1993).

A single or two-stage trickling filter can remove N through biological nitrification. The nitrification process uses oxygen and microorganisms to convert ammonia to nitrite nitrogen, which is then converted to nitrate nitrogen by other microorganisms. Nitrate nitrogen is less toxic to fish and can be converted to nitrogen gas, which can be released to the atmosphere through denitrification, a separate anaerobic process following nitrification. Note that trickling filters are not capable of denitrifying.

A single-stage trickling filter removes BOD in the upper portion of the unit while nitrification occurs in the lower portion. A two-stage system removes BOD in the first stage while nitrification occurs in the second stage. Trickling filters do not typically remove P, but can be adapted to remove P from the wastewater effluent by chemical precipitation following BOD removal and nitrification (AWT Environment, ETI, 1998).

It is critical to have a properly designed trickling filter system. An improperly designed system can impact treatment performance and effluent quality. Media configuration, bed depth, hydraulic loading, and residence time all need to be carefully considered when designing a trickling filter system (Viessman, 1993).

In a study using municipal wastewater, the average BOD removal was greater than 90 percent and TSS removal was greater than 87 percent using a trickling filter. The average effluent BOD concentration was 13 mg/L, while the average effluent TSS concentration was 17 mg/L (AWT

Environment). In another similar study that included municipal and dairy waste, BOD and TSS concentrations were slightly greater, but never exceeded 100 mg/L (Bio-Systems, 1999).

In another study using municipal wastewater and an anaerobic upflow filter prior to the trickling filter, the average effluent BOD and TSS concentrations both ranged from 5 to 10 mg/L, and the total N removal ranged from 80 to 95 percent. Pathogen reduction for this particular system is expected to be good, due to the upflow filter component. The estimated cost for this system is approximately $18,000 in annualized present day (Year 2000) costs (annualized over 20 years and not including design and permitting) (City of Austin, 2000).

Information on the reduction of pathogens, antibiotics, and metals in trickling filters is not available, but it is expected to be minimal based on engineering judgment.

Advantages and Limitations: An advantage of operating a trickling filter is that it is a relatively simple and reliable technology that can be installed in areas that do not have a lot of space for a treatment system. This technology is also effective in treating high concentrations of organics and nutrients. It can be cost-effective because it entails lower operating and maintenance costs than other biological processes, including less energy and fewer skilled operators. The wasted biomass, or sludge, can be processed and disposed of, although it contains high concentrations of nutrients. Finally, it also effectively handles and recovers from nutrient shock loads (ETI, 1998).

Disadvantages of operating a trickling filter are that additional treatment may be needed to meet stringent effluent limitations, the operation generates sludge that needs to be properly disposed of, poor effluent quality results if the system is not properly operated, and regular operator attention is needed. The system is susceptible to clogging from the biomass as well as odors and flies. The high solids content of CAFO waste would most likely require solids separation prior to treatment to also prevent clogging. Only the liquid waste may be treated in this system. In addition, a high investment cost may also prevent certain farms from installing this technology (ETI, 1998).

Operational Factors: Trickling filters are typically preceded by primary clarification for solids separation and are followed by final clarification for collection of microbiological growths that slough from the media bed. They can also be preceded by other treatment units such as septic tanks or anaerobic filters. Trickling filters effectively degrade organic pollutants, but can also be designed to remove N and P from the wastewater.

Trickling filters are relatively simple to operate, are lower in cost than other biological treatment processes, and typically operate at the temperature of the wastewater as modified by that of the air, generally within the 15-25°C range. A high wastewater temperature increases biological activity, but may result in odor problems. Cold wastewater (e.g., 5-10°C) can significantly reduce the BOD removal efficiency (Viessman, 1993).

Demonstration Status: Trickling filters are most commonly used to treat municipal wastewater, although the technology is applicable to agricultural wastewater treatment. They are best used to treat wastewaters with high organic concentrations that can be easily biodegraded. EPA was not able to locate any AFO facilities that currently operate trickling filters; however, based on the information gathered, several wastewater treatment vendors market this technology to such facilities.

Practice: Fluidized Bed Incinerators

Description: Fluidized bed incinerators (FBIs) are currently being evaluated for use at CAFOs given the high volume of manure they generate. The technology is typically used for wastewater sludge treatment (e.g., municipal sludge), but may be used for wastewater treatment. The main purpose of an FBI is to break down and remove volatile and combustible components of a waste stream and to reduce moisture. Its most prominent application to CAFO industries would be for animal waste disposal and treatment, because manure has a higher solids content than wastewater from CAFO operations.

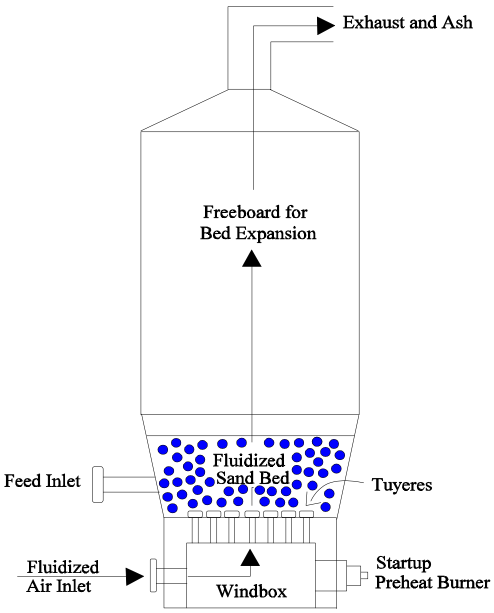


Figure 8-10. Fluidized Bed Incinerator

An FBI is a vertical, cylindrical shaped apparatus that requires media (typically sand), injected air, and an influent fuel to operate. An FBI contains three basic zones: a windbox, a sand bed, and a freeboard reactor chamber. Air enters the windbox and moves upward into the media bed through orifices called “tuyeres” at a pressure of 3 to 5 pounds per square inch. The injected air acts to fluidize the bed and to generate combustion. The term “fluidized bed” refers to the “boiling” action of the sand itself, which occurs when air is injected into the reactor. The fuel, or animal waste, directly enters the fluidized sand bed and is mixed quickly within the bed by the turbulent action. Any moisture in the animal waste evaporates quickly, and the sludge solids combust rapidly. Combustion gases and evaporated water flow upward through the freeboard area to disengage the bed material and to provide sufficient retention time to complete combustion. Gases and ash exit the bed out the top of the FBI. Exit gases may be used to preheat the injected air or may be recovered for energy. Exit ash is removed from exit gas in an air pollution device such as a venturi scrubber. Ash can either be disposed of or reused (typically as fertilizer) depending on its characteristics (Metcalf and Eddy, 1991).

Prior to injection, the sand media is kept at a minimum temperature of 1300 °F and controlled at between 1400 and 1500 °F during treatment. This temperature range varies with specific design criteria. The FBI typically ranges in size from 9 to 25 feet in diameter; the media bed is typically 2.5 feet thick, when settled (Metcalf and Eddy, 1991). The system has a capacity of up to 30 tons per hour (UNIDO, 2000). The combustion process is optimized by varying the animal waste and air flow, with exit gas retention times greater than 1 second and solids retention times greater than 30 minutes (Versar, 2000). Figure 8-10 represents a typical FBI.

Application and Performance: Animal waste enters the FBI and quickly combusts in the media bed. Organic constituents of the waste are burned to produce carbon dioxide and water, while volatile pollutants are evaporated and captured in the air control device. Solid material may be recycled through the system for further treatment. The ash contains many of the pollutants in the animal waste itself, although waste volume is reduced and most of the N in the waste is evaporated. The ash will still contain high levels of metals, P, and K.

The high temperature of the system typically eliminates the spread of pathogens, reducing biosecurity concerns. Similarly, any antibiotics or hormones remaining in the waste will also be broken down and reduced. Although FBIs operate at very high temperatures, they typically operate at lower temperatures than other types of incinerators, which results in lower air emissions, particularly of NO_x compounds and volatile organic compounds (VOCs).

Advantages and Limitations: Fluidized bed incineration is an effective and proven technology for reducing waste volume and for converting the waste to useful products (e.g., energy). Resulting ash may be used as an end- product fertilizer, or as an intermediate product used in manufacturing commercial fertilizers. Animal waste incineration eliminates aesthetic concerns (e.g., odors) as well as nuisance concerns (e.g., pest attraction) (Versar, 2000).

Although fluidized bed incineration is viewed as an efficient system, it is very sensitive to moisture content and fuel particle size. The higher the moisture content, the less efficient the system is because the moisture acts to depress the reactor temperature, thereby reducing combustion capabilities. Moisture can be reduced in animal waste by combining the waste with other biomass such as wood chips or straw. Air drying or dewatering the animal waste also reduces moisture content before treatment in the FBI. Blockages may often occur in input and output pipes triggering shut-down and maintenance (Versar, 2000).

Air emissions must also be considered when operating any type of incinerator. Organic and N compounds are easily removed from the waste; however, they are then emitted to the air, potentially creating a cross-media impact if not properly controlled. Furthermore, nutrients such as P, K, and metals typically remain in the ash and are not treated. Finally, FBIs entail high operating and maintenance costs, especially compared with other types of incinerators (Versar, 2000).

Operational Factors: As discussed above, FBIs are most sensitive to moisture content and fuel particle size. The less moist the influent fuel, the more efficient the system is. Acceptable influent moisture levels range from 15 to 20 percent moisture. Fuel particle size should also be minimized to avoid clogging the system. Another consideration is that depending on the metals concentrations and local regulations, the ash, if intended for disposal, may need to be handled as hazardous waste (Versar, 2000).

FBI costs depend on size and capacity. Capital costs can range from approximately $5 to 25 million for a 5-ton-per-hour and a 30-ton-per-hour FBI, respectively (UNIDO, 2000). FBIs are complex technologies and require operation by trained personnel. Because of this, FBIs are more economical for medium to large facilities, or when operated in cooperation with several businesses that are able to provide fuel sources. Therefore, FBIs may not be a cost-effective waste management technique for an individual farm, but, when operated on a larger scale, they may prove to be cost-effective. Capital and annual operating costs are generally higher for FBIs than for other types of incinerators because of the sensitive design parameters (e.g., moisture content and solid particle size). On the other hand, the system operates efficiently, and energy can usually be recovered from the process and may be sold to another party or used to reduce on-site operating costs.

Demonstration Status: ERG is not aware of any U.S. feedlots currently operating FBIs or sending animal waste to larger-scale municipal or private FBIs. According to information gathered for this program, FBIs are more commonly used in Europe and in Japan to treat animal waste, although some U.S. companies using waste-to-energy technology may be operating FBIs using animal waste with other fuel sources. FBIs are most commonly used in the United States to manage municipal sludge.

In a study done to assess the engineering and economic feasibility of using poultry litter as a fuel to generate electric power, researchers found that combusting poultry litter (combined with wood chips) can be an effective waste-to-energy technology (Versar, 2000). Although the study did not specifically evaluate fluidized bed incineration, the application and results are expected to be similar. The study found litter samples to have a heat content between 4,500 and 6,400 BTU per pound at approximately 16 percent moisture, which is a slightly higher content than the wood chips alone. The ash content of the litter was reported to be between 9 and 20 percent, which is significantly higher than the wood chips alone. However, although the air emissions data in this study were considered preliminary, they showed that the facility could trigger air permitting requirements. The study also found that poultry litter ash may be classified as hazardous waste under individual state regulations (Versar, 2000).

Practice: Constructed Wetlands

Description: Constructed wetlands (CWs) can be an important tool in the management of animal waste by providing effective wastewater treatment in terms of substantial removal of suspended solids, 5-day biochemical oxygen demand (BOD_5), fecal coliform, and nutrients such as N and P (CH2M Hill, 1997). The treatment process in CWs generates an effluent of better quality that can be applied on agricultural land or discharged to surface waters (CH2M Hill, 1997). Wastewater treatment in CWs occurs by a combination of mechanisms, including biochemical conversions, settling/filtration, litter accumulation, and volatilization. Removal of pollutants in CWs is facilitated by shallow water depth (which maximizes the sediment-water interface), slow flow rate (which enhances settling), high productivity, and the presence of aerobic and anaerobic environments (Cronk, 1996).

Wetland media (soil, gravel) and vegetation provide a large surface area that promotes microbial growth. Biochemical conversion of various chemical compounds through microbial activity is the main factor in the wetland treatment process. Through microbial activities, organic N is converted to ammonia (ammonification), which is used by plants as a nutrient; ammonia is converted to nitrate and nitrite (nitrification), which is used by microbes and some plants for growth; and N is volatilized (denitrification) and is lost to the atmosphere (CH2M Hill, 1997). Ammonia may be removed through volatilization, uptake by plants and microbes, or oxidized to nitrate. Volatilization of ammonia in CWs appears to be the most significant mechanism for N removal for animal waste treatment (Payne Engineering and CH2M Hill, 1997).

Phosphorus removal is achieved mainly by fixation by algae and bacteria, plant uptake, and adsorption onto sediments (Cronk, 1996) when oxidizing conditions promote the complexing of nutrients with iron and aluminum hydroxides (Richardson, 1985). Plant uptake of P is only a short-term sink because plant P is rapidly released after the death of plant tissues (Payne Engineering and CH2M Hill, 1997). Fixation of P by microbes ultimately results in the storage of P in the bottom sediments (Corbitt and Bowen, 1994), yet they may become saturated with P, resulting in an export of excess P (Richardson, 1985).

Rooted emergent aquatic plants are the dominant life form in wetlands (Brix, 1993) and are the only aquatic plants recommended for planting in CWs used for animal waste treatment (Payne Engineering and CH2M Hill, 1997). These aquatic plants have specialized structures that allow air to move in and out as well as through the length of the plant, have roots that allow adsorption of gases and nutrients directly from the water column, and are physiologically tolerant to chemical products of an anaerobic environment (Brix, 1993). For these reasons, emergent aquatic plants can survive and thrive in wetland environments. The most common emergent aquatic plants used in CWs for animal waste treatment are cattail (*Typha* spp.), bulrush (*Scirpus* spp.), and common reed (*Phragmites* spp.) (CH2M Hill and Payne Engineering, 1997).

Roles of emergent aquatic plants in the wastewater treatment process include the following: (1) providing a medium for microbial growth and a source of reduced carbon for microbial growth; (2) facilitating nitrification-denitrification reactions; (3) assimilating nutrients into their tissue; (4) facilitating entrapment of solids and breakdown of organic solids; and (5) regulating water temperature by shading the water (Payne Engineering and CH2M Hill, 1997). The vascular tissues of these plants move oxygen from overlying water to the rhizosphere and thus provide aerobic microsites (within the anaerobic zone) in the rhizosphere for the degradation of organic matter and growth of nitrifying bacteria (Brix, 1993). Dissolved nitrates, from nitrification, can then diffuse into the surrounding anaerobic zone where denitrification occurs. Furthermore, wetland macrophytes remove small amounts (<5 percent, Hammer, 1992) of nutrients, for nutritional purposes, by direct assimilation into their tissue. Removal of nutrients, however, increases slightly in CW systems that incorporate periodic harvesting of plants (Hammer, 1992) or may be considerably higher (67 percent) in specially designed systems that maximize influent-root zone contact (Breen, 1990).

The two principal types of CWs for treating wastewater are surface flow (SF) and subsurface flow (SSF) systems. The SF systems are shallow basins or channels, carefully graded to ensure uniform flow, planted with emergent vegetation, and through which water flows over the surface at relatively shallow (~30 cm) depths. The SSF systems consist of a trench or bed with, a barrier to prevent seepage, planted emergent vegetation growing in a permeable media (soil, gravel) designed such that the wastewater flows horizontally through the media, with no open surface flow. The base media and plant roots provide large surface areas for biofilm growth and thus, functions somewhat like a rock trickling filter at a municipal wastewater treatment plant (Payne Engineering and CH2M Hill, 1997).

Some authors also refer to the SF system as the free water surface system, while the SSF type is also referred to as the vegetated rock-reed filter, vegetated submerged bed system, gravel-bed system, and root-zone system. Compared with SSF systems, the SF wetlands are capable of receiving a wider range of wastewater loads, have lower construction costs, and are relatively easy to manage (Payne Engineering and CH2M Hill, 1997). Additionally, mass removal of ammonia-N, the major form of N in animal wastewater (CH2M Hill and Payne Engineering, 1997), in SSF wetlands is significantly less compared with the SF type because there is less time and oxygen to support necessary nitrification reactions (USEPA, 1993). For these reasons, the SF system is the most commonly used wetland type for treating animal waste (Payne Engineering and CH2M Hill, 1997) and is the only one recommended for animal waste treatment by the USDA Natural Resources Conservation Service (USDA NRCS, 1991).

Application and Performance: A database, developed by CH2M Hill and Payne Engineering (1997), containing design, operational, and monitoring information from 48 livestock CW systems (in the United States and Canada), indicates that CWs have been and continue to be used successfully to treat animal waste, including wastewater from dairy, cattle, swine, and poultry operations. The majority of CW sites included in the database have begun operations since 1992. SF systems constitute 84 percent of cells in the database, and the remainder consists of SSF or other wetland systems. Cattail, bulrush, and reed, in that order, dominate the aquatic vegetation planted in the surveyed CWs.

Typically, effluent from a CW treating animal waste is stored in a waste storage lagoon. Final dispersal occurs through irrigation to cropland and pastureland, though the potential for direct discharge of effluent exists. Direct discharge may, however, require a permit under the EPA's National Pollutant Discharge Elimination System.

A performance summary of CWs used for treating animal waste indicates a substantial reduction of suspended solids (53 to 81 percent), fecal coliform (92 percent), BOD_5 (59 to 80 percent), ammonia-N (46 to 60 percent), and N (44 to 63 percent) for wastewater from cattle feeding, dairy, and swine operations (CH2M Hill and Payne Engineering, 1997). In a study by Hammer et al. (1993), swine effluent was treated in five CW cells, located below lagoons, that were equipped with piping that provided a control for variable application rates and water level control within each cell. Performance data indicate notable (70 to 90 percent) pollutant removal rates and reliable treatment of swine lagoon effluent to acceptable wastewater treatment standards for BOD_5, suspended solids, N, and P during the first year of the reported study.

Removal efficiency of N is variable depending on the system design, retention time, and oxygen supply (Bastian and Hammer, 1993). Low availability of oxygen can limit nitrification, whereas a lack of a readily available carbon source may limit denitrification (Corbitt and Bowen, 1994). Fecal coliform levels are significantly reduced (>90 percent) by sedimentation, filtration, exposure to sunlight, and burial within sediments (Gersberg et al., 1990). Compared with dairy systems, higher reduction of pollutants have been reported for swine wastewater treatment in CWs, probably because loading rates have tended to be lower at swine operations (Cronk, 1996).

Advantages and Limitations: In addition to treating wastewater and generating water of better quality, CWs provide ancillary benefits such as serving as wildlife habitat, enhancing the aesthetic value of an area, and providing operational benefits to farm operators and their neighbors (CH2M Hill, 1997). CWs, in contrast to natural wetlands, can be built with a defined (desired) composition of substrate (soil, gravel) and type of vegetation and, above all, offer a degree of control over the hydraulic pathways and retention times (Brix, 1993). An SF system is less expensive to construct than an SSF system, the major cost difference being the expense of procuring and transporting the rock or gravel media (USEPA, 1993). An SSF system, however, has the advantage of presenting an odor- and insect-free environment to local residents.

Major limitations include a need for relatively large, flat land areas for operation (Hammer, 1993), a possible decrease in SF system performance during winter in temperate regions (Brix, 1993), and a reduction in functional sustainability of the SSF systems if the pore spaces become clogged (Tanner et al., 1998). Other limitations include (1) an inadequacy of current designs of SF systems to store flood waters and use stored water to supplement low stream flows in dry conditions and (2) potential pest problems and consequent human health problems from improperly designed or operated SF systems (Hammer, 1993). Moreover, because CW technology for animal waste treatment is not well established, long-term status and effects, including accumulation of elemental concentrations to toxic levels, are poorly documented. Further research is needed to better understand the nutrient removal mechanisms in CWs so that improved designs and operating criteria can be developed.

Operational Factors: Because untreated wastewater from AFOs has high concentrations of solids, organics, and nutrients that would kill most wetland vegetation, wastewater from AFOs is typically pretreated in a waste treatment lagoon or settling pond prior to discharge to a CW (Payne Engineering and CH2M Hill, 1997). Incorporating a waste treatment lagoon in the treatment process reduces concentrations of BOD_5 and solids considerably (>50 percent) and provides storage capacity for seasonal application to the wetlands (Hammer, 1993).

Figure 8-11 shows the typical components and a typical treatment sequence of a CW. Constructed wetlands may be built with cells that are parallel or in a series. Construction of cells needs to be determined by the overall topography as well as by the drainage slope of individual cells to maintain shallow water depth for the wetland plants (CH2M Hill and Payne Engineering, 1997). The land slope should be small (<0.5 percent), and the length-to-width ratios should be between 1:1 and 10:1, with an ideal ratio being 4:1 (USDA NRCS, 1991). Data for the surveyed CWs, reported by CH2M Hill and Payne Engineering (1997), indicate the following average

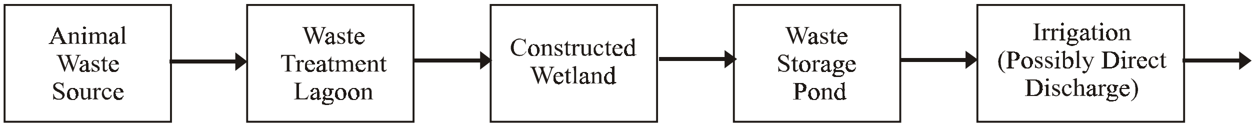


Figure 8-11. Schematic of Typical Treatment Sequence Involving a Constructed Wetland

design conditions: water depth of 38 cm; bottom slope of 0.7 percent; length-to-width ratio of 6.5:1; hydraulic loading rate of 4.7 cm/day; and a size of 0.03 hectare.

Design criteria for CWs for animal waste treatment are described in USDA NRCS (1991), including methods to determine the surface area of a proposed wetland. The NRCS *Presumptive Method* is based on an estimate of BOD_5 loss in the pretreatment process, which is used to calculate BOD_5 concentration in the pretreatment effluent. Size of the wetland is then determined based on a loading rate of 73 kg BOD_5/ha/day that would achieve a target effluent of <30 mg/L of BOD_5, <30 mg/L total suspended solids, and <10 mg/L ammonia-N. The NRCS *Field Test Method* is based on laboratory data for average influent BOD_5 concentration to the CW. The influent BOD_5 concentration, together with average temperature data, is used to determine the hydraulic residence time needed to obtain a desired effluent BOD_5 concentration.

Advances in research and technology of CW during the 1990s have provided additional information to allow modification of the USDA NRCS (1991) methods. CH2M Hill and Payne Engineering (1997) developed the *Modified Presumptive USDA-NRCS Method*, which takes into account pollutant mass loading and volume of water applied, and relates the results to a data table developed from existing CWs for animal waste treatment. The *Field Test Method #2* was also proposed by CH2M Hill and Payne Engineering (1997) based on the areal loading equation developed by Kadlec and Knight (1996), which includes rate constants specific to concentrated animal waste.

Operation and maintenance requirements for CWs include maintenance of water level in the wetland cells, monitoring water quality of influent and effluent, regular inspection of water conveyance and control structures to ensure proper flow, and maintenance of the embankments to avoid damage from rodents.

Demonstration Status: CWs have been demonstrated successfully as a management technology treatment for swine waste (Maddox and Kinglsey, 1990; Hammer et al., 1993) and dairy waste (Chen et al., 1995; Tanner et al., 1995; Schaafsma et al., 2000), and have been relatively less successful in the treatment of poultry waste (Hill and Rogers, 1997). Results of several other successful case studies, performed in several regions of North America, are reported in DuBowy and Reaves (1994), DuBowy (1996), and Payne Engineering and CH2M Hill (1997).

Practice: Vegetated Filter Strips

Description: Vegetated filter strips are an overland wastewater treatment system. They consist of strips of land located along a carefully graded and densely vegetated slope that is not used for crops or pasture. The purpose of a vegetated filter strip is to reduce the nutrient and solids content of wastewater and runoff from animal feeding operations. The filters are designed with adequate length and limited flow velocity to promote filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilization of contaminants.

The wastewater is distributed evenly along the width of a slope in alternating application and drying periods. The wastewater may be applied to the slope by means of sprinklers, sprays, or

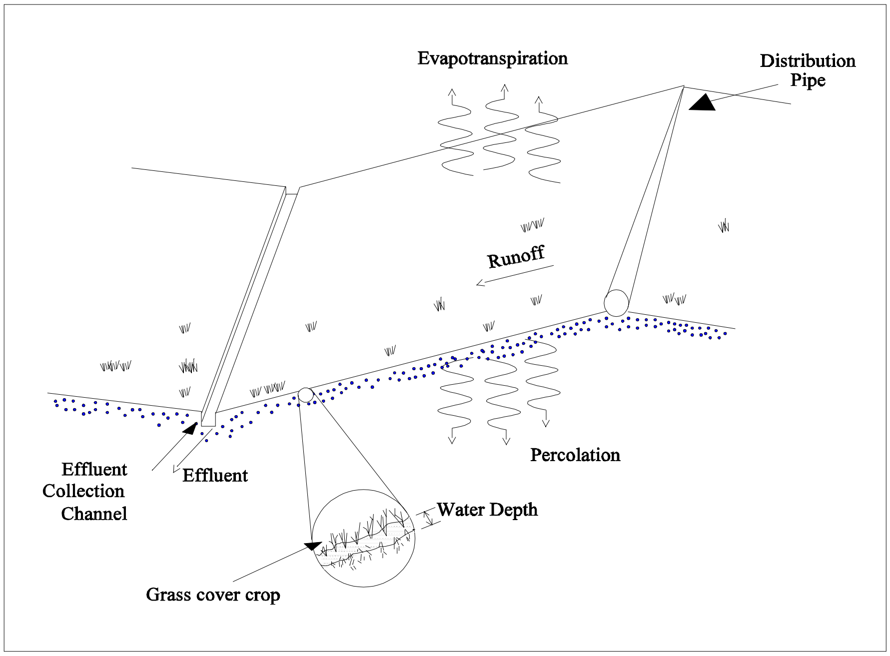


Figure 8-12. Schematic of a Vegetated Filter Strip Used to Treat AFO Wastes

gated, slotted, or perforated pipe. As the wastewater flows down the slope, suspended solids are deposited and some nutrients are absorbed into the vegetation. The effluent from the system is collected in a channel at the bottom of the slope and then discharged (see Figure 8-12).

Application and Performance: The design of a vegetated filter strip is typically based on the BOD concentration of the wastewater (Metcalf and Eddy, 1991). The total treatment area required is calculated from the hydraulic loading rate, assumed length of slope (generally 100 to 150 feet), and an operating cycle. The operating cycle and application rate can be varied to optimize the system. An operating cycle of 1 day is typical, with 8 to 12 hours of application and 12 to 16 hours of drying. Ammonia removal from primary effluent can be expected to vary inversely with the ratio of application period to drying period. A properly designed system can remove up to 95 percent of ammonia. The application rate is critical for considering BOD removal because it is important to maintain aerobic conditions that are required for microbial decomposition. Too high an application rate can create anaerobic conditions because the oxygen transfer through natural aeration from the atmosphere will be insufficient.

The vegetative cover should be dense in growth, such as a grass, and well suited to the climatic conditions. The vegetation must be dense enough to slow the wastewater flow to allow adequate treatment and prevent erosion. Consideration should also be given to the nutrient uptake potential of the vegetation to maximize nutrient removal rates.

Proper grading is also critical to the design of a vegetated filter strip to prevent the channeling of wastewater and allow for efficient treatment. Sites with an existing slope of 2 to 6 percent are best suited for vegetated filter strips to keep regrading costs to a minimum without causing water to pond.

Vegetated filter strips are also best suited to sites that have low permeability soils to prevent wastewater from infiltrating the subsurface. In areas where soils are relatively permeable, it may be necessary to amend the existing soils or install an impermeable barrier.

A study conducted to determine the effectiveness of milkhouse wastewater treatment using a vegetative filter strip at a dairy farm in Vermont (Clausen and Schwer, 1989) found that removals of total suspended solids, total P, and total Kjeldahl N were 92 percent, 86 percent, and 83 percent, respectively. However, the total P concentration in the effluent was more than 100 times greater than the average P concentration of streams draining agricultural areas in the northeast. Moreover, only 2.5 percent of the total input of P and 15 percent of the input of N were removed in the vegetation.

The EPA Chesapeake Bay Program studied the use of vegetative filter strips to reduce agricultural nonpoint source pollutant inputs to the bay (Dillaha et al., 1988). A series of nine experimental field plots were constructed, each containing a simulated feedlot source area and a vegetated filter strip of known length. A rainfall simulator was used to produce runoff, which was collected from the base of each vegetated filter strip. Analysis indicated that 81 to 91 percent of incoming sediment, 58 to 69 percent of the applied P, and 64 to 74 percent of the applied N were removed.

Advantages and Limitations: Compared with many treatment technologies, vegetated filter strips effectively reduce the nutrient and solids concentration of wastewater with relatively low construction and maintenance costs. This is particularly true for sites where available land is well suited for such a system.

However, to effectively treat high volumes of wastewater, such as from a milking parlor, excessive acreage may be required. In addition, because overland flow systems such as vegetated filter strips depend on microbiological activity at or near the surface of the soil, cold weather adversely affects their performance. Winter use of this in colder climates will therefore be limited and an appropriate amount of wastewater storage will be required. Storage is recommended when the average daily temperature is below 32°F.

Operational Factors: Maintenance of a vegetated filter strip consists of periodic removal of the vegetative growth, which contains many of the nutrients. The biomass has various potential uses—as forage, fiber, or mulch, for example. In addition, the slope needs to be periodically inspected and regraded to ensure a level flow surface and prevent channeling and erosion.

Demonstration Status: Vegetated filter strips have been used to treat milkhouse wastewater in New York and North Carolina. They have also been used to treat a variety of other wastes, including feedlot runoff.

Practice: Composting—Aerobic Treatment of Solids

Description: Composting is the aerobic biological decomposition of organic matter. It is a natural process that is enhanced and accelerated by the mixing of organic waste with other ingredients in a prescribed manner for optimum microbial growth. Composting converts an organic waste material into a stable organic product by converting N from the unstable ammonia form to a more stable organic form. The end product is safer to use than raw organic material and one that improves soil fertility, tilth, and water holding capacity. In addition, composting reduces the bulk of organic material to be spread, improves its handling properties, reduces odor, reduces fly and other vector problems, and can destroy weed seeds and pathogens. There are three basic methods of composting: windrow, static pile, and in-vessel.

Windrow composting consists of placing a mixture of raw organic materials in long, narrow piles or windrows, which are agitated or turned on a regular basis to facilitate biological stabilization. Windrows aerate primarily by natural or passive air movement (convection and gaseous diffusion). Windrow composting is suitable for large quantities of organic material. For composting dense materials like manure mixtures, windrows are usually no more than 3 feet high and 10 to 20 feet wide. The equipment used for turning, ranging from a front-end loader to an automatic mechanical turner, determines the size, shape, and spacing of the windrows.

The **static pile method** consists of mixing the compost material and then stacking the mix on perforated plastic pipe or tubing through which air is drawn or forced. Forcing air (by suction or positive pressure) through the compost pile may not be necessary with small compost piles that are highly porous or with a mix that is stacked in layers with highly porous material. If layering is not practiced, the materials to be composted must be thoroughly blended before they are placed in a pile. The exterior of the pile is typically insulated with finished compost or other material. The dimensions of the static pile are limited by the amount of aeration that can be supplied by the blowers and by the stacking characteristics of the waste. The pile height generally ranges from 8 to 15 feet, and the width is usually twice the height. The spacing between individual piles is usually equal to about half the height.

The **in-vessel method** involves the mixing of manure or other organic waste with a bulking agent in a reactor, building, container, or vessel, and may involve the addition of a controlled amount of air over a specific detention time. This method has the potential to provide a high level of process control because moisture, aeration, and temperature can be maintained in some of the more sophisticated units (USDA, 1999).

Application and Performance: Composting is an accepted process for the biological stabilization of the organic material in waste, providing an alternative to long-term liquid and semisolid manure storage. It turns waste organic material (dead poultry, manure, garbage, and so forth) into a resource that can be used as a soil amendment and fertilizer substitute. Proper composting minimizes nutrient loss while killing pathogenic organisms by process generated heat. For example, two waste products from a municipal and a dairy source were composted in the lab under controlled temperature and air flow rates (Hall and Aneshansley, 1997). Researchers found that maintaining high and constant temperatures destroys pathogens and accelerates decomposition.

In general, only manure from confined animals is available for composting. Usually, manure must be dewatered or mixed with sawdust or wood chips to lower the moisture content, which may range from 60 to 85 percent. The presence of plant nutrients such as N, P, and K; the organic content; and the absence of significant levels of heavy metals makes animal manure a very attractive raw material for producing compost. In-vessel composting has been conducted successfully with dairy cattle manure, swine manure, horse manure, and poultry and turkey litter.

Advantages and Limitations: Compost and manure are both good soil conditioners that contain some fertilizer value. On a growing number of farms, however, manure is considered more of a liability than an asset. Animal waste generators may find themselves with surpluses of manure in the winter, yet lacking manure by spring planting. Odor complaints associated with manure are common in populated areas. Other concerns include polluted runoff from manure spread on frozen ground and nitrate contamination of wells.

Composting converts the nutrients in manure into forms that are less likely to leach into ground water or be carried away by surface runoff. Compost releases its nutrients more slowly than commercial fertilizers, so it does not burn crops and can feed them over a longer period of time. The nutrient value of manure was demonstrated in a study in which five combinations of composted cattle feedyard manure and liquid phosphate were applied to provide 100 percent of the P requirement for corn (Auvermann and Marek, 1998). Five replicates were tested for each treatment. No significant difference was determined between corn yields in treatment-by-treatment comparisons, indicating that composted feedlot manure may be an adequate substitute for chemical fertilizers.

A well-managed composting operation generates few odors and flies, and the heat generated by the composting process reduces the number of weed seeds contained in the manure. Composting also reduces the weight, moisture content, and volatility of manure, making it easier to handle and store. Because of its storage qualities, compost can be held for application at convenient times of the year. Composted manure and composted manure solids can also be used as bedding material for livestock.

Different types of in-house, deep litter manure management systems were tested at a 100,000-chicken high-rise layer operation in Georgia (Thompson et al., 1998). Composting was conducted using raw manure, a manure and leaf mixture, and manure and wood chip mixture. The in-house composting was found to reduce the weight and volume of wastes more efficiently than conventional methods of stacking manure under the house. Wood chip and leaf manure both had lower moisture content and more concentrated nutrients compared with the raw manure.

Disposal is less of a problem for compost than for manure because there is usually someone willing to take the compost. One of the strongest incentives for composting is that a market exists for the product, especially in populated areas. Potential buyers include home gardeners, landscapers, vegetable farmers, garden centers, turf growers, golf courses, and ornamental crop producers. Bulk compost prices range from $7 to $50 per cubic yard, depending on the local market, compost quality, and the raw materials used.

Countering these advantages are several limitations. Managing and maintaining a composting operation takes time and money, and compost windrows and storage facilities for raw materials can take land, and possibly building space, away from other farming activities. When processing only small volumes of farm wastes, the equipment needed is probably already available on the farm, but composting may become a very capital- and labor-intensive task for larger operations. Farmers might need to invest in special composting equipment, which can cost anywhere from $7,000 to more than $100,000. The main equipment needed for composting on a moderate to large scale is machinery to construct, mix, and move material in a compost pile or windrow. A front-end loader and truck may be all that is required. Other equipment, such as chipping or shredding equipment, a windrow turner, screening equipment, aeration equipment, and a composting thermometer or temperature probe, might be needed as well.

Although the end product of composting is odor-free, the raw materials used to make compost may not be. Even the compost piles themselves, if not maintained properly, can become malodorous. Cold weather slows the composting process by lowering the temperature of the composting material. Heavy precipitation adds water to the composting mix, and snow and mud can limit access to windrows.

There is also some ambiguity as to whether manure or compost provides crops with more N. Compost can contain less than half the N of fresh manure; however, the N in manure is less stable than that in compost. Farmers must apply more compost than manure to farmland to achieve the same results because compost nutrients are released very slowly. Generally, less than 15 percent of the N in compost is released in the first year.

Last, although compost is a salable product, selling compost involves marketing. This means searching out potential buyers, advertising, packaging, managing inventory, matching the product to the customer's desires, and maintaining consistent product quality.

In addition to these general limitations, there are specific limitations associated with composting different types of animal manure. Wastes containing excessively high water content, such as poultry manure from egg laying operations and wet manure from free-stall dairy CAFOs, may require additional processing prior to composting. The conditions for optimal composting (see Operational Factors below for greater detail) are not always met with these wastes; for example, the water content is too high (usually greater than 70 percent), the biomass is poorly aerated, and the C:N ratio is often less than 15:1. In these cases, bulking agents such as wood chips or similar wood products are added to make the mix more suitable for efficient composting, but bulking agents must be purchased if not readily available on the farm. Table 8-17 summarizes some of the key advantages and disadvantages of composting.

Operational Factors: Because composting is a biological process, environmental factors influence organism activity, thus determining the speed of decomposition and the length of the composting cycle. The composting period typically lasts from 3 to 8 weeks for conventional composting methods under normal operating conditions. Users of some highly controlled mechanical systems claim to produce compost in as little as 1 week. The length of time depends upon many factors, including the materials used, temperature, moisture, frequency of aeration, and ultimate use of the material. Conditions that slow the process include lack of moisture, a high C:N ratio, cold weather, infrequent or insufficient aeration, and large or woody materials. A month-long "curing" period usually follows the active composting stage. Curing continues to stabilize the compost but at a much slower pace. At this stage, the compost can be stockpiled without turning or aeration and without the fear of odor problems (Rynk, 2000).

Table 8-17. Advantages and Disadvantages of Composting

Advantages of Composting	Disadvantages of Composting
Compost is an excellent soil conditioner.	Composting is labor and management intensive.
Compost is a salable product.	Selling compost involves marketing costs (advertising, packaging, management, customer service, and so forth).
Compost reduces the weight, moisture content, and activity of manure, making it easier to handle and store.	The composting site, raw materials storage, and compost storage require a large land area.
Composting converts the N content of manure into a more stable organic form. Manure that has been composted provides a better carbon/nitrogen ratio (C:N) in the soil, contains fewer weed seeds, and poses a lower risk of pollution and nuisance complaints (due to less odor and fewer flies).	Nutrients in compost are in complex form and, therefore, need to be mineralized for plant intake; thus a greater volume of compost is needed to meet crop demands.
Composting kills pathogens.	Effectiveness is weather dependent.
Compost is a suitable bedding substitute.	Large operations require expensive equipment
Land-applied compost has proven to suppress soil-borne plant diseases without the use of chemical controls.	Odors can be a recurring problem.
Some farmers have begun accepting payment (referred to as "tipping fees") to compost off-site wastes.	Acceptance of off-site organic wastes may result in the operation being classified as commercial and increase compliance costs under zoning and environmental regulations.

The characteristics of the raw organic material are the most important factors determining the quality of compost, including moisture content, C:N ratio, aeration, material particle size, and temperature. Acceptable and preferred ranges for nutrient balance (C:N ratio), moisture content, pH, and bulk density are provided in Table 8-18 (NREAS, 1992). Additional factors considered when formulating a raw organic material recipe are degradability, odor potential, and cleanness. For example, swine manure is very odorous and should not be composted on locations prone to odor complaints. Cleanness refers to the degree of contamination from unwanted materials (glass and heavy metals), chemicals (pesticides), and organisms (human pathogens). If the compost is to be sold offsite, the raw material content will greatly affect its market value.

The optimum **moisture content** for composting varies with particle size and aeration. At high moisture content, voids fill with liquids and aeration is hindered. Low moisture levels, on the other hand, retard or stop microbial activity, although some composting occurs with moisture as low as 25 percent. Depending on the raw materials, there is ultimately a 30 to 60 percent reduction in volume of the compost material, much of it due to water loss. If the water content falls below 40 to 50 percent, water should be added and mixed into the composting feedstocks. Warm weather enhances water loss from compost windrows by surface evaporation. Increased turning also results in a higher evaporation rate. This can be an advantage if a drier compost is desired, but if the evaporation rate becomes too high, water should be added to reduce potential fire hazards.

Periods of high rainfall can also be a problem for windrow composting. Windrows usually absorb water from normal rainfall or snow without saturating the materials. If the windrows become wetter than desired, more turnings are required to evaporate the added moisture. Rain can also produce muddy conditions, making it difficult to operate turning equipment. Snow can halt operation altogether until plowed from equipment paths. In addition, puddles and standing water can lead to anaerobic conditions at the base of a windrow. It is important that the composting site has adequate drainage to compensate for periods of high rainfall.

Table 8-18. Desired Characteristics of Raw Material Mixes

Characteristic	**Reasonable Range**	**Preferred Range**
Carbon to Nitrogen (C:N) Ratio	20:1-40:1	25:1-30:1
Moisture Content	40-65 percent	50-60 percent
pH	5.5-9	6.5-8.5
Bulk Density (lbs/y^3)	Less than 1,100	No preferred range

Source: NREAS, 1992.

Carbon and nitrogen serve as nutrients for the microorganisms, and for efficient composting they should be available in the right balance. A good **C:N ratio** falls between 25:1 and 35:1, although recommendations vary based upon site-specific conditions. For example, a study by Virginia Polytechnic Institute and State University concluded that the best combination of straw and raw swine manure for composting has a C:N ratio of 16:1 and a moisture level of 50 to 70 percent (Collins and Parson, 1993). Above the optimum range of C:N ratio, the materials break down at a slower rate, while a lower ratio results in excess nitrogen loss. For example, a study of poultry litter composting as a function of the C:N ratio and the pH of the starting materials showed that ammonia emissions decreased substantially as the C:N ratio increased through addition of short paper fiber (C:N ratio(> 200:1) to broiler litter (Ekinci et al., 1998). As composting progresses, the C:N ratio will fall gradually because the readily compostable carbon is metabolized by microorganisms and the nitrogen is converted to nitrate and organic forms.

In animal manure, the C:N ratio is usually 10:1 to 15:1. The C:N ratios for different manures vary: poultry litter 10:1, layer manure 5:1, cattle feedlot manure 13:1, dairy manure 18:1, swine feedlot manure 3:1, and horse stable manure 25:1. Bulking materials can be added to increase the C:N ratio in the compost pile. Typical bulking materials include grass clippings (C:N ratio of 12:1 to 25:1); hay (15:1 to 32:1); oak leaves (50:1); shrub and tree trimmings (50:1 to 70:1); straw, cornhusks, and cobs (50:1 to 100:1); pine needles (60:1 to 100:1); sawdust (150:1 to 700:1); wood chips (500:1 to 600:1); or newspaper (400:1 to 850:1). For example, dairy manure is a good substrate for composting because it breaks down quickly and supplies the microorganisms with most of the required nutrients, but it is also nitrogen-rich, excessively wet, and has a carbon-to-nitrogen ratio ranging from 12:1 to 18:1. Moisture content varies from about 75 percent for manure collected from stanchion barns to about 85 percent from free-stall operations, with the variability determined primarily by the amount of bedding used. To make dairy manure more suitable for composting, it must be mixed with bulking agents that can be easily incorporated into the composting mix by using them as bedding.

The feasibility of using sawdust and chopped fescue hay as a low-cost waste carbon source to compost with separated swine manure solids was investigated using 21-liter vessels and bin composting units (Hoehne et al., 1998). Manure and fescue hay produced the lowest C:N ratio in both small and large composting units. Temperature trends were used to indicate biological activity. Composting manure with a carbon source was recommended because the product was easy to transport, appropriate for transport through residential areas, and odor-stable, even though composting is labor intensive.

The rate of air exchange and effectiveness of **aeration** of windrows depends on the porosity of the windrow. For example, a wet, dense windrow containing manure is less porous than a windrow of leaves. Windrows that are too large may result in anaerobic zones occurring near the center and causing odors when the windrow is turned. Periodic turning of window compost piles exposes the decomposing material to the air and keeps temperatures from getting too high (exceeding 170 ^{o}F). The most important effect of turning is rebuilding the windrow's porosity. Turning fluffs up the windrow and restores pore spaces lost from decomposition and settling, thereby restoring oxygen within the pore spaces for microorganisms and improving passive air exchange. Turning also exchanges the material at the surface with material in the interior. The materials compost evenly and, as a result, more weed seeds, pathogens, and fly larvae are destroyed by the high temperatures. The minimum turning frequency varies from 2 to 10 days, depending on the type of mix, volume, and ambient air temperature. As the compost ages, the frequency of turning can be reduced.

A study in Ohio measured ammonia concentrations from dairy manure and rice hulls composted with various aeration rates (Hong et al., 1997). Temperature and ammonia concentrations peaked 48 days after aeration begins and then declined steadily, leveling off after 150 hours. The effect of intermittent aeration on composting swine waste was studied to determine changes in ammonia emissions and dry matter loss (Hong et al., 1998). Continuous and intermittent aeration treatments were tested on composting hog manure amended with sawdust in pilot-scale 200-liter vessels. Ammonia emissions were 39 percent lower from the intermittent aeration treatments, and nitrogen losses as NH_3-N were 26 percent lower for continuous aeration and 14 percent lower for intermittent aeration. Dry solids loss and other physicochemical properties were similar between the two treatments. It was concluded that intermittent aeration may be a practical method of reducing nitrogen loss and ammonia emissions when composting swine manure with sawdust.

Smaller **particle size** provides greater surface area and more access for the degrading organisms. It may be necessary to reduce by grinding the particle size of some material such as corn stalks.

Windrow turning blends raw materials and breaks up particles into smaller pieces, thus accelerating biodegredation through increased surface area.

Heat produced during the composting process raises the **temperature** of the composting materials. Because the heat produced is directly related to the biological activity, temperature is the primary gauge of the composting process. During the first few days of composting, pile temperatures increase to between 104 and 158 ^{o}F. This range enhances the growth and activity of the microorganisms. In addition, temperatures above 131 ^{o}F kill most pathogens, fly larvae, and weed seeds. The high temperature might be maintained for several days, until the microorganisms begin to deplete their food source or until moisture conditions become less than optimal. Mixing the composting feedstock brings more undecomposed food into contact with the microorganisms, replenishing their energy supply. Once the optimum moisture level is restored and the feedstocks have been remixed, the temperature increases again. After the readily decomposable material is depleted, the compost pile no longer heats upon remixing. The temperature continues to drop to ambient, and only very slow decomposition continues.

Although composting can be accomplished year-round, seasonal and weather variations often require operational adjustments. This is especially true for windrow composting. Cold weather can slow the composting process by increasing the heat loss from piles and windrows. The lower temperatures reduce the microbial activity, which decreases the amount of heat generated. To compensate for cold weather, windrows should be large enough to generate more heat than they lose to the environment, but not so large that the materials become excessively compacted. Windrows that are too small can lose heat quickly and may not achieve temperatures high enough to cause moisture to evaporate and kill pathogens and weed seeds.

Demonstration Status: Agricultural composting is experiencing a resurgence of activity, particularly in the northeastern United States. A growing number of farmers are now composting significant quantities of organic materials. These farmers have incorporated composting of a wide variety of organic wastes generated on and off farm into their normal operations. Some own large commercial enterprises; others are small “hobby” farms. A number operate otherwise traditional dairy enterprises, and several are organic vegetable growers. Some use all or most of the finished compost on the farm, and some produce compost and soil mixes as a primary agricultural product. Many use existing on-farm technology to manage the compost piles, and others have invested in specialized compost production equipment.

Several Massachusetts dairy farms have adopted composting as a manure management technique. In a study of five farms practicing composting in that state, it was found that three used the windrow method of composting, one used the passive method, and one experimented with several composting methods, finding the windrow method the most successful (Rynk, 2000). The Rosenholm-Wolfe Dairy farm in Buffalo County, Wisconsin, has successfully produced compost for the commercial market using organic solids separated from manure that had been flushed from a 250-head free-stall barn (Rosenow and Tiry, _____). The raw composting material has a C:N ratio of 30:1 and a moisture content of 60 percent, which is ideal for rapid production of a high-quality product using windrow composting.

A pilot project conducted at the Purdue Animal Science Research Center has shown that composting can be an efficient way to manage waste from dairy farms, hog farms, beef feedlots, and poultry operations at a lower cost than that associated with other waste management methods (*Purdue News,* August 1998). The composting site has 13 rows of compost material, of them each 5 feet tall, 10 feet wide, and 250 feet long. The rows are turned using a specialized windrow turner.

Three fundamental factors driving this renewed interest in composting are environmental and community constraints on traditional manure management options, increased understanding of the agronomic benefits of compost use, and rising disposal costs for such materials as municipal yard waste and food processing wastes, which might be managed for a profit in an agricultural setting. Despite growing interest, however, the environmental and possible economical benefits of composting are challenged by a variety of constraints. An agricultural composting study conducted by Cornell University (Fabian, 1993) concluded that governmental agencies need to take a number of steps to further encourage agricultural composting, including minimizing regulatory constraints on farm-composted materials, encouraging local zoning to allow compost facilities as a normal agricultural operation, providing governmental assistance for composting equipment and site preparation, developing procurement guidelines for state agencies to use compost in preference to peat and topsoil, and supporting research and demonstration programs that explore new applications for compost in the agricultural sector.

Practice: Dehydration and Pelleting

Description: Dehydration is the process by which the moisture content of manure is reduced to a level that allows the waste to be used as a commercial product, such as fertilizer for horticulture.

Applicability and Performance: Dehydration has been used on a variety of animal waste products, including poultry manure and litter. The output material (dried to about 10 percent moisture content) is an odorless, fine, granular material. With a moisture content of from 10 percent to 15 percent, a slight odor may be noted. Crude protein levels of from 17 percent to 50 percent have been reported in dried poultry waste (USEPA, 1974). The material can also be formed into pellets prior to drying. Pelleting can make the material easier to package and use as a commercial fertilizer.

Operational Factors: Manure is collected and dried from an initial moisture content of about 75 percent to a moisture content of from 10 percent to 15 percent. The drying process is usually accomplished using a commercial drier. The input requirement for most commercial driers is that the raw material be mixed with previously dried material to reduce the average moisture content of the input mixture to less than 40 percent water.

The mixture is fed into a hammer mill, where it is pulverized and injected into the drier. An afterburner is generally incorporated to control offensive odors. The resultant dried material is either stockpiled or bagged, depending on the ultimate method of disposal selected. Units reported range in size from small portable units to systems capable of processing 150,000 tons per year (USEPA, 1974).

Advantages and Limitations: The drying of animal waste is a practiced, commercial technology with the dehydrated product sold as fertilizer, primarily to the garden trade. It is an expensive process that can be economical only where the market for the product exists at the price level necessary to support the process.

Development Status: The status of dehydrating animal manure is well established. Full-scale drying operations have been established with animal manure, in some cases since the late 1960s. A number of manufacturers offer a line of dehydration equipment specifically designed for this purpose. At least one large-scale facility, currently under construction on the Delmarva Pennisula, will be used to treat broiler manure.

Practice: Centralized Incineration of Poultry Waste

Description: Centralized incineration is an alternative method of disposing of excess poultry litter. Most poultry litter has energy content and combustion qualities similar to those of other biomass and commercially used alternative fuels (e.g., wood and refuse-derived fuels from municipal trash). Under a centralized incineration approach, poultry litter that is removed from the houses is collected and transported to a centralized facility that has been designed or retrofitted to burn poultry litter. The concentration of the poultry industry in several areas of the country and the dry composition of the manure facilitates litter transport, which is critical to the success of this alternative treatment technology. The centralized incineration unit could be located at a processing plant to provide power to the plant or at a stand-alone facility that would generate power for public use.

Application and Performance: Most of the nutrients in the litter would not be destroyed by combustion, but would be captured in the combustion ash and could be managed safely and economically. Consequently, the most immediate environmental benefit from burning litter is that its nutrients would not be applied to cropland and therefore would not run off into waterways.

Advantages and Limitations: The incineration of poultry litter to generate energy offers several clear advantages over current practices. The energy recovered by burning poultry litter would displace conventional fossil fuels and thereby avoid greenhouse gas emissions. The pollution control equipment required for major fuel burning units would likely minimize other combustion emissions when the manure is burned.

Limitations of using poultry litter as fuel include variability in litter composition, litter production rates, and litter caloric content. One of the most important determinants of the suitability of any substance as a fuel is its moisture content, and there is no guarantee that litter would undergo any sort of drying process prior to combustion. Moisture in a fuel represents a reduction in its heating value because some of its energy content must be used to vaporize the moisture, reducing the fuel's effective energy output. Poultry litter has a much lower British thermal unit (Btu) content, higher moisture content, and higher ash content than conventional fuels. It can pose greater operational problems (such as corrosion) and would probably be convertible to steam at a lower efficiency than conventional fuels. Moreover, because of its much higher ash content, litter will yield far more unburned residuals than other fuels. Metals, P, and K from the litter will concentrate in the residual ash; however, bottom ash and fly ash can be sold as fertilizer, contributing to the profitability of the technology.

Metals (e.g., copper, arsenic, zinc) may be present in litter because they are added to poultry feed as a dietary supplement. Other metals may be unintentionally present in feed and bedding, or may be scraped from the floor of a poultry house when the litter is removed. Aluminum may be found in litter because alum is added to limit ammonia volatilization, and aluminum sulfate is added to bind the P in litter, reducing P in runoff when applied to land. Metals in poultry litter can affect its suitability for combustion in several ways. First, the concentration of metals could affect the nature of air emissions from a poultry-fired boiler. Second, metals might pose a problem in the ash created from litter combustion. Most toxic metals concentrate significantly in combustion ash relative to the unburned litter.

Although litter combustion has significant environmental advantages, adverse environmental impacts might result from using poultry litter as a fuel source. Air emissions and treatment residuals result from the incineration of any fuel, however, and the chemical and physical properties of litter as a fuel do not suggest that burning litter would result in significantly worse pollution emissions than would burning conventional fuels. When compared with the combustion of conventional fuels, combustion of poultry litter produces fewer tons of nitrogen oxides (NO_x), sulfur oxides (SO_x), and filterable particulate matter (PM) emissions at the boiler than coal or residual (No. 6) oil. In comparison with distillate fuel oil, litter has a less desirable emissions profile. A comparison with wood is mixed; litter shows lower emissions of carbon monoxide (CO), filterable PM, and methane, whereas wood shows lower emissions of NO_x, SO_x, and carbon dioxide (CO_2). Despite the high N content of poultry litter, burning litter should not increase NO_x emissions. NO_x emissions from combustion primarily depend on the nature of the combustion process itself (affecting the degree to which atmospheric nitrogen is oxidized) and only secondarily on the amount of N in the fuel. In fact, the high ammonia levels in poultry litter may act to reduce much of the NO_x that is formed during combustion back into elemental N. This is the reaction that underlies most of the modern NO_x control technologies (selective catalytic and noncatalytic reduction) used in utility boilers.

SO_x formation in combustion processes depends directly on the sulfur content of the fuel. Therefore, SO_x emissions from burning poultry litter should be lower than those from high-sulfur fuels (residual oil or higher-sulfur coal) and higher than those from low-sulfur fuels (distillate oil, low-sulfur coal, wood, natural gas). The relatively high alkali (potassium and sodium) content of litter and litter combustion ash may cause problems in the combustion system: a low ash melting point, which can lead to slagging and deposition of “sticky” ash on combustion surfaces, and high particulate emissions in the form of volatile alkali compounds. However, this high alkali ash content also has the likely benefit of reducing SO_x in the flue gas through a “scrubbing” effect. If the uncontrolled emissions from burning poultry litter appear likely to exceed emission standards, an appropriate air pollution control device would be installed at the unit, just as it would be at a conventional fuel-burning unit.

Costs for this technology include cleanout and storage/drying costs, as well as the cost of transporting the litter to the incineration facility. A fuel user might hire a contractor to remove litter from a poultry house and load it onto a truck for delivery, hire a contractor to load the litter and pay a grower for the litter and cleanout, or hire a contractor to get the litter from the shed and load it onto a truck, paying the grower for the litter, cleanout, and storage. In addition, fuel users may also need to install new fuel-handling and management equipment and perform some redesign of the combustion process. Burning litter effectively might entail new plant construction, such as construction of a direct-fired biomass facility, retrofitting of an existing plant for direct firing poultry litter, or retrofitting of an existing cogeneration facility or boiler to co-fire poultry litter with conventional fuels (such as oil or coal). Most operations would also require a storage structure and litter supply system. The costs of retrofitting a processing plant boiler or feed mill boiler to co-fire litter do not appear excessive. The cost savings from burning litter would continue indefinitely and would increase as fuel users find more effective and efficient ways of burning litter.

Operational Factors: One of the first steps in using poultry litter as a fuel is to estimate the amount of litter produced by a feedlot. This amount is then compared with the quantity of litter that could be spread appropriately on local cropland to meet agricultural nutrient needs. The amount by which litter production exceeds the litter needed for crop nutrient purposes is the measure of the amount available for fuel. Several approaches are in use to project the volume of litter that a poultry operation will generate. The differing results of these approaches are mostly a function of the wide range of variables that affect poultry litter production—type of bird, feed and watering programs, bird target weight, type of bedding, litter treatment for ammonia control, house type, crusting procedures, and cleanout schedules. One method uses a calculation of 10.8 lb of manure produced per broiler per year, another assumes an average of 35 lb of manure per 1,000 birds per day, and another assumes an average of 2.2 lb of litter per bird. Other more sophisticated methods apply a rate of litter produced per unit of bird weight produced. However, the most straightforward and commonly used calculation relies on an assumption of 1 ton of litter per 1,000 birds. It should be noted that since a significant portion of the weight of litter is water, having drier litter means fewer tons per bird. Therefore, the 1 ton of litter per 1,000 birds assumption should be treated strictly as a rough estimate.

The most important characteristic of litter with regard to its value as a fuel is its caloric content. Although the energy content of litter varies significantly, there is less variation after it is air-dried or oven-dried. For example, research conducted on the Btu content of several litter samples under varying moisture conditions showed that litter with a moisture content ranging from 0 percent to 30 percent having a caloric content ranging from 7,600 Btu per pound to 4,700 Btu per pound, respectively. Litter has a much lower caloric value than conventional fuels, but it has an energy content similar to that of several other commonly used alternative fuels. In addition, when litter is used as a fuel, its density affects the nature of the fuel feed systems and boiler configurations required. The density of litter also affects how the litter can be stored, handled, transported, and land-applied. Estimates of litter density vary widely, depending largely on the moisture content of the litter. Estimates range from 19 to 40 pounds per ft^3, with the average being roughly 30 pounds per ft^3.

Because poultry litter is quite variable with respect to several characteristics important to its use as a fuel, the fuel user must develop quality control and quality assurance guidelines to ensure that the litter is of consistent quality and well suited for combustion. Criteria for accepting litter may include acquiring only litter that has been covered in storage for some period of time to avoid excessive moisture and increase Btu content per ton, or mixing a large quantity of litter on site prior to burning to reduce fluctuations in quality across individual loads of litter. One plant in operation in the United Kingdom employs the following measures: (1) litter shipments are examined for moisture content with infrared equipment, and shipments with excessive moisture are rejected; (2) core samples are taken and analyzed for moisture, ash, and Btu content; (3) based on the results of the analysis, the load is sorted into one of several storage pits; and (4) an overhead crane draws from the different storage pits in a manner providing an appropriate blend of wet and dry material, giving a reasonably constant caloric value when fed to the furnace.

Demonstration Status: This technology is not currently used in the United States for poultry waste; however, existing boilers could be retrofitted to co-fire litter with conventional fuels such as oil or coal, or litter could be burned in a direct-fired biomass facility to generate electricity, steam, or heat at power plants or in boilers at poultry processing plants to supplement energy needs. Other agricultural and silvicultural wastes such as bagasse, almond shells, rice hulls, and wood wastes are burned for energy recovery in scattered utility and industrial plants in the United States. In the United Kingdom, several medium-sized, profitable electric power plants are fueled by poultry litter. This indicates that centralized incineration of poultry waste has the potential to develop into a commercially viable alternative treatment technology for poultry growers.

A British company, Fibrowatt, conceived of, developed, and operates the electricity plants in the United Kingdom that use poultry litter as fuel. Fibrowatt's three plants (two operating, one under construction) are all new and are all electricity-generating plants rather than industrial boilers for steam heat or cogeneration facilities. Fibrowatt's litter storage and handling system is proprietary. The Fibrowatt plant at Eye in Suffolk, the first plant fueled by poultry litter, came on line in July 1992. The second plant, in Glanford at Humberside, came on line in November 1993. The third and largest plant is at Thetford in Norfolk, which was scheduled to begin operations in 1998.

The basic operations at the three plants are similar. Each plant is situated in the heart of a poultry-producing region. Trucks designed to minimize odor and the risk of biocontamination transport the litter from farms to the power plants. The trucks enter an "antechamber" to the litter storage structure, and the doors of the antechamber are closed before the truck unloads. Upon arrival, the litter is sampled for nearly 40 different traits, including Btu content and moisture. The litter is stored and conditioned in a way that homogenizes the fuel. It is kept under negative pressure to control odor, and the air from the fans in the storage structure is directed to the boilers and used in combustion. The Glanford plant uses Detroit Air-jet spreader-stokers (reciprocating grate, solid-fuel combustors) to burn fuel. The Eye plant employs a stepped grate stoker. The boilers are Aalborg Ciserv three-pass, natural-circulation, single-drum water tube boilers. There are modifications to the ash removal process because the high alkali content of the litter can cause corrosion in the boiler. The steam from the boiler is passed to a turbo-alternator, and electricity is sold to the grid. The Fibrowatt plants are commercially viable in the United Kingdom because the prices Fibrowatt can charge for the electricity delivered to the grid are far higher than the prices charged in the United States. In addition, farmers are charged a disposal fee for their litter, and Fibrowatt is able to earn money on the ash produced by combustion, which the plants collect and sell as concentrated fertilizer with a guarantee analysis. Theoretically, the process could be replicated in the United States, but a full-market study would be needed.

Poultry litter is not currently used as fuel in the United States; however, research into the feasibility of burning litter for electricity, steam, or heat is under way. Maryland Environmental Services (MES) has asked the Power Plant Research Program (PPRP), an arm of the Maryland Department of Natural Resources, to help investigate the possibility of burning poultry litter at the cogeneration plant at the Eastern Correctional Institute. In February 1998, Exeter Associates published a report for MES projecting the costs of various scenarios for using poultry litter at the plant. One of the recommendations in the report was that a full engineering study be done to obtain a better estimate of the costs involved. MES submitted a request for proposals on this basis in April 1998 and received bids from several companies. Among the companies that bid were Fibrowatt and two companies that build gasifiers. As of July 1998, the gasifier company bids had been rejected and the remaining bids were still under consideration. MES is determined to turn the cogeneration plant at the Eastern Correctional Institute into a working facility and is interested in a Fibrowatt-style system, the technology of which is proven and currently operational.

Other Technologies for the Treatment of Animal Wastes

Practice: Aquatic Plant Covered Lagoons

Aquatic plant covered lagoons provide low cost wastewater treatment by removing suspended solids, BOD, N, and P in structures that are mechanically simple, relatively inexpensive to build, and low in energy and maintenance requirements (WPCF-TPCTF, 1990). Wastewater treatment occurs through a combination of mechanisms including biochemical conversion through plant-microbial reactions, plant uptake, settling, volatilization, and adsorption onto sediments. Free-floating aquatic plants such as duckweed (*Lemnaceae*) and water hyacinth (*Eichhornia crassipes*) grow rapidly (in a matter of days) and take up large amounts of nutrients from wastewaters (Reddy and De Busk, 1985). In addition, the extensive root system of water hyacinth provides a large surface area for microbial growth, which promotes degradation of organic matter and microbial transformation of N (Brix, 1993). Greater than 70 percent removal of pollutants by aquatic plant covered lagoons has been reported for domestic wastewater treatment (Orth and Sapkota, 1988; Alaerts et al., 1995; Vermaat and Hanif, 1998). Depending on the lagoon design, water depth, and retention time, effluent from hyacinth and duckweed covered lagoons can potentially meet secondary and sometimes advanced wastewater discharge standards for BOD, suspended solids, N, and P (Buddhavarapu and Hancock, 1991; Bedell and Westbrook, 1997).

In addition to providing wastewater treatment, nutrient uptake by water hyacinth and duckweed produces a protein rich biomass (Reddy and Sutton, 1984; Oron et al., 1988) that can be harvested and used as an agricultural fertilizer or a feed supplement (Oron, 1990). Furthermore, duckweed and hyacinths provide a dense cover that restricts algal growth by impeding sunlight at the water surface (Brix, 1993), reduces odor by preventing gaseous exchange, and acts as a physical barrier to reduce the breeding of mosquitoes (Buddhavarapu and Hancock, 1991). Limitations of aquatic plant covered lagoons include a need for large treatment areas, pretreatment of wastewater in settling ponds, and floating grid barriers to keep plants from drifting (Brix, 1993). Cold temperature reduces the growth rate of floating plants (Brix, 1993). Although duckweed removes fewer nutrients than do water hyacinths (Reddy and De Busk, 1985), duckweed has higher protein and lower fiber, a faster growth rate, and lower harvesting costs (Oron, 1990), and can grow at temperatures as low as 1 to 3°C (Brix, 1993). Duckweed prefers ammonia over nitrate (Monselise and Kost, 1993), transforms nutrients to a protein-rich (25-30 percent) biomass (Oron, 1990), and selected duckweed species (*Lemna gibba*, *Lemna minor*) have been demonstrated to grow on undiluted swine lagoon effluent (Bergmann et al., 2000). For these reasons, duckweed is potentially effective in the treatment of animal waste. Further studies are needed to understand better the application and performance of aquatic plant covered lagoons for animal waste treatment.

Practice: Nitrification -Denitrification Systems—Encapsulated Nitrifiers

Description: Nitrification-denitrification refers to the biological conversion of ammonium first to nitrate, then to nitrogen gas. Many schemes for nitrification-denitrification have been researched, including the use of nitrifying bacteria encapsulated in polymer resin pellets to speed up the reaction (Vanotti and Hunt, 1998). The theory is that elevated populations of nitrifying bacteria immobilized on resin pellets that are retained in a treatment system will convert more ammonia to nitrate faster than free swimming bacteria. There is ample evidence that attached media systems that retain bacteria on their surface remove the target pollutants more effectively than bacteria that have to swim to their food and can be washed from the system.

Vanotti and Hunt demonstrated in the lab that an enriched solution of encapsulated nitrifiers in an oxygen-saturated solution at 30 ºC, with 150 ppm BOD and 250 ppm TKN, could nitrify 90 percent of the ammonia in a batch if sufficient alkalinity was added. The research also documented that a solution with encapsulated nitrifiers had more and faster nitrification than an aerated equivalent volume of anaerobic lagoon effluent with no nitrifiers added.

A pilot plant using imported pellets operating on anaerobic lagoon effluent followed the laboratory work. The effluent was first screened, and then introduced into a contact aeration treatment to reduce BOD. The aeration sludge was settled next, and then treated effluent was introduced into a nitrification tank in which another aeration blower was used to maintain a dissolved oxygen concentration of 3 milligrams per liter. The pH was maintained at 7.8 or greater with sodium hydroxide as necessary. The results of 3 months of operation were that, given adequate pretreatment, high nitrification rates of swine wastewater could be attained using enriched nitrifying populations immobilized on polymer resins.

Application and Performance: The technology specifically targets nitrification of ammonia, and could reduce the loss of ammonia-N to the atmosphere. When set up and operated properly, the treatment can convert 90 percent of the ammonia-N remaining in pretreated lagoon effluent to nitrate. A nitrified farm effluent can be denitrified easily by either returning it to an anaerobic environment resulting in release of nitrogen gas (N_2). This technology will have little if any effect on pathogens, metals, growth hormones, or antibiotics. It can be assumed that most of these constituents were removed in the process of aerating the manure to reach oxygen-saturated conditions, which would enable the encapsulated nitrifiers to function.

Advantages and Limitations: A facility to support this process would be expensive to build, operate, and maintain. It is difficult to imagine this process being used on a farm. One area not considered is the sludge generated by aerobic pretreatment. Another limitation is the anaerobic lagoon pretreatment step used to reduce initial BOD and limit sludge production.

Operational Factors: Nitrifying bacteria are temperature sensitive, but the effect of temperature was not discussed by Vanotti. Rainfall and varying concentration should not affect performance; however, seasonal temperature variation may reduce nitrification.

Demonstration Status: North Carolina State University has operated a pilot plant in Duplin County, North Carolina.

Disinfection—Ozonation and UV Radiation

Ozonation is commonly used to disinfect wastewater after biological treatment. Ozone is a highly effective germicide against a wide range of pathogenic organisms, including bacteria, protozoa, and viruses. It oxidizes a wide range of organics, can destroy cyanide wastes and phenolic compounds, and is faster-acting than most disinfectants. Moreover, unlike chlorine, ozone does not generate toxic ions in the oxidation process.

UV radiation is used primarily as a disinfectant. It inactivates organisms by causing a photochemical reaction that alters molecular components essential to cell function. It is very effective against bacteria and viruses at low dosages and produces minimal disinfection by-products. To enhance the inactivation of larger protozoa, UV radiation is often considered in conjunction with ozone.

Disinfection measures such as ozonation and UV radiation are not commonly practiced in the United States for treatment of animal wastes. Animal wastewater would require primary and/or biological treatment prior to disinfection . Ozone is generally effective for aqueous waste streams with less then 1 percent organic content. Both processes are costly and require higher levels of maintenance and operator skill. Wastewater with high concentrations or iron, calcium, turbidity, and phenols may not be appropriate for UV disinfection. The effectiveness of UV disinfection is greatly hindered by high levels of suspended solids.

Vermicomposting

Composting is the controlled decomposition of organic materials and involves both physical and chemical processes (see Composting—Aerobic Treatment of Solids). During decomposition, organic materials are broken down through the activities of various invertebrates that naturally appear in compost, such as mites, millipedes, beetles, sowbugs, earwigs, earthworms, slugs, and snails. Vermicomposting is accomplished by adding worms to enhance the decomposition process.

Vermicomposting uses “redworms” (Eisenia foetida), which perform best at temperatures between 50 and 70 ^{o}F. Bones, meats, fish, or oily fats should not be added to a worm compost box because of odors and rodent problems they could create. Successful operation requires a great amount of maintenance because the worms are highly sensitive to alterations in oxygen levels, temperature, moisture, pH, nutrients, and feed composition and volume. Heavy metals are not treated by any means of composting and can be toxic to the microorganisms and invertebrate population.

Farm-scale systems for vermicomposting have been developed. They tend to be simple systems using conventional material-handling equipment. Labor and equipment are required to add material to the bed, remove composted material, separate the compost from the worms by screening, and process the compost and worms for their respective markets (the compost as a protein additive to animal feed; the worms as fish bait). Flies are a potential problem since this process occurs at a lower temperature than the general composting process. Pathogen destruction and drying are also reduced. A drying or heating step may be required to produce the desired compost.

Chemical Amendments

Chemical amendments to poultry litter have been proven to enhance nutrient removal and odor elimination. Ammonia volatilization from poultry litter often causes high levels of atmospheric ammonia in poultry houses, which is detrimental to both farm workers and birds. Ammonia emissions from houses can also result in a loss of fertilizer nitrogen and aggravate environmental problems such as acid rain. Litter amendments, such as aluminum sulfate (alum), ferrous sulfate, and phosphoric acid, have been proven to reduce ammonia volatilization from litter dramatically. Alum has also been shown to reduce water-soluble P concentrations in litter (whereas phosphoric acid greatly increases water-soluble P levels) and alum has the ability to reduce the solubility of metals (arsenic, copper, iron, and zinc), thereby reducing metal concentrations in rainwater runoff. Ferrous sulfate is also effective in reducing soluble P in the runoff from land-applied poultry litter, but is not favored as an option for use inside poultry houses because chickens might ingest the toxic substance.

Odor control is a major concern at many CAFOs. Chemical additives such as potassium permanganate have been used to reduce levels of sulfides, mercaptans, and other odor-causing agents in manure storage structures, particularly lagoons. Large amounts of lime are often added to wastewaters (raising the $pH>10$) to eliminate odor by reducing microbial activity. Hydrogen peroxide is applied to liquid manure to control sulfides during waste removal and land spreading. Zeolite (a volcanic mineral), cement kiln, and power-plant alkaline by-products are frequently used to reduce volatilization and odors.

Gasification

The fuel produced by gasification is viewed today as an alternative to conventional fuel. A gasification system consists of a gasifier unit, purification system, and energy converters (burners or internal combustion engine). The gasification process thermochemically converts biomass materials (e.g., wood, crop residues, solid waste, animal waste, sewage, food processing waste) into a producer gas containing carbon dioxide, hydrogen, methane and some other inert gases. Mixed with air, the producer gas can be used in gasoline and diesel engines with little modification.

Gasification is a complex process best described in stages: drying, pyrolysis, oxidation, and reduction. Biomass fuels have moisture contents ranging from 5 to 35 percent. For efficient operation of a gasification system, the biomass moisture content must be reduced to less than 1 percent. The second stage of the process, pyrolysis, involves the thermal decomposition of the dried biomass fuels in the absence of oxygen. The next stage, oxidation, produces carbon dioxide and steam. The last stage, reduction, produces methane and residual ash and unburned carbon (char).

Gasification is one of the cleanest, most efficient combustion methods known. It eliminates dependence on fossil fuel and reduces waste dumping. It extracts many substances, such as sulfur and heavy metals, in elemental form. Factors limiting the use of this process include stringent feed size and materials handling requirements. Process efficiency is strongly influenced by the physical properties of the biomass (surface, size, and shape), as well as by moisture content, volatile matter, and carbon content (see Pyrolysis below for additional limitations).

Gasification of animal wastes is still in the developmental stages. It is currently considered a better alternative to incineration for its lower NO_x emissions. However, this treatment option is limited to the animal feed operations that have a market in which to sell the excess power or heat generated by the gasification unit. Without this advantage, such facilities would be inclined to resort to less expensive waste treatment technologies.

Pyrolysis

Pyrolysis is a major part of the gasification process described above. It is formally defined as chemical decomposition induced in organic material by heat in the absence of oxygen. Pyrolysis transforms organic materials into gaseous components, small quantities of liquid, and a solid residue (coke or char) containing fixed carbon and ash. Pyrolysis of organic materials produces combustible gases, including carbon monoxide, hydrogen and methane, and other hydrocarbons. If the off-gases are cooled, liquids condense, producing an oil/tar residue and contaminated water.

Target contaminant groups for pyrolysis are volatile organic compounds and pesticides. The process is applicable for the separation of organics from refinery wastes, coal tar wastes, wood-treating wastes, creosote-contaminated soils, hydrocarbon-contaminated soils, mixed (radioactive and hazardous) wastes, synthetic rubber processing wastes, and paint waste.

Economic factors have limited the applicability of pyrolysis to the animal waste management field. There are also a number of handling factors that limit applicability. Pyrolysis involves specific feed size and materials handling requirements. The technology requires that the biomass be dried to low moisture content (<1 percent). Slight inconsistencies in moisture content and biomass properties (both physical and chemical) greatly increase operational costs. These considerations make it difficult to apply this technology to animal waste. Pyrolysis is not effective in either destroying or physically separating inorganics from the contaminated medium. Volatile metals may be removed as a result of the higher temperatures associated with the process but are not destroyed. Biomass containing heavy metals may require stabilization.

Pyrolysis is still an emerging technology. Although the basic concepts of the process have been validated, the performance data for this technology have not been validated according to methods approved by EPA and adhering to EPA quality assurance/quality control standards. Site characterization and treatability studies are essential for further refining and screening of this process. Pyrolysis has been considered for animal waste treatment as part of the gasification technology, but is currently not in high demand because of operation and maintenance costs.

Freeze Drying and Freeze Crystallization or Snowmaking

Freeze drying involves freezing the waste, which causes the solids and liquids to separate. When the frozen sludge melts, the liquid is easily drained away for reprocessing. The remaining sludge is high in solids, completely stabilized, and capable of being spread on land with conventional agricultural equipment. The process has proven to lower waste management costs by reducing waste volume.

Freeze crystallization, or snowmaking, is a treatment process in which wastewater is turned to snow, thus readily stripping volatile gases from water. Other contaminants are precipitated from the water in a process called atomizing freeze-crystallization. Meltwaters may have a nutrient reduction of up to 60 percent, with almost 100 percent of pathogens killed (MacAlpine, 1997).

Both processes are scarcely utilized due to applicability limitations. These processes are suited only to colder climates. The freeze drying process requires significant storage capacity, and facilities must be capable of storing up to 1 year's production of sludge on site.

Practice: Photosynthetic Purification

A proprietary new animal waste treatment technology, Photosynthetic Purification, uses the nutrients in concentrated animal waste to grow algae and photosynthetic bacteria that yield a harvestable crop (Biotechna, 1998). Photosynthetic Purification technology is reported to treat high-strength, high-moisture waste streams with minimal loss of manure nutrients and generate a clean effluent that can be recycled or safely discharged. The resultant biomass can be used as a high protein animal feed supplement. Nutritional value of the biomass is at least equivalent to that of soy protein. Along with producing a valuable biomass, the main advantage of this technology is that it reduces the potential environmental impact of land application or discharge of animal waste in regions with concentrated animal feeding operations. A possible disadvantage is that animal waste will need to be transported to a processing facility.

The technology has been under development by Biotechna Environmental (2000) Corporation (BE2000) since the early 1990s. Successful tests are reported to have been carried out at pilot scale in Ireland (1994-95) and Connecticut, USA (1998). A laboratory-scale system and a full-scale commercial demonstration plant are planned. Photosynthetic Purification produces high-protein feed supplements and a range of other value added products for the feed and nonfood markets. Because of proprietary information and patent pending status, little information on this technology is currently available to the public.

Deep Stacking of Poultry Litter

Research dating back to the 1960s (Bhattacharya and Fontenot, 1965) has shown that poultry litter has significant nutritive value as a feedstuff for ruminants. Subsequently, concerns about the potential public health impacts of using poultry litter as well as other animal manures as feedstuffs emerged. The presence and impact of pathogens, such as species of Salmonella and Clostridium, in manures being used as feedstuffs was one of these concerns. There have been a number of reports from foreign countries of botulism in animals fed diets containing animal wastes (Fontenot et al., 1996).

For poultry litter, the response to this concern about potential pathogen transmission was the development of the practice known as deep or dry stacking (McCaskey, 1995). It consists simply of piling litter in a conical pile or stack after it is removed from a poultry house and raises in temperature to a maximum of 140 $^\circ$F (60 $^\circ$C) by microbes. Litter with a moisture content exceeding 25 percent may reach temperatures above 140 $^\circ$F if not covered to exclude air.

McCaskey et al. (1990) have shown that higher temperatures produce a material with a "charred" appearance and reduced nutritive value. They reported that excessively heated litter has about 50 percent of the dry matter digestibility of litter that has not been excessively heated. This estimate was based on the percentage of litter dry matter solubilized in rumen fluid after 48 hours. Also, it was observed that the amount of N bound to acid detergent fiber and considered not available approximately tripled in overheated litter.

The practice of deep stacking of poultry litter enhances its value as a feedstuff for ruminants by reducing concern about possible pathogen transmission. However, deep stacked poultry litter cannot be considered pathogen-free because the stacked litter is not mixed out of concern that reaeration will create the potential for excessive heating. Thus, outer regions of the deep stacked litter might not reach the temperatures necessary for pathogen destruction. In reality, deep stacking is composting in which oxygen availability limits the temperature and the degree to which dry matter (volatile solids) are destroyed.

When deep stacking is done in a roofed structure such as a litter storage shed or in covered piles, the potential water quality impacts are essentially nil; however, deep stacking in uncovered piles creates the potential for leaching and runoff losses of nutrients, oxygen-demanding organics, and pathogens, as well as producing a feedstuff with reduced nutritive value. Because of the heat generated, some ammonia volatilization is unavoidable, but is probably no greater than the losses associated with land application. With proper management, odor is not a significant problem.

The impact of deep stacking on land application for litter disposal is a direct function of the ability to market poultry litter as a feedstuff. If such a market exists, on-site land application requirements are reduced or become unnecessary; however, the impact on a larger scale is less clear. Although the utilization of litter N by ruminants can be relatively high, much of the litter P consumed will probably be excreted. Thus, typical values for the P content of beef cattle manure might not be appropriate for developing nutrient management plans for beef operations that feed significant quantities of broiler litter. Also, total manure production by the beef cattle fed poultry litter-amended rations may increase, depending on the dry matter digestibility and the ash content of the litter fed (Martin et al., 1983).

As with the temporary storage of solid poultry manure in a dedicated structure, fire due to spontaneous combustion is a risk associated with deep stacking of poultry litter. Thus, structure design to exclude precipitation and routine monitoring of litter temperature are important operational factors.

Although reliable data regarding the extent of the use of deep stacking are unavailable, anecdotal evidence indicates that the use of poultry litter as a feedstuff for beef cattle is fairly extensive in regions with significant broiler or turkey and beef cattle production. Thus, it appears reasonable to assume that the use of deep stacking is also fairly extensive.

Practice: The Thermo Master™ process

Thermo Tech™ Technologies, Inc., is a Canadian corporation in the business of converting food wastes into a high-energy and high-protein animal feed supplement, and converting municipal wastewater treatment sludges into a fertilizer material. The company has constructed several organic waste conversion facilities, known as “Thermo Master™ Plants,” that employ the company’s proprietary microbial organic waste digestion technology. The technology is protected by U.S. and Canadian patents with patent applications pending in several other countries.

The Thermo Master™ process was originally developed to create an animal feed supplement from relatively high solids content food wastes such as fruit and vegetable processing wastes and wastes of animal origin including meat, dairy, and fish processing wastes. Animal manures and wastewater treatment sludges also were considered for conversion into a fertilizer material. The process has been modified to enable processing of materials with a lower solids content.

In the Thermo Master™ process, autoheated aerobic digestion is operated at the relatively short residence time of 30 hours to maximize single-cell protein production using the influent waste material as substrate. The effluent from the digestion process is then dried and pelletized.

The Thermo Master™ process could, in theory, be a viable method for poultry and swine carcass disposal. In addition to recovering nutrients for use as an animal feed supplement, the absence of any pollutant discharges is an attractive characteristic of this process. Given that the process operates at thermophilic temperatures, at least a two- to three-log $_{10}$ reduction in pathogen densities should be realized (Martin, 1999). The process, however, has never been used for animal carcass disposal.

As with rendering, the problems of preserving, collecting, and transporting carcasses could limit use of this disposal alternative. A more significant limitation is the lack of any operating Thermo Master™ plants in the United States. Only two plants are in operation as of April, 2000, and they are both located in Canada near Toronto, Ontario. A third, located near Vancouver, British Columbia, is being rebuilt following a fire. Even if new plants were to be constructed in the United States, it is likely that they would be located in or near major metropolitan areas given the nature of the primary sources of process feedstocks. This would exacerbate the problem of carcass transportation.

8.2.3.2 Mortality Management

Improper disposal of dead animals at AFOs can result in ground water contamination and health risks. Most mortality management is accomplished through rendering of the dead animals. Rendering involves heating carcass material to extract proteins, fats, and other animal components to be used for meat, bone, and meal. Beef and dairy operations handle mortality management almost exclusively through rendering operations. In most instances the rendering operation will pick up the dead animals, resulting in no environmental impact on the operation. For this reason, the remainder of this section focuses on swine and poultry mortality management, and it will cover rendering, composting, and incineration.

Mortality Management: Swine

Large swine operations must dispose of significant numbers of dead pigs on a daily basis. For example, a 1,000 sow farrow-to-wean operation with an average of 22 piglets per litter and a pre-wean mortality rate of 12 percent will generate almost 16 tons of piglet carcasses per year, assuming an average weight of 6 pounds per carcass. Assuming an average sow weight of 425 pounds and a sow mortality rate of 7 percent per year, the total carcass disposal requirement increases to over 30 tons per year.

Improper disposal of swine carcasses can lead to surface or ground water contamination, or both, as well as noxious odors and the potential for disease transmission by scavengers and vermin. Historically, burial was the most common method of carcass disposal. Burial has been prohibited in many states, largely because of concerns regarding ground water contamination. The following subsections briefly describe and discuss the principal alternatives to burial for swine carcass disposal: composting, incineration, and rendering.

Practice: Composting

Description: Composting is the controlled decomposition or stabilization of organic matter (Gotaas, 1956). The process may be aerobic or anaerobic. If the composting mass is aerobic and suitably insulated, the energy released in the oxidation of organic carbon to carbon dioxide and water will produce a fairly rapid increase in the temperature of the composting mass. With suitable insulation, thermophilic temperature levels will be reached. The higher temperature increases the rate of microbial activity and results in quicker stabilization. Under anaerobic conditions, the rate of biological heat production is lower because fermentation generates less heat than oxidation, so the temperature increase in the composting mass is less rapid. Thermophilic temperature levels can still be attained with suitable insulation; however, the rate will be slower.

Application and Performance: Composting is a suitable method of carcass disposal for all swine operations. The compost produced can be spread on site if adequate land is available. Another recently cited disposal option for the compost is distribution or marketing as an organic fertilizer material or soil amendment. Thorough curing to preclude development of odor or vermin problems and screening to remove bones are necessary to make marketing a viable option. Another requirement for composting as a method of swine carcass disposal is the availability of a readily biodegradable source of organic carbon, such as sawdust, wood shavings, or straw.

When carcass composting is managed correctly, potential negative impacts on water and air quality are essentially nonexistent, assuming proper disposal of the finished compost. Mismanagement, however, can lead to seepage from the composting mass. This seepage has high concentrations of oxygen-demanding organics, N, and P; is a source of noxious odors; and attracts vermin.

Advantages and Limitations: One of the advantages of swine carcass composting is the relatively low capital cost of the necessary infrastructure. Depending on the volume of carcasses generated daily, one or more of a series of two composting bins are required. These bins should be located on a concrete pad in an open or partially enclosed shed-like structure. Critical to this capital cost advantage is the availability of a skid-steer or tractor-mounted front-end loader for handling materials. Federal and, in some instances, state cost sharing has been used to encourage the construction and use of swine mortality composting facilities.

A recent comparison of carcass composting and incineration for disposal of poultry mortalities suggests that the lower capital cost of carcass composting is offset by higher labor costs (Wineland et al., 1998). The development of more fuel-efficient incinerators has made incineration more cost competitive in recent years.

While the temperatures that can be attained in a mass of composting carcasses (130 to 150 °F) will result in significant reductions in pathogen densities, finished swine mortality compost cannot be considered pathogen-free. Therefore, appropriate biosecurity measures are necessary in the handling and ultimate disposal of the finished compost. Collection of carcasses by renderers presents a higher biosecurity risk, especially the risk of introducing disease from other operations. In contrast, the ash from carcass incineration is sterile.

Carcass composting in the swine industry appears to be best suited for the disposal of pre-wean and nursery mortalities because of the relatively small size of these carcasses. For larger animals (sows, gilts, boars, and feeder pigs), at least partial carcass dismemberment, an unpleasant task, is necessary.

Operational Factors: In the composting of swine mortalities, a single layer of carcasses or carcass parts is placed on a layer of the carbon source and finished compost or manure, followed by another layer of the carbon source and finished compost, and then carcasses. The pattern is repeated until a height of about 5 feet is reached. The pile is capped with a carbon source. Inadequate moisture will retard decomposition, whereas too much moisture will result in anaerobic conditions and process failure.

A proper facility is critical to the success of composting swine carcasses. As noted above, one or more of a series of two composting bins are required depending on the daily volume of carcasses generated. To maximize the rate of carcass decomposition and also to ensure complete decomposition of soft tissue, the composting mass should be transferred to a second bin after about 2 weeks of decomposition. This transfer process results in both mixing and aeration of the composting mass. Following an additional 2 weeks, the compost should be ready for storage and curing or ultimate disposal. While satisfactory decomposition can be realized without transfer and mixing, the time required is significantly longer.

Also critical to the success of composting swine carcasses is the initial combination of carcasses, a source of biodegradable carbon such as sawdust or chopped straw, a source of adapted microorganisms, and moisture. Although some cooperative extension publications recommend using manure as the source of an adapted microbial population, finished compost is equally suitable (Martin and Barczewski, 1996). The ratio, on a volume basis, of these ingredients should be 1 part carcasses, 1.5 parts of the carbon source, 0.5 to 0.75 part finished compost, and 0 to 0.5 part water. The objective is to create an initial C to N ratio of 20:1 to 30:1.

Demonstration Status: The first use of composting for animal carcass disposal occurred in the poultry industry during the 1980s (Murphy, 1988; Murphy and Handwerker, 1988). Since that time, this method of carcass disposal has also been adopted by the swine industry. It was estimated that 10.5 percent of swine operations use composting for mortality disposal (USDA APHIS, 1995).

Practice: Incineration

Description: Incineration or cremation is the reduction of swine carcasses to ash by burning at a high temperature under controlled conditions using specially designed equipment. Incineration temperatures can be as high as 3,500 °F, depending on equipment design. Incinerators using natural gas, propane, or No. 2 distillate fuel oil as a fuel are available.

Application and Performance: Incineration of swine carcasses is applicable to all operations where the cost of the equipment required can be justified by the volume of carcasses generated.

The potential for surface or ground water contamination associated with incineration is minimal, provided that liquid fuel tanks are contained properly and residual ash is disposed of properly. The P, K, and other elements contained in the carcasses are concentrated in the ash. Because of the high temperature of incineration, this ash is pathogen-free if cross-contamination with carcasses is avoided.

Odors and other air quality concerns led to a significant decline in carcass incineration in the past. Newly designed equipment, however, incorporates secondary combustion of stack gases, essentially eliminating these problems. Yet the emission of low levels of some air pollutants is unavoidable, as with any combustion process. Improper operation of the incinerator (e.g., reducing process temperature by overloading) can result in unacceptably high air pollutant emissions.

Advantages and Limitations: One of the more attractive aspects of incineration relative to other swine carcass disposal options, such as composting and rendering, is the complete destruction of pathogens. Another advantage is the relatively small mass of residual material (ash) requiring some form of ultimate disposal, especially in comparison with composting. Moreover, incineration has a relatively low labor requirement.

The principal perceived limitation of incineration is cost. The initial investment required is relatively high. A recent comparison of incineration and composting costs for poultry carcass disposal, however, suggests that the former has become cost competitive with the latter because of lower labor costs and improvements in incinerator fuel efficiency (Wineland et al., 1998).

Another limitation of incineration for swine carcass disposal is fixed capacity. This can be problematic when disease or other factors such as heat stresses cause a sizable increase in the rate of mortality.

Operational Factors: Because of the fixed capacity of incineration equipment, incineration of swine carcasses must occur on a regular basis. Ideally, carcass incineration should occur at least on a daily basis to minimize the potential for disease transmission. Routine maintenance of incineration equipment is also important to ensure reliability and minimize emission of air pollutants. An air pollutant emissions permit, a siting permit, or both, may be required for an incinerator.

Demonstration Status: Incineration has been used in the swine industry as a method of carcass disposal for many years. With recent technological advances in incinerator fuel efficiency and odor control, a reversal in the shift away from incineration and to other carcass disposal options, such as composting, may occur. It was estimated that 12.5 percent of swine operations use incineration, described as burning, for mortality disposal (USDA APHIS, 1995).

Practice: Rendering

Description: Rendering is the process of separating animal fats and proteins, usually by cooking. The recovered proteins are used almost exclusively as animal feedstuffs, while the recovered fats are used both industrially and in animal feeds.

There are two principal methods of rendering (Ensminger and Olentine, 1978). The first and older method uses steam under pressure in large closed tanks. A newer and more efficient method is dry rendering, in which all of the material is cooked in its own fat by dry heat in open steam-jacketed drums until the moisture has been evaporated. One advantage of dry rendering is the elimination of a separate step to evaporate the moisture in the material being rendered. Cooking temperatures range from 240 to 290 °F. Rendering can be a batch or a continuous flow process.

The two basic protein feedstuffs derived from rendering are meat meal and meat and bone meal. The basis for this differentiation is P content (National Academy of Sciences, 1971). Meat meal contains a maximum of 4.4 percent P on an as-fed basis. Meat and bone meal contains a minimum of 4.4 percent P.

Application and Performance: Most of the animal fat and protein recovered by rendering is derived from meat and poultry processing, but rendering can also be used to recover these products from swine carcasses. The ability to use rendering as a method of swine carcass disposal depends on the presence of a rendering facility servicing the area. Rendering plants are not widely distributed and are generally located near meatpacking and poultry processing plants. As the meatpacking and poultry processing industries have consolidated into fewer but larger operations, a similar pattern of consolidation in the rendering industry has also occurred. Because swine carcasses have minimal monetary value as a raw material for rendering, transportation only over limited distances can be justified economically.

Rendering is a capital-intensive process and requires careful process control to generate acceptable products. In addition, product volume has to be substantial to facilitate marketing. Because on-farm rendering is unlikely to be a viable option for swine carcasses, performance measures are not included.

Advantages and Limitations: For swine producers, disposal of mortalities by rendering has several advantages. One is that capital, managerial, and labor requirements are minimal in comparison with other carcass disposal options. A second advantage is the absence of any residual material requiring disposal, as is the case with both composting and incineration, albeit to a lesser degree. If carcass volume is adequate to justify daily pickup by the renderer, capital investment for storage is also minimal.

As discussed above, rendering is a feasible option for swine carcass disposal only if the swine production operation is located in an area serviced by a rendering plant. Also, not all rendering operations will accept mortalities, largely because of concerns about pathogens in the finished products.

Well-managed rendering operations will not accept mortalities more than 24 hours after death because of the onset of decomposition of fats and proteins, adversely affecting the quality of the final products. For swine operations that do not generate an adequate volume of carcasses to justify daily pickup by the renderer, carcass preservation by freezing, for example, is a necessity. While preservation of piglet carcasses by freezing may be justifiable economically, the cost of preserving larger animals is probably not justifiable because payment by renderers for carcasses is usually nominal at best. Typically, payment is no more than one to two cents per pound. Payment can be less, or there may even be a charge for removal, depending on transport distance.

Operational Factors: Since renderers usually pick up carcasses, stringent biosecurity precautions are essential to prevent disease transmission by vehicles and personnel serving several swine operations. Ideally, trucks should be disinfected before entering individual farms, and collection personnel should use disposable shoe coverings. Also, necessary carcass preservation measures should be employed to ensure that the renderer will continue to accept carcasses.

Demonstration Status: It was estimated that 32 percent of swine operations use rendering for mortality disposal, with 25.1 percent allowing the renderer to enter the operation and 6.9 percent placing carcasses at the perimeter of the operation for pickup (USDA APHIS, 1995).

Mortality Management: Poultry

Large poultry operations generate significant numbers of dead birds on a daily basis. For example, a flock of 50,000 broilers with an average daily mortality of 0.1 percent (4.9 percent total mortality) will result in approximately 2.4 tons of carcasses over a 49-day grow-out cycle (Blake et al., 1990). A flock of 100,000 laying hens averaging a 0.5 percent monthly mortality (6 percent annual mortality) will generate 11.25 tons of carcasses per year (Wineland et al., 1998). For a flock of 30,000 turkeys averaging 0.5 percent weekly mortality (9 percent total mortality), approximately 13.9 tons of carcasses will require disposal (Blake et al., 1990).

Improper disposal of poultry mortalities can lead to surface or ground water contamination, or both, as well as noxious odors and the potential for disease transmission by scavengers and vermin. The following subsections briefly describe and discuss the principal alternatives to burial used for dead bird disposal: composting, incineration, and rendering. Burial of dead birds has been prohibited in many states, principally because of concerns regarding ground water contamination. These alternatives for carcass disposal are also used in the swine industry and have been described in the previous section. Differences between the two sectors, however, are briefly noted.

Practice: Composting

Description: The general description of composting presented in the preceding section on swine mortality management also applies to poultry.

Application and Performance: As with swine, composting as a method of carcass disposal is suitable for all poultry operations. The compost produced can be spread on site if adequate land is available. Another disposal option for the compost is distribution or marketing as an organic fertilizer material or soil amendment. Thorough curing to preclude development of any odor or vermin problems and screening to remove bones are necessary to make marketing of carcass compost disposal a viable option. Another requirement for composting as a method of poultry carcass disposal is the availability of a readily biodegradable source of organic carbon such as sawdust, wood shavings, or straw.

When poultry carcass composting is managed correctly, potentially negative impacts on water and air quality are essentially nonexistent, assuming proper disposal of the finished compost. Mismanagement, however, can lead to seepage from the composting mass. This seepage has high concentrations of oxygen-demanding organics, N, and P; is a source of noxious odors; and attracts vermin.

Advantages and Limitations: As with swine carcass disposal, one of the advantages of poultry carcass composting is the relatively low capital cost of the necessary infrastructure, especially when compared with incineration. Depending on the volume of carcasses generated daily, one or more of a series of two composting bins are required. These bins should be located on a concrete pad in an open or partially enclosed shed-like structure. Critical to this capital cost advantage is the availability of a skid-steer or tractor-mounted front-end loader for handling materials. Federal and, in some instances, state and integrator cost sharing has been used to encourage the construction and use of poultry mortality composting facilities.

A recent comparison of carcass composting and incineration for disposal of poultry mortalities suggests, however, that the lower capital cost of carcass composting is offset by higher labor costs (Wineland et al., 1998). The development of more fuel-efficient incinerators has made incineration more cost competitive in recent years.

While the temperatures that can be attained in a mass of composting carcasses (130 to 150 °F) will result in significant reductions in pathogen densities, finished poultry mortality compost cannot be considered pathogen-free. Therefore, appropriate biosecurity measures are necessary in the handling and ultimate disposal of the finished compost. Collection of carcasses by renderers presents a higher biosecurity risk, especially the risk of introducing disease from other operations. In contrast, the ash from carcass incineration is sterile.

Operational Factors: In the composting of poultry mortalities, a single layer of carcasses is placed on a layer of the carbon source and finished compost or litter, followed by another layer of the carbon source and finished compost, and then carcasses. The pattern is repeated until a height of about 5 feet is reached. The pile is capped with a carbon source. Inadequate moisture will retard decomposition, while too much moisture will result in anaerobic conditions and process failure.

A proper facility is critical to the success of composting poultry carcasses. As noted above, one or more of a series of two composting bins are required depending on the daily volume of carcasses generated. To maximize the rate of carcass decomposition and also to ensure complete decomposition of soft tissue, the composting mass should be transferred to a second bin after about 2 weeks of decomposition. This transfer process results in both mixing and aeration of the composting mass. Following an additional 2 weeks, the compost should be ready for storage and curing or ultimate disposal. While satisfactory decomposition can be realized without transfer and mixing, the time required increases significantly.

Also critical to the success of composting poultry carcasses is the initial combination of carcasses, a source of biodegradable carbon such as sawdust, wood shaving, or chopped straw, a source of adapted microorganisms, and moisture. Although some cooperative extension publications recommend using litter or cake as the source of an adapted microbial population, finished compost is equally suitable (Martin and Barczewski, 1996). Martin et al. (1996) have suggested that use of cake be avoided. One recommendation, on a volume basis, is 1 part dead birds, 1.5 parts straw, 0.5 to 0.75 part litter, and 0 to 0.5 part water (Poultry Water Quality Handbook, 1998). Sawdust or shavings have been used successfully in place of straw. Basically, this same combination of materials is used for swine carcass composting. Again, the objective is to create an initial C to N ratio of 20:1 to 30:1.

Demonstration Status: The first use of composting for animal carcass disposal occurred in the poultry industry during the 1980s (Murphy, 1988; Murphy and Handwerker, 1988). Currently, composting for disposal of poultry mortalities is readily accepted by producers and used extensively. In a recent survey of broiler producers on the Delmarva Peninsula, 52.7 percent of 562 respondents reported using composting for dead bird disposal (Michel et al., 1996).

Practice: Incineration

Description: The general description of incineration presented in the precedingsection on swine mortality management also applies to poultry.

Application and Performance: As with swine, the use of incineration for poultry carcass disposal is applicable to all operations where the cost of the equipment required can be justified by the volume of carcasses generated.

As with swine carcass incineration, the potential for surface or ground water contamination associated with incineration is minimal, provided that liquid fuel tanks are properly contained and residual ash is disposed of properly. The P, potassium, and other elements contained in the carcasses are concentrated in the ash. Because of the high temperature of incineration, this ash is pathogen-free if cross-contamination with carcasses is avoided.

Odors and other air quality concerns led to a significant decline in carcass incineration in the past. Newly designed equipment, however, incorporates secondary combustion of stack gases, essentially eliminating these problems. Yet the emission of low levels of some air pollutants is unavoidable, as with any combustion process. Improper operation of the incinerator (e.g., reducing process temperature by overloading) can result in unacceptably high air pollutant emissions.

Advantages and Limitations: One of the more attractive aspects of incineration relative to other poultry carcass disposal options, such as composting and rendering, is the complete destruction of pathogens. Another advantage is the relatively small mass of residual material (ash) requiring some form of ultimate disposal, especially in comparison with composting. Moreover, incineration has a relatively low labor requirement.

The principal perceived limitation of incineration is cost. The initial investment required is relatively high. A recent comparison of incineration and composting costs for poultry carcass disposal, however, suggests that the former has become cost competitive with the latter because of lower labor costs and improvements in incinerator fuel efficiency (Wineland, et al., 1998).

Another limitation of incineration for poultry carcass disposal is fixed capacity. This can be problematic when disease or other factors such as heat stresses cause a sizable increase in the rate of mortality.

Operational Factors: Because of the fixed capacity of incineration equipment, incineration of poultry carcasses must occur on a regular basis. Ideally, carcass incineration should occur at least on a daily basis to minimize the potential for disease transmission. Routine maintenance of incineration equipment is also important to ensure reliability and minimize emissions of air pollutants. An air pollutant emissions permit, a siting permit, or both, may be required for an incinerator.

Demonstration Status: Incineration has been used to a limited degree in the poultry industry for carcass disposal for many years. In recent years, cost and odor problems resulted in a shift away from incineration to more seemingly attractive options such as composting. In a recent survey of broiler producers on the Delmarva Peninsula, only 3.3 percent of 562 respondents reported using incineration for dead bird disposal (Michel et al., 1996). Improvements in fuel efficiency and odor control, however, have renewed interest in this option for carcass disposal.

Practice: Rendering

Description: The general description of rendering presented in the previous section on swine mortality management also applies to poultry.

Application and Performance: As with swine, the ability to use rendering as a method of poultry carcass disposal depends on the presence of a rendering facility servicing the area. Because on-farm rendering is unlikely to be a viable option, performance measures are not included.

Advantages and Limitations: Rendering has the same advantages for poultry producers that it has for swine producers: (1) minimal managerial and labor requirements; and (2) the absence of any residual material requiring disposal.

Limitations include the need to preserve carcasses, because many operations will not generate a sufficient volume of carcasses to justify daily collection by a renderer. Several options have been demonstrated to be technically feasible for poultry carcass preservation. They include freezing, preservation using organic or mineral acids (Malone et al., 1998; Middleton and Ferket, 1998), preservation using sodium hydroxide (Carey et al., 1997), and lactic acid fermentation (Dobbins, 1988; Murphy and Silbert, 1990). All of these preservation strategies increase the cost of carcass disposal, and all but freezing increase labor requirements.

Another factor limiting the use of rendering for poultry carcass disposal is the problems that feathers create in the rendering process. Feathers absorb the fat separated by rendering and make the product difficult to handle and market. Feathers also dilute the nutritional and resulting market value of poultry by-products meal, especially when used as a feedstuff for nonruminant animals which cannot digest feathers.

Although feathers can be removed by hydrolysis, cooking at high temperature under pressure, protein quality is degraded. It has been shown, however, that feathers can be removed successfully up to 24 hours postmortem, using a batch scalding and picking system (Webster and Fletcher, 1998). Thus, renderers with feather picking equipment can accept significant quantities of poultry mortalities without compromising product quality.

Operational Factors: As with swine, stringent biosecurity precautions are essential to prevent disease transmission by vehicles and personnel serving several poultry operations. Moreover, carcass preservation measures are generally necessary.

Demonstration Status: Overall, the use of rendering for disposal of poultry mortalities is minimal because of the necessity of carcass preservation and the problem of feathers described above. In a recent survey of broiler producers on the Delmarva Peninsula, none of the 562 respondents reported using rendering for dead bird disposal (Michel et al., 1996). One of the major broiler integrators, however, is currently evaluating the use of rendering after the grower preserves the carcasses by freezing. The integrator supplies the freezer and the grower pays for the electricity. Preliminary indications are that the growers are pleased with this approach.

8.3 Nutrient Management Planning

Nutrient management is a planning tool farmers use to control the amount, source, placement, form, and timing of the application of nutrients and soil amendments (USDA NRCS, 1999). Planning is conducted at the farm level because nutrient requirements vary with such factors as the type of crop being planted, soil type, climate, and planting season. The primary objective of a nutrient management plan is to balance crop nutrient requirements with nutrient availability over the course of the growing season. By accurately determining crop nutrient requirements, farmers are able to increase crop growth rates and yields while reducing nutrient losses to the environment.

Proper land application of manure is dependent on soil chemistry, timing of application, and recommended guidelines for applying at agronomic rates (the amount of manure or commercial fertilizers needed to provide only the amount of a particular nutrient that will be used by a specific crop or crop rotation). Manure is an excellent organic fertilizer source and is a soil amendment that benefits a soil's chemical, physical, and biological properties. The predominant chemical benefit of manure to the soil is the supply of the major plant nutrients—N, P, and K. In addition, livestock manure supplies micronutrients and non-nutrient benefits such as organic matter, which are advantageous to plant growth. The organic matter increases the nutrient- and water-holding capacity of the soil and improves the physical structure. Finally, manure is a source of food and energy for soil microorganisms, which can directly and indirectly benefit the physical, chemical, and biological properties of the soil. The combination of these non-nutrient benefits to soil health has been found to boost corn yields by 7 percent, soybean yields by 8 percent, and alfalfa yields by 9 percent (Vetsch, 1999).

In spite of the benefits listed above, repeated applications of manure can cause high levels of N, P, K, and other micronutrients, as well as acidify soils and increase salinity. Excessive application of these nutrients can lead to surface runoff or leaching. Therefore, land application of manure, if improperly managed, can contribute to the degradation of surface water and ground water (Liskey et al., 1992). Excessive amounts of some nutrients in soils can also reduce crop yields (Brown, 1995).

More efficient use of fertilizer, animal manure, and process wastewater can result in higher yields, reduced input requirements, greater profits, and improved environmental protection. It is possible to further reduce fertilizer expenses and diminish water pollution by employing specific farming practices that help to reduce nutrient losses from manured fields. The best ways to conserve manure P and K are to apply only the amount of manure needed to meet the crop's nutrient needs and use conservation practices that reduce erosion and runoff from fields. This approach also aids in preventing N losses, but N management must also include proper handling, storage, treatment, and timing of manure application and incorporation into the soil.

CNMPs and PNPs:

When the sources of nutrients used on a farm include animal manure and process wastewater, manure management planning is incorporated within what is referred to by USDA (and described in Section 8.3.1) as a comprehensive nutrient management plan or CNMP (USEPA, 1999b). EPA is proposing to require all CAFO operators to develop and implement a Permit Nutrient Plan, or PNP. A PNP is a site-specific plan that describes how the operator intends to meet the effluent discharge limitations and other requirements of the NPDES permit. EPA's PNP and USDA's voluntary CNMP are very similar, and EPA used USDA's *Technical Guidance for Developing Comprehensive Nutrient Management Plans* as the template for developing the PNP. The PNP, however, establishes specific regulatory requirements that must be followed by CAFO operators to ensure adequate protection of surface water. The PNP is also narrower in scope than a CNMP since the CNMP guidance addresses certain aspects of CAFO operations that are not included as part of EPA's effluent guidelines and standards. For example, the CNMP guidance indicates that a CNMP should include insect control activities, disposal of animal medical wastes, and visual improvement considerations, but EPA's proposed regulations and PNP do not include such requirements.

The proposed PNPs are intended to be living documents that must be updated as circumstances change. As the primary planning document for determining appropriate practices at the CAFO, the PNP must be developed and modified by a certified nutrient management specialist. The PNP is intended to establish the allowable manure application rate for land applying manure and wastewater and to document how the rate was derived. The PNP would also describe other site-specific conditions that could affect manure and wastewater application, sampling techniques to be used in sampling manure and soils, the calibration of manure application equipment, and operational procedures for equipment used in the animal production areas.

8.3.1 Comprehensive Nutrient Management Plans (CNMPs)

As discussed in the USDA-EPA Unified National Strategy for Animal Feeding Operations (USEPA, 1999b), site-specific CNMPs may include some or all of the six components described below, based on the operational needs of the facility. Many of the CNMP components described in the strategy have been addressed in other parts of this document and are cross-referenced below. This section focuses on parts of component 2 (Land Application of Manure and Wastewater) and component 4 (Record Keeping), however, all six of the CNMP components, as described in the strategy, are presented here to illustrate what a CNMP may contain.

Component 1: Manure and Wastewater Handling and Storage: This portion of a CNMP, addressed more fully in Section 8.2, identifies practices for handling and storing manure to prevent water pollution. Manure and wastewater handling and storage practices should also consider odor and other environmental and public health concerns. Handling and storage considerations include the following:

- Clean water diversion. Siting and management practices should divert clean water from contact with feedlots and holding pens, animal manure, or manure storage systems. Clean water can include rain falling on the roofs of facilities, runoff from adjacent land, and other sources.

- Leakage prevention. Construction and maintenance of buildings, collection systems, conveyance systems, and permanent and temporary storage facilities should prevent leakage of organic matter, nutrients, and pathogens to ground or surface water.

- Adequate storage. Liquid manure storage systems should safely store the quantity and contents of animal manure and wastewater produced, contaminated runoff from the facility, and rainfall. Dry manure, such as that produced in broiler and turkey operations, should be stored in production buildings or storage facilities or otherwise stored in such a way as to prevent polluted runoff. The location of manure storage systems should consider proximity to water bodies, floodplains, and other environmentally sensitive areas.

- Manure treatments. Manure should be handled and treated to reduce the loss of nutrients to the atmosphere during storage; make the material a more stable fertilizer when applied to the land; or reduce pathogens, vector attraction, and odors, as appropriate.

- Management of dead animals. Dead animals should be disposed of in a way that does not adversely affect ground or surface water or create public health concerns. Composting and rendering are common methods used to dispose of dead animals.

Component 2: Land Application of Manure and Wastewater: Land application is the most common, and usually the most desirable, method of using manure and wastewater because of the value of the nutrients and organic matter they contain. Land application should be planned to ensure that the proper amount of nutrients are applied in a manner that does not adversely affect the environment or endanger public health. Land application in accordance with the CNMP should minimize the risk of adverse impacts on water quality and public health. Considerations for appropriate land application should include the following:

- Nutrient balance. The primary purpose of nutrient management is to achieve the level of nutrients (e.g., N and P) required to grow the planned crop by balancing the nutrients already in the soil and provided by other sources with those which will be applied in manure, biosolids, and commercial fertilizer. At a minimum, nutrient management should prevent the application of nutrients at rates that will exceed the capacity of the soil and the planned crops to assimilate nutrients and prevent pollution. Soils, manure, and wastewater should be tested to determine nutrient content.

- Timing and methods of application. Care must be taken when applying manure and wastewater to the land to prevent them from entering streams, other water bodies, or environmentally sensitive areas. The timing and methods of application should minimize the loss of nutrients to ground or surface water and the loss of N to the atmosphere. Manure and wastewater application equipment should be calibrated to ensure that the quantity of material being applied is what was planned. These topics are discussed in Section 8.4.

Component 3: Site Management: Tillage, crop residue management, grazing management, and other conservation practices should be used to minimize movement to ground and surface water of soil, organic material, nutrients, and pathogens from lands to which manure and wastewater are applied. Forest riparian buffers, filter strips, field borders, contour buffer strips, and other conservation practices should be installed to intercept, store, and use nutrients or other pollutants that might migrate from fields to which manure and wastewater are applied. Site management is addressed in Section 8.4.

Component 4: Record Keeping: CAFO operators should keep records that indicate the quantity of manure produced and how the manure was used, including where, when, and the amount of nutrients applied. Soil and manure testing should be incorporated into the record keeping system. The records should be kept after manure leaves the operation.

Component 5: Other Utilization Options: Where the potential for environmentally sound land application is limited, alternative uses of manure, such as sale of manure to other farmers, centralized treatment, composting, sale of compost to other users, and using manure for power generation may also be appropriate. Several of these options are described in Section 8.2. All manure use options should be designed and implemented in such a way as to reduce risks to human health and the environment, and they must comply with all relevant regulations.

Component 6: Feed Management: Animal diets and feed may be modified to reduce the amounts of nutrients in manure. Use of feed management activities, such as phase feeding, amino acid-supplemented low-protein diets, use of low-phytate-phosphorus grain, and enzymes such as phytase or other additives, can reduce the nutrient content of manure, as described in Section 8.1. Reduced inputs and greater assimilation of P by the animal reduce the amount of P excreted and produce a manure that has a nitrogen-phosphorus ratio closer to that required by crop and forage plants.

Other information that should be part of a nutrient management plan is provided in the USDA-NRCS Nutrient Management Conservation Practice Standard Code 590 (USDA NRCS, 1999); it includes aerial photographs or site maps; crop rotation information; realistic crop yield goals; sampling results for soil, manure, and so forth; quantification of all nutrient sources; and the complete nutrient budget for the crop rotation.

Practice: Developing a Comprehensive Nutrient Management Plan

Description: Effective nutrient management requires a thorough analysis of all the major factors affecting field nutrient levels. In general, a CNMP addresses, as necessary and appropriate, manure and wastewater handling and storage, land application of manure and other nutrient sources, site management, record keeping, and feed management. CNMPs also address other options for manure use when the potential for environmentally sound land application of manure is limited at the point where the manure is generated.

Nutrient management planning typically involves the use of farm and field maps showing acreage, crops and crop rotations, soils, water bodies, and other field limitations (e.g., sinkholes, shallow soils over fractured bedrock, shallow aquifers). Realistic yield expectations for the crops to be grown, soil and manure testing results, nutrient analysis of irrigation water and atmospheric deposition, crop nutrient requirements, timing and application methods for nutrients, and provisions for the proper calibration and operation of nutrient application equipment are all key elements of a nutrient management plan.

Application and Performance: CNMPs apply to all farms and all land to which nutrients are applied. Plans are developed by the grower with assistance, as needed, from qualified company staff, government agency specialists, and private consultants. To be effective, nutrient management plans must be site-specific and tailored to the soils, landscapes, and management of the particular farm (Oldham, 1999).

A wide range of studies has found that implementation of nutrient management plans result in improved nutrient use efficiency. In some cases, producers increased nutrient applications based on nutrient budget analyses, but reduced applications of N and P are more common. For example, average annual nutrient application rates were reduced by 14 to 129 pounds per acre for N and 0 to 106 pounds per acre for P in 19 USDA projects from 1991 to 1995 (Meals et al., 1996). The introduction of improved fertilizer recommendations in Pennsylvania resulted in a 40 percent reduction in N use statewide (Berry and Hargett, 1984). A pilot program on 48 farms in Iowa resulted in an average reduction of 9.6 pounds per acre N because of improved nutrient management (Hallberg et al., 1991).

Reductions in field losses of N and P due to implementation of nutrient management plans vary considerably, but a comprehensive review of field and modeling studies concluded that load reductions averaged 15 percent for N and 35 percent for P (Pennsylvania State University, 1992).

In a 6-year study of nutrient management in Pennsylvania, baseflow loads of N and P forms decreased, but stormflow discharges of total N and total P increased by 14 and 44 percent, respectively (Langland and Fishel, 1996).

Advantages and Limitations: A good nutrient management plan should help growers minimize adverse environmental impacts and maximize the benefits of using litter and manure. In a national survey of growers of corn, soybeans, wheat, and cotton, more than 80 percent of those who had used manure in the Northeast, southern plains, Southeast, and Corn Belt reported that they had reduced the amount of fertilizer applied to land receiving manure (Marketing Directions, 1998). Approximately 30 percent of the respondents reported that they had saved money through crop nutrient management, while more than 20 percent reported increased yields, about 18 percent claimed reduced fertilizer costs, and approximately 10 percent reported that profits had increased and the soil quality had improved. Despite the potential savings, some farmers are reluctant to develop nutrient management plans because of the cost. Only 4 to 22 percent of respondents indicated that they have a nutrient management plan.

Proper crediting and application of hog manure has been reported to save $40 to $50 per acre in fertilizer expenses in Iowa (CTIC, 1998a). Similarly, injecting hog manure has resulted in savings of $60 to $80 per acre in Minnesota. Although savings vary from farm to farm, proper crediting and application of manure under a good nutrient management plan can result in considerable cost savings for producers.

When animal manure and litter are used as nutrient sources, those activities which affect the availability and characteristics of such sources need to be factored into the nutrient management plan. For example, a nutrient management plan in which poultry litter is used as a nutrient source should take into account the amount of litter to be removed and the time of removal so that sufficient land is available for proper land application shortly after removal. Alternatively, the plan would need to consider whether storage facilities are available for the quantity of material that must be handled prior to land application. Whenever possible, litter removal should be planned so that fresh litter, containing the maximum amount of nutrients, can be applied immediately to meet crop or forage plant needs.

The CNMP will need to be revisited and possibly revised if the livestock facility increases in size, or if there are changes in animal types, animal waste management, processes, crops, or other significant areas.

Nutrient management services are available in the major farming regions, and both low-tech and high-tech options, such as precision agriculture, are available to producers. A CNMP is only as good as the information provided; the extent to which assumptions regarding yield, weather, and similar factors prove true; and the extent to which the plan is followed precisely.

Operational Factors: Climate, temperature, and rainfall are all critical factors to be considered in the development of a nutrient management plan. Since CNMPs are site-specific, the requirements of each CNMP will vary depending on the conditions at each facility.

Demonstration Status: A report on state programs related to AFOs indicates that 27 states already require the development and use of waste management plans (USEPA, 1999a). The complexity and details of these plans vary among states, but the plans typically address waste generated, application rate, timing, location, nutrient testing, and reporting provisions. Further, industry data and site visits conducted by EPA indicate that practically all CAFOs have some form of management plan in place.

8.3.2 Nutrient Budget Analysis

For animal operations at which land application is the primary method of final disposal, a well-designed nutrient management plan determines the land area required to accept manure at a set rate that provides adequate nutrients for plants and avoids overloading soils and endangering the environment. The four major steps of this process are as follows:

1. Determine crop yield goals based on site-specific conditions (e.g., soil characteristics).

2. Determine crop nutrient needs based on individual yield goals.

3. Determine nutrients available in manure and from other potential sources (e.g., irrigation water).

4. Determine nutrients already available in the soil.

These four steps constitute a nutrient budget analysis, which provides the operator with an estimate of how much animal waste can be efficiently applied to agricultural crops so that nutrient losses are minimized. Various organizations, including Iowa State University (ISU, 1995), USDA NRCS (1998b), and USEPA (1999b), have developed guidance on performing nutrient budget analysis. The Iowa State University guidance includes detailed worksheets for estimating nutrient needs versus supply from animal manure and other sources.

8.3.2.1 Crop Yield Goals

Practice: Establishing Crop Yield Goals

Description: Establishing realistic yield goals should be the first step of a nutrient management plan. The yield goal is the realistic estimate of crop that will be harvested based on the soil and climate in the area (USDA NRCS, 1995). Realistic yield goals can be determined through the following:

- Historical yield information (Consolidated Farm Service Agency-USDA)

- Soil-based estimates of yield potential (county soil survey books and current soil nutrient content reports)

- Farmer’s or owner’s records of past yields

- Yield records from a previous owner

Yield potential is based on soil characteristics and productivity. The soil’s yield potential can be obtained from Soil Survey Reports, county extension agencies, or Natural Resources Conservation Service (NRCS) offices. As the equation below shows, individual yield goals are calculated by multiplying the total acreage of a certain soil type by the yield potential of that soil, then dividing that sum by the total acres in the field:

$$\frac{\text{Total Acreage} \times \text{Yield Potential}}{\text{Total Acres in the Field}} = \frac{(\quad)}{(\quad)} = \_\_\_\_\_\_ \text{ bu / acre (Individual Yield Goal)}$$

Application and Performance: Realistic yield goals apply to all farms and all land to which nutrients are applied. Yield goals can be developed by the grower with assistance, as needed, from qualified company staff, government agency specialists, and private consultants. To be effective, yield goals must be site-specific, tailored to the soils on each field.

How well this practice performs depends on both good science and good fortune. Farmers are typically encouraged to set yield goals 5 to 10 percent above the average yield for the past 5 years or so (Hirschi et al., 1997). The intent is allow the farmer to benefit from a good year, while still reducing waste in the event that an off year occurs. Hirschi reports, however, that a survey of farmers in Nebraska showed that only one in ten reached their yield goals, with a full 40 percent of the farmers falling more than 20 percent below their yield goals.

Estimation of realistic yield goals does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: Reliance on a realistic yield goal is, by its very nature, an advantage for farmers. The challenge is to establish a yield goal that is truly realistic. Farmers who rely on their own yield records should use an average from the past 5 to 7 years, recognizing that it is impossible to foretell growing seasons accurately (Oldham, 1999).

If yield goals are set too high, there is the risk that nutrients will be applied in excess of crop needs. This translates into increased expense, increased levels of nutrients in the soil, and increased risk to surface water and ground water (Hirschi et al., 1997). If yield goals are set too low, the crop yield may be diminished because of a lack of nutrients. Further, if the crop yield is low during a bumper crop year, the producer risks a substantial loss of profits.

Universities publish yield goal information for use by farmers in all states, providing a ready source of information in the absence of better, site-specific records. In addition, seed suppliers have yield information that can be shared with farmers, including the results from local field trials.

Operational Factors: A key challenge in estimating crop yield is determining which historic yield data, industry data, and university recommendations are most appropriate for a given farm. Farmers need to recognize that exceptionally good years are rare (Hirschi et al, 1997). Assumptions regarding the year’s weather are also key, and, because farming is a business, crop prices affect farmers’ estimates of realistic yield as well.

If planting dates are affected by spring weather, yields may suffer, creating the potential for overapplication of nutrients. Similarly, extended droughts or wet periods may affect yields. Hail and other similar weather events can also harm crops, resulting in actual yields that fall short of even reasonable yield goals.

Demonstration Status: Estimation of crop yield is a basic feature of farming, although the methods used and accuracy of the estimates vary.

8.3.2.2 Crop Nutrient Needs

Practice: Estimating Crop Nutrient Needs

Description: Crop nutrient needs are the nutrients required by the crop and soil to produce the yield goal. Crop nutrient needs can be calculated for detailed manure nutrient planning. For animal feeding operations, N and P are the primary nutrients of concern, and significant research has been conducted on specific crop requirements for these nutrients. In some cases, nutrient planning analyses also evaluate K requirements.

Crop nutrient needs can be estimated by multiplying the realistic yield goal by a local factor for each nutrient-crop combination. For example, N factors for corn are provided for three regions in Iowa (USDA NRCS, 1995). If the yield goal is 125 bushels per acre and the N factor is 0.90, the N need for corn is 112.5 pounds per acre (125 x 0.90).

Application and Performance: Estimation of crop nutrient needs is a practice that applies to all farms and all land to which nutrients are applied. These estimates can be developed by the grower with assistance, as needed, from qualified company staff, government agency specialists, and private consultants. Nutrient uptake and removal data for common crops are available from the NRCS, the local extension office, and other sources (Oldham, 1999).

The accuracy of this calculation depends on the accuracy of the yield goal and nutrient factors for the crop. In the case of Iowa corn, for example, N factors vary from 0.90 to 1.22. A farmer preparing for a good year might add a 10 percent cushion to the yield goal of 125 bushels per acre used above, resulting in a revised yield goal of 137.5 bushels per acre. The N need increases to 123.75 pounds per acre, an increase of 10 percent as well. If the year turns sour and the yield is 112.5 bushels per acre (10 percent less), the excess N applied becomes 22.5 pounds per acre (123.75-101.25) instead of 11.25 pounds per acre (112.5-101.25), or 100 percent greater.

Estimation of crop nutrient needs does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: The determination of N needs should account for any N in the organic fraction of manure that is not available the first year, any N carryover from previous legume crops, N carryover from previous manure applications, and any commercial N that will be applied. The major factors determining the amount and availability of carryover N are the total amount of N applied, N uptake in the initial crop, losses to air and water, N concentration, carbon-to-nitrogen ratio, soil temperature, and soil moisture (Wilkinson, 1992).

In their analysis of nutrient availability from livestock, Lander et al. (USDA NRCS, 1998a) assumed that 70 percent of N applied in manure would be available to the crop. Ammonia volatilization, nitrate leaching, and runoff losses reduce the amount of available nutrient, and the percentage available also varies depending on soil temperature, soil moisture, organism availability, and the presence of other nutrients and essentials. When dry or liquid manure is incorporated immediately following application in the north-central region of the United States, about 50 percent of the N is available to the crop (Hirschi et al., 1997).

In North Carolina, it is estimated that half of the total N in irrigated lagoon liquid and 70 percent of the total N in manure slurries that are incorporated into the soil is available to plants (Barker and Zublena, 1996). Plant availability coefficients for N range from 25 percent (dry litter or semisolid manure broadcast without cultivation, and liquid manure slurry irrigated without cultivation) to 95 percent (injected liquid manure slurry and lagoon liquid), depending on form of the manure and method of application (Barker, 1996). For both P and K, the range is 60 to 80 percent, with the higher values for injection of liquid manure slurries and lagoon liquids, and application of lagoon liquids through broadcasting or irrigation with cultivation. The lower values in the range apply to broadcasting dry litter and semisolid manure with no cultivation. The results from plot studies conducted on Cecil sandy loam in Georgia indicate that carryover N from broiler litter should be factored into nutrient management planning for periods longer than 3 years (Wilkinson, 1992).

In Ohio, only about one-third of the organic N in animal manure is available to crops during the year it is applied (Veenhuizen et al., 1999). The P and K in the manure are available during the year they are applied, as are the equivalent amounts of fertilizer-grade P and K. Ohio State University Extension has published tables that show the estimated percentage of residual organic N that will be available in the 10 years after initial application.

In addition to organic N in manure, other sources of N can be significant and are included in the calculation of N needs:

- Mineralization of soil organic matter
- Atmospheric deposition
- Residue mineralization
- Irrigation water

If appropriate, contributions from these sources should be subtracted from the total amount of N needed. A general value for calculating the N mineralized per acre from soil organic matter (SOM) is 40 pounds per year for each 1 percent of SOM. The amount of N from atmospheric deposition can be as much as 26 pounds per acre per year, but local data should be used for this estimate. Irrigation additions can be estimated by multiplying the N concentration (in parts per million) by the quantity of water applied (in acre-inches) by 0.227 (USDA NRCS, 1996a).

As discussed earlier, nutrient planning based on N levels alone could lead to excessive soil P levels, thereby increasing the potential for P to be transported in runoff and erosion. Soil P levels should be determined and compared with crop needs before manure or fertilizer containing P is applied. This can be accomplished by comparing annual P removal rates based on the type of crop planted with the amount of P applied the previous year. As with N, data are available for plant removal rates by specific crop.

Operational Factors: As noted above, the major factors determining the amount and availability of carryover N include losses to air and water, soil temperature, and soil moisture (Wilkinson, 1992). In addition, mineralization of soil organic matter, atmospheric deposition, residue mineralization, and irrigation water applications are all related to climate, temperature, and rainfall.

Demonstration Status: Estimation of crop nutrient needs is a basic feature of farming. The methods used vary, however, as does the accuracy of the estimates.

8.3.2.3 Nutrients Available in Manure

Manure is an excellent fertilizer because it contains at least low concentrations of every element necessary for plant growth. The most important macronutrients in manure are N, P, and K, all of which come from urine and feces. The chemical composition of manure when it is excreted from the animal is determined largely by the following variables:

- Species of animal
- Breed
- Age
- Gender
- Genetics
- Feed ration composition

The composition of manure at the time it is applied usually varies greatly from that at the time it was excreted from the animal. The nutrients in manure undergo decomposition at varying rates influenced by the following factors:

- Climate (heat, humidity, wind, and other factors)

- Length of time the manure is stored

- Amount of feed, bedding, and water added to manure before removal from the animal housing facility

- Type of production facility

- Method of manure handling and storage

- Method and timing of land application

- Use of manure/pit additives
- Soil characteristics at time of application
- Type of crop to which manure is applied
- Net precipitation/evaporation in storage structure
- Uncontrollable anomalies (e.g., broken water line)
- Ratio of nutrients that have been transformed and/or lost to the atmosphere or soil profile

Given these many factors, it is nearly impossible to predict the nutrient content of manure in every animal production setting. Several state extension and university publications have attempted to predict nutrient contents for different species of animals at specific production phases. These book values are an educated guess at best and vary widely from state to state. It is imperative that livestock producers monitor the nutrient content of their manure on a consistent basis. Knowing the content of macronutrients in manure is an important step to proper land application.

Nitrogen

The total amount of N in manure is excreted in two forms. Urea, which rapidly hydrolyzes to ammonia, is the major N component of urine. Organic N, excreted in the feces, is a result of unutilized feed, microbial growth, and metabolism in the animal.

$$\text{Total N} = NH_3 \text{ (ammonia)} + \text{organic N}$$

The ratio of ammonia to organic N in the manure at the time of excretion is largely dependent on species, feed intake, and the other factors discussed above.

Before land application, inorganic N forms can be lost either to the atmosphere or into the soil profile, decreasing the nutrient value of the manure. Depending on the type of manure- handling and storage system and other factors described above, variable amounts of organic N can be mineralized to inorganic forms, which then can be lost to the atmosphere or into the soil profile. Nitrogen can be lost from manure in the following three ways:

1. NH_3 (ammonia) is volatilized into the atmosphere.

2. NO_3 (nitrate, a product of mineralization and nitrification) undergoes denitrification and is released into the atmosphere as N_2 (inert N gas).

3. NO_3 (nitrate, a water soluble form of N) is leached and carried down through the soil profile, where it is unavailable to plants.

Agitation of liquid manure prior to land application is extremely important. Solids will separate from still manure. The liquid will largely consist of the mineralized, inorganic forms of N, whereas the solid portions will contain the organic forms of N that are unavailable to plants. Proper agitation suspends the solids and helps ensure that the manure will be a more uniform and predictable fertilizer.

When manure is applied to land, the N content exists in two major forms, the ratio of which can be determined only by manure analysis. The amount of N that will be available to fertilize the plant will depend on the method and timing of application. The balance of the N available to the plant will be lost in one of the three ways described above or will remain immobilized in the organic form. It is generally agreed that 25 to 50 percent of N applied in the organic form will undergo mineralization and become available to plants in the first year. The remaining organic N will mineralize and become available in subsequent years.

When manure is applied to the surface of land without incorporation into the soil, much of the inorganic N remains on the surface, is lost, and will never be available to the plant. Volatilization of ammonia is the most significant loss factor and is greatest when drying conditions (dry, warm, sunny days) dominate. Field estimates of volatilization loss from surface-applied manure range from about 10 to 70 percent of ammonia N applied (CAST, 1996).

When manure is incorporated into the soil, inorganic forms of N available to the plant are placed directly into the root zone and volatilization is minimized. The inorganic ammonia/ammonium is either taken up by the plant or converted to nitrate. The nitrate can then be taken up by the plant, denitrified, and released into the atmosphere as N gas, or carried by water through the root zone. In addition, the organic N fraction has more contact with soil microbes when incorporated, resulting in a greater rate of mineralization.

Phosphorus

The vast majority of P contained in manure is derived from the feces. Only small amounts of P are present in livestock urine. As with N, the amount of P excreted by an animal depends on several factors already discussed.

The introduction of water, bedding, and feed into the manure can affect both the nutrient concentration and the content of the manure product. Manure handling and storage have little influence on the P concentration. Any loss of P is a result of runoff from feedlots or solids settling in holding basins, storage tanks, or lagoons. This will not be a loss if it is collected and used later.

Most of the P is present in solid manure. As stated for N, proper agitation resuspends the solids and makes the manure a more uniform and predictable fertilizer.

Although method and timing of land application have little direct effect on the transformation of P to plant-available forms, they greatly influence the potential loss of P through runoff. Estimates of P vary widely (CAST, 1996); however, by current estimates, somewhere near 70 percent is available for plant uptake in the first year following manure application (Koelsch, 1997).

Potassium

In most species, K is equally present in both urine and feces. Similarly, the amount of K in manure is fairly constant between liquids and solids and is not influenced by agitation. As with the other macronutrients, the amount of K excreted by an animal depends on a multitude of factors already discussed.

As with P, the introduction of water, bedding, and feed to the manure can affect both the K concentration and the content of the manure product. Manure handling and storage have little influence on the K concentration. Any loss of K is a result of runoff from feedlots or solids settling in holding basins, storage tanks, or lagoons. This will not be a loss if it is collected and used later.

As for P, the method and timing of land application have little direct effect on the transformation of K to plant-available forms, but they greatly influence the potential loss of K through runoff. Most of the K in manure is in the soluble form and is therefore readily available for plant uptake. Availability is estimated to be about 90 percent (Koelsch, 1997).

Swine Specific Information

Swine excrete approximately 80 percent of the N and P and approximately 90 percent of the K in the feed ration (Sutton et al., 1996). Swine manure can be handled as a slurry, liquid (with the addition of wastewater), or solid (with the addition of large amounts of bedding).

Estimates of the nutrient content of swine manure classified by manure handling type and production phase are given in Table 8-19. The values were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Poultry Specific Information

Excreted poultry manure has a moisture content of around 80 percent. It can be handled as a slurry or liquid, or in a dry form with added bedding (referred to as litter). Estimates of the nutrient content of chicken and turkey manure are given in Table 8-20. The values were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Dairy Specific Information

Because of the variety of housing and production options associated with dairies, many dairies have a combination of solid-, liquid-, and/or semisolid-based handling systems. Milking parlors commonly generate a large amount of wastewater from frequent flushing and cleaning of facilities and cows. Dry cows are often housed outdoors in open lots, while cows being milked may be kept in covered or completely enclosed freestall barns or holding pens.

Estimates of the nutrient content of dairy manure classified by manure handling type are given in Table 8-21. The values were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Table 8-19. Swine Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998	pounds/ton	12.4	6.9	4.3	4.4
USDA NRCS, 1996a (farrow, storage tank under slats)	pounds/1,000 gal	29.2	23.3	15.0	23.3
USDA NRCS, 1996a (nursery, storage tank under slats)	pounds/1,000 gal	40.0	33.3	13.3	13.3
USDA NRCS, 1996a (grow/finish, storage tank under slats)	pounds/1,000 gal	52.5	—	22.5	18.3
USDA NRCS, 199a6 (breeding/gestation, storage tank under slats)	pounds/1,000 gal	25.0	—	10.0	17.5
USDA NRCS, 1996a (anaerobic lagoon liquid)	pounds/1,000 gal	2.9	1.8	0.6	3.2
USDA NRCS, 1996a (anaerobic lagoon sludge)	pounds/1,000 gal	25.0	6.3	22.5	63.3
USDA NRCS, 1998a (Breeding hogs, after losses)	pounds/ton	3.3	—	3.6	7.0
USDA NRCS, 1998a (Other types of hogs, after losses) [a]	pounds/ton	2.8	—	2.8	7.2
Jones and Sutton, 1994 (farrow, pit storage)	pounds/1,000 gal	15.0	7.5	5.2	9.1
Jones and Sutton, 1994 (nursery, pit storage)	pounds/1,000 gal	24.0	14.0	8.7	18.3
Jones and Sutton, 1994 (grow/finish, pit storage)	pounds/1,000 gal	32.8	19.0	11.5	22.4
Jones and Sutton, 1994 (breeding/gestation, pit storage)	pounds/1,000 gal	25.0	12.0	13.5	22.4
Jones and Sutton, 1994 (farrow, anaerobic lagoon)	pounds/1,000 gal	4.1	3.0	0.9	1.7
Jones and Sutton, 1994 (nursery, anaerobic lagoon)	pounds/1,000 gal	5.0	3.8	1.4	2.7
Jones and Sutton, 1994 (grow/finish, anaerobic lagoon)	pounds/1,000 gal	5.6	4.5	1.7	3.5
Jones and Sutton, 1994 (breeding/gestation, anaerobic lagoon)	pounds/1,000 gal	4.4	3.3	1.9	3.3
Reichow, 1995 (no bedding)	pounds/ton	10.0	6.0	3.9	6.6
Reichow, 1995 (bedding)	pounds/ton	8.0	5.0	3.1	5.8
NCSU, 1994 (paved surface scraped)	pounds/ton	13.0	5.6	5.8	7.6
NCSU, 1994 (liquid manure slurry)	pounds/1,000 gal	26.5	16.8	8.3	12.6
NCSU, 1994 (anaerobic lagoon liquid)	pounds/1,000 gal	4.7	3.8	0.8	4.0
NCSU, 1994 (anaerobic lagoon sludge)	pounds/1,000 gal	24.4	5.9	23.0	5.4

—, data not available.
[a] selected for nutrient production calculations throughout this document

Table 8-20. Poultry Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998 (layer)	pounds/ton	26.3	6.6	9.4	9.4
USDA NRCS, 1996a (layer, anaerobic lagoon supernatant)	pounds/1,000 gal	6.3	4.6	0.8	8.3
USDA NRCS, 1996a (layer, anaerobic lagoon sludge)	pounds/1,000 gal	32.5	7.7	45.8	6.0
USDA NRCS, 1996a (layer with no bedding or litter)	pounds/ton	35.4		22.9	25.0
Jones and Sutton, 1994 (layer, pit storage)	pounds/1,000 gal	60.0	13.0	19.7	23.2
Jones and Sutton, 1994 (layer, anaerobic lagoon)	pounds/1,000 gal	7.0	5.5	1.7	2.9
NCSU, 1994 (layer paved surface scraped)	pounds/ton	28.2	14.0	13.8	16.2
NCSU, 1994 (layer unpaved deep pit storage)	pounds/ton	33.6	11.8	22.3	21.9
NCSU, 1994 (layer liquid manure slurry)	pounds/1,000 gal	57.3	36.8	22.7	27.5
NCSU, 1994 (layer anaerobic lagoon liquid)	pounds/1,000 gal	6.6	5.6	0.7	8.5
NCSU, 1994 (layer anaerobic lagoon sludge)	pounds/1,000 gal	20.8	6.5	33.7	8.1
ASAE, 1998 (broiler)	pounds/ton	25.9	—	7.1	9.4
USDA NRCS, 1996a (broiler litter)	pounds/1,000 gal	38.9	—	19.4	22.9
USDA NRCS, 1998a (broiler, as excreted)	pounds/ton	26.8	—	7.8	10.5
USDA NRCS, 1998a (broiler, after losses) [a]	pounds/ton	16.1	—	6.6	9.5
Jones and Sutton, 1994 (broiler, pit storage)	pounds/1,000 gal	63.0	13.0	17.5	24.1
Jones and Sutton, 1994 (broiler, anaerobic lagoon)	pounds/1,000 gal	8.5	5.0	1.9	2.9
NCSU, 1994 (broiler litter)	pounds/ton	71.4	12.0	30.3	38.7
NCSU, 1994 (stockpiled broiler litter)	pounds/ton	32.6	6.9	33.5	26.6
NCSU, 1994 (broiler house manure cake)	pounds/ton	45.5	11.8	23.0	29.9
ASAE, 1998 (turkey)	pounds/ton	26.4	3.4	9.8	10.2
USDA NRCS, 1996a (turkey litter)	pounds/1,000 gal	72.4	0.8	32.9	37.0
USDA NRCS, 1998a (turkeys for slaughter, as excreted)	pounds/ton	30.4	—	11.8	11.6
USDA NRCS, 1998a (turkeys for slaughter, after losses) [a]	pounds/ton	16.2	—	10.1	10.4
USDA NRCS, 1998a (turkey hens, as excreted)	pounds/ton	22.4	—	13.2	7.6
USDA NRCS, 1998a (turkey hens, after losses) [a]	pounds/ton	11.2	—	11.2	6.8
Jones and Sutton, 1994 (turkey tom, pit storage)	pounds/1,000 gal	53.0	16.0	17.5	24.4
Jones and Sutton, 1994 (turkey hen, pit storage)	pounds/1,000 gal	60.0	20.0	16.6	26.6
Jones and Sutton, 1994 (turkey tom, anaerobic lagoon)	pounds/1,000 gal	8.0	6.0	1.7	3.7
Jones and Sutton, 1994 (turkey hen, anaerobic lagoon)	pounds/1,000 gal	8.0	6.0	1.7	3.3
NCSU, 1994 (turkey house manure cake)	pounds/ton	44.8	20.1	20.3	24.8
NCSU, 1994 (stockpiled turkey litter)	pounds/ton	31.6	5.5	30.4	25.0

—, data not available.
[a] selected for nutrient production calculations throughout this document

Table 8-21. Dairy Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998	pounds/ton	10.5	1.8	2.2	6.7
USDA NRCS, 1996a (as excreted, lactating cow)	pounds/ton	11.3	—	1.8	6.5
USDA NRCS, 1996a (as excreted, dry cow)	pounds/ton	8.8	—	1.2	5.6
USDA NRCS, 1996a (heifer)	pounds/ton	7.3	—	0.9	5.6
USDA NRCS, 1996a (anaerobic lagoon supernatant)	pounds/1,000 gal	1.7	1.0	0.5	4.2
USDA NRCS, 1996a (anaerobic lagoon sludge)	pounds/1,000 gal	20.8	4.2	9.2	12.5
USDA NRCS, 1996a (aerobic lagoon supernatant)	pounds/1,000 gal	0.2	0.1	0.1	—
USDA NRCS, 1998a (milk cows, as excreted)	pounds/ton	10.7	—	1.9	6.7
USDA NRCS, 1998a (milk cows, after losses) [a]	pounds/ton	4.3	—	1.7	6.0
USDA NRCS, 1998a (heifer & heifer calves, as excreted)	pounds/ton	6.1	—	1.3	5.0
USDA NRCS, 1998a (heifer & heifer calves, after losses) [a]	pounds/ton	1.8	—	1.1	4.5
Reichow, 1995 (dry without bedding)	pounds/ton	9.0	4.0	1.7	8.3
Reichow, 1995 (dry with bedding)	pounds/ton	9.0	5.0	—	—
Jones and Sutton, 1994 (mature cow, pit storage)	pounds/1,000 gal	31.0	6.5	6.6	15.8
Jones and Sutton, 1994 (heifer, pit storage)	pounds/1,000 gal	32.0	6.0	6.1	23.2
Jones and Sutton, 1994 (dairy calf, pit storage)	pounds/1,000 gal	27.0	5.0	6.1	19.9
Jones and Sutton, 1994 (mature cow, anaerobic lagoon)	pounds/1,000 gal	4.2	2.3	0.8	2.5
Jones and Sutton, 1994 (heifer, anaerobic lagoon)	pounds/1,000 gal	4.3	2.1	0.9	2.5
Jones and Sutton, 1994 (dairy calf, anaerobic lagoon)	pounds/1,000 gal	3.0	2.0	0.4	2.1
NCSU, 1994 (paved surface scraped)	pounds/ton	10.3	2.5	3.1	7.1
NCSU, 1994 (liquid manure slurry)	pounds/1,000 gal	22.0	9.2	6.0	16.6
NCSU, 1994 (anaerobic lagoon liquid)	pounds/1,000 gal	4.9	3.2	1.2	5.4
NCSU, 1994 (anaerobic lagoon sludge)	pounds/1,000 gal	19.2	6.2	18.3	7.7

—, data not available.
[a] selected for nutrient production calculations throughout this document

Beef Cattle Specific Information

Most beef cattle are produced in an open-lot setting, but some moderate-sized operations produce beef in confinement. The nutrient content of feedlot manure is extremely difficult to quantify because of inconsistency in collection methods and content. Varying amounts of dirt, bedding, and precipitation are mixed with the bedding at different times of the year.

Estimates of the nutrient content of beef manure are given in Table 8-22. The ranges were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Practice: Manure Testing

Description: The nutrient composition of manure varies widely among farms because of differences in animal species and management, and manure storage and handling (Busch et al., 2000). The only method available for determining the actual nutrient content of manure for a particular operation is laboratory analysis. Typical laboratory reports show the moisture content and percentage of N, P, K, Ca, Mg, and Na, as well as the concentration (parts per million) of Zn, Fe, Cu, Mn (McFarland et al., 1998; USDA NRCS, 1996a). Other information, such as the pH and conductivity for liquid samples, is also provided.

Sampling should be performed as close as possible to the time of land application to limit error resulting from losses occurring during handling, storage, and application (Schmitt, 1999; Busch et al., 2000; Bonner et al., 1998; Sharpley et al., 1994). The best time to collect a representative manure sample is during the loading or application process (Schmitt, 1999), but the test results from such sampling cannot be used to plan the current manure applications. Sampling during hauling is considered more accurate and safer than sampling at storage structures (Busch et al., 2000). Subsamples should be collected from several loads and then composited into a single sample. This applies to liquid, solid, or semisolid systems. Because the nutrients in manure are not distributed evenly between the urine and feces portions, mixing is critical to obtaining a representative sample.

Barker and Zublena (1996) recommend that land-applied manure be sampled and analyzed twice annually for nutrient and mineral content. New sampling should be conducted whenever animal management practices change. For example, if there is a significant change in animal rations or operation management (e.g., a change in the size or type of animals raised), new sampling should be conducted. If manure is applied several times a year, samples should be taken during the period of maximum manure application. For example, if the manure that has accumulated all winter will be used as a nutrient source, sampling should be done before application in the spring.

Table 8-22. Beef Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998	pounds/ton	11.7	3.0	3.2	7.2
USDA NRCS, 1996a (as excreted, high forage diet)	pounds/ton	10.5	—	3.7	8.1
USDA NRCS, 1996a (as excreted, high energy diet)	pounds/ton	10.2	—	3.2	7.1
USDA NRCS, 1996a (feedlot manure)	pounds/ton	24.0	—	16.0	3.4
USDA NRCS, 1998a (beef cows, as excreted)	pounds/ton	11.0	—	3.8	8.3
USDA NRCS, 1998a (beef cows, after losses) [a]	pounds/ton	3.3	—	3.2	7.4
USDA NRCS, 1998a (steers, calves, bulls, & bull calves, as excreted)	pounds/ton	11.0	—	3.4	7.9
USDA NRCS, 1998a (steers, calves, bulls, & bull calves, after losses) [a]	pounds/ton	3.3	—	2.9	7.1
USDA NRCS, 1998a (fattened cattle, as excreted)	pounds/ton	11.0	—	3.4	7.9
USDA NRCS, 1998a (fattened cattle, after losses) [a]	pounds/ton	4.4		2.9	7.1
Reichow, 1995 (dry without bedding)	pounds/ton	21.0	7.0	6.1	19.1
Reichow, 1995 (dry with bedding)	pounds/ton	21.0	8.0	7.9	21.6
Jones and Sutton, 1994 (pit storage)	pounds/1,000 gal	20.0	—	3.1	16.5
Jones and Sutton, 1994 (anaerobic lagoon)	pounds/1,000 gal	4.0	—	0.6	2.7
NCSU, 1994 (paved surface scraped)	pounds/ton	13.8	1.9	4.2	10.7
NCSU, 1994 (unpaved surface scraped)	pounds/ton	25.0	4.7	7.8	17.9
NCSU, 1994 (liquid manure slurry)	pounds/1,000 gal	35.0	14.6	9.9	61.6
NCSU, 1994 (anaerobic lagoon, liquid)	pounds/1,000 gal	3.4	2.3	0.8	4.1
NCSU, 1994 (anaerobic lagoon, sludge)	pounds/1,000 gal	38.2		25.7	12.1

—, data not available.
[a] selected for nutrient production calculations throughout this document

For systems that are emptied or cleaned out once a year, it is recommended that sampling be conducted each time the manure is applied (Busch et al., 2000). This applies to uncovered lagoons, pits, basins, and stacking slabs. Manure from under-barn concrete pits or covered aboveground tanks will not vary as much between applications, unless the type of animal or another significant factor changes. Systems emptied twice a year or more might differ between application times, so a fall analysis might not be accurate for planning spring applications.

Application and Performance: Manure sampling is a practice that applies to all farms and all land on which manure is applied. The farmer or trained consultants can conduct the sampling.

Manure sampling does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: Manure analysis is the only way in which the actual nutrient content can be determined. Standardized tables of manure nutrient content do not reflect how variable the true nutrient content can be, but they can be useful in planning facilities and land application areas (Hirschi et al., 1997).

Convenient laboratory reports allow farmers to easily determine the pounds per ton of nutrients in solid manure or pounds per acre-inch in liquid manure (McFarland et al., 1998). Laboratories are available at universities in most states, and lists of service providers can be obtained from county offices and the Internet.

Without manure analysis, farmers might buy more commercial fertilizer than is needed or spread too much manure on their fields (USDA NRCS, 1996a). Either practice can result in overfertilization, which, in turn, can depress crop yields and cut profits. Improper spreading of manure also can pollute surface and ground water.

Sampling from manure application equipment is quick, but the test results cannot be used to plan the current year's manure applications. Sampling before hauling allows use of the test results for the current year, but retrieving an accurate sample is difficult because the manure is not mixed. Further, there is the danger of falling into manure storage structures.

Operational Factors: Sample collection procedures vary considerably depending on manure form and storage, but all are intended to provide representative samples in a safe and convenient manner. Homogeneity is the key to simple sampling procedures, but the nutrient content of manure usually varies considerably within storage structures and stockpiles. For this reason, agitation of liquid manure and mixing of solid manure are generally recommended prior to sampling. Alternatively, several samples can be taken from different locations and depths within a lagoon, pit, or manure stack. Sampling each of several loads of hauled manure is another option to address spatial variability of manure nutrient content. The process of agitating and loading manure is believed to provide mixing that ensures representative sampling (Busch et al., 2000).

The number of samples to be taken for suitable results depends on the variability of the manure sampled (Busch et al., 2000). One sample may be adequate for agitated liquid slurries and lagoon liquids, whereas three or more samples may be needed for stacked solids. It is recommended that one sample be taken per poultry house.

Hirschi et al. (1997) recommend taking solid manure samples from several locations in a manure stack or on a feedlot, mixing them together in a tied, 1-gallon plastic bag, placing that bag inside another bag, and then freezing the sample before shipping to a laboratory for analysis.
Busch et al. (2000) say that 10 to 20 subsamples should be taken from different depths and locations using a pitchfork or shovel. In Texas, five to seven random subsamples are recommended (McFarland et al., 1998). The subsamples are placed in a pile and mixed before a composite sample is taken.

Busch et al. (2000) recommend that samples be taken from the manure in the tank or spreader box on its way to the field for application. For solid manure, samples should be collected from application equipment using a pitchfork, shovel, or plastic glove, avoiding large pieces or chunks of bedding. The sample taken to the lab should be a mixture of manure taken from several (5 to 10) loads representing the beginning, middle, and end of the application process. Subsamples should be mixed thoroughly, prior to filling a sample jar three-fourths full, allowing room for gas expansion. Jars should be cleaned and sealed in a plastic bag, and samples should be frozen before being mailed.

Bonner et al. (1998) suggest that samples can be collected by using catch pans in the field as the material is applied to the land. Samples from multiple pans are mixed to form the overall sample, and a 1-liter plastic bottle is filled halfway to allow for gas expansion. Samples should be frozen or kept cold until delivered to a laboratory.

Rather than sampling from the lagoon or pit, samples can be retrieved with a plastic pail or a coffee can on a pole from the top of the spreader or from the bottom unloading port (Busch et al., 2000). Sampling should be done immediately after filling.

Hirschi et al. (1997) recommend agitating or mixing liquid manures prior to sampling unless it is more practical to take samples from several areas within a lagoon or pit and then mix them. To sample from lagoons and storage facilities, a plastic container attached to a pole or rod is recommended (Bonner et al., 1998; McFarland et al., 1998; Busch et al., 2000). Alternatively, a ½- or ¾- inch PVC pipe can be pushed into the manure to a depth no closer than 1 foot from the bottom (Busch et al., 2000). The sample can be secured by placing a hand over the top of the pipe and pulling the pipe up. Samples should be taken from 5 to 10 locations around the lagoon, covering several depths to include solids. After mixing the samples in a bucket, a representative sample is then taken to a laboratory for analysis.

Demonstration Status: Manure sampling is practiced widely across the United States, but many farmers still do not test manure or employ a N credit from manure when determining commercial fertilizer needs (Stevenson, 1995). A 1995 survey of 1,477 swine producers showed that 92 percent of operations had not had their manure tested for nutrients within the past 12 months (USDA APHIS, 1995). Approximately 6 percent had tested their manure for nutrients once during the past 12 months, while another 1.5 percent had tested it twice. These findings are supported by a crop nutrient management survey in which only 2 to 17 percent of respondents in various regions stated that they factored manure nutrient values into their nutrient management plans (Marketing Directions, 1998).

8.3.2.4 Nutrients Available in Soil

A major problem in using organic nutrient sources such as animal waste is that their nutrient content is rarely balanced with the specific soil and crop needs. For example, the N: P ratio in applied manure is usually around 3 or less, whereas the ratio at which crops use nutrients typically ranges from 5 to 7. Therefore, when manure is applied at rates based solely on N analysis and crop need for N, P is applied in excess of crop needs. Because the amounts of P added in manure exceed the amounts removed by crops, continuous use of manure can result in accumulations of excess P in the soil, increasing the potential for P to be transported in runoff and erosion (Sharpley et al., 1999).

A recent change of emphasis in nutrient management programs has been to base manure application rates on both P and N needs. Different soil types can accommodate different P concentrations before experiencing significant P export in runoff. The amount of P that a soil can hold depends on the availability of binding sites. For example, a clayey soil will tend to be able to retain more P than a sandy soil because clays have a greater surface area and typically contain a greater proportion of iron, which has a strong affinity for P. Table 8-23 demonstrates the variability of the P binding capacity of several soils. Phosphorus bound to soils is primarily in a particulate form; however, as a soil becomes saturated with P, the finite number of binding sites will be overwhelmed and P can be released into runoff in a soluble form.

Table 8-23. Maximum P-Fixation Capacity of Several Soils of Varied Clay Contents

Soil Great Group (and series)	Location	Percent clay	Maximum P fixation (mg P/ kg soil)
Evesboro (Quartzipsamment)	Maryland	6	125
Kitsap (Xerochrept)	Washington	12	453
Matapeake (Hapludult)	Maryland	15	465
Newberg (Haploxeroll)	Washington	38	905

Source: Brady and Weil, 1996.

The concept of a P threshold (TH) has been developed to identify soil P levels at which soluble losses of P in runoff become significant. The recently revised USDA NRCS nutrient management policy (Part 402) addressing organic soil amendments, such as manures, proposes that for soils with a known P TH the following P manure application rates apply:

- If soil P levels are below 75 percent of the P TH, N-based manure application is allowed.

- If soil P levels are between 75 percent and 150 percent of the P TH, manure application rates should be based on the amount of P estimated to be removed by the crop.

- If soil P levels are between 150 percent and 200 percent of the P TH, manure application rates should be based on one-half the amount of the P estimated to be removed by the crop.

- If soil P levels are greater than twice (200 percent) the P TH, no manure should be added to the soil.

- When no soil-specific TH data are available, P application should be based on soil P test levels.

- If the soil P test level is low or medium, the application rate of organic soil amendments (e.g., manure) can be based on the soil's N content.

- If the soil P level is high, the manure application rate should be based on 1.5 times the P estimated to be removed by the crop.

- If the soil P level is very high, the manure application rate should be based on the P estimated to be removed by the crop.

- If the soil P level is excessive, no manure should be applied.

Using this threshold concept, several states are developing P indexes to account for site-specific conditions that influence both soluble P losses and particulate P losses resulting from erosion (Lemunyon and Gilbert, 1993; Sharpley, 1995). This approach would categorize agricultural fields using a quantitative index that can be helpful in assessing the potential risk of P contamination of local water bodies. Manure and fertilizer application programs can then be developed accordingly. For instance, an area prone to P transport, such as a field rich in P located on erodible soils adjacent to a reservoir, would receive a high score identifying the importance of a strict nutrient management program. The economic concerns raised by a P-based plan may be significant because a larger land area may be required in order to dispose of manure from livestock operations.

Practice: Soil Testing

Description: Soil testing, an important tool for determining crop nutrient needs, evaluates the fertility of the soil to determine the basic amounts of fertilizer and lime to apply (USDA NRCS, 1996a). Soil tests should be conducted to determine the optimum nutrient application of N and P, pH, and organic matter. Typical laboratory reports show soil pH, P, K, Ca, Mg, Zn, and Mn levels, plus fertilizer and lime recommendations (USDA NRCS, 1996a). Special analyses for organic matter, nitrate-N, and soluble salts can be requested.

The best time to sample soil is after harvest or before fall or spring fertilization. Late summer and fall are best because K test results are most reliable at these times (Hirschi et al., 1997). The worst time to sample is shortly after the application of lime, commercial fertilizer, or manure, or when the soil is extremely wet. Samples are usually composited to determine a general application rate for a specific field or field section. The goal is to obtain a representative view of the field conditions. This can be achieved by sampling in areas that have similar soil types, crop rotation, tillage type, and past fertility programs. In addition, soil samples should be taken at random in a zigzag pattern, making sure to avoid irregularities in the land (e.g., fence lines, very wet areas) to get samples that accurately portray the landscape. Two weaknesses of random sampling in a zigzag pattern are the assumptions that the composite sample is representative of the entire field and that the result of the sampling produces an average value for the field (Pocknee and Boydell, 1995). Samples can be gathered and composited over smaller areas to determine distinct treatment options. To evaluate the variability of the land, the grid method of dividing the field into 5-acre plots can also be used. Treatment decisions can be made by balancing labor requirements, environmental concerns, and economics.

Grid-cell sampling and grid-point sampling are two sampling methods used on farms where precision farming is practiced. In grid-cell sampling, an imaginary grid is laid over the sampling area and soil cores are taken randomly within each cell, bulked, and mixed. A subsample is then taken from the composite sample for analysis. This approach is considered similar to the random sampling method, with the exception that the sampled area is divided up into many smaller "fields." In grid-point sampling, a similar imaginary grid is used, but the soil cores are taken from within a small radius of each grid intersection, bulked, mixed, and subsampled for analysis. Each of these methods has its limitations. Grid-cell sampling is very time-intensive because most of the field needs to be covered in the sampling process, whereas grid-point sampling will not work well unless grid sizes are very small. Thus, both methods tend to be expensive because of the labor involved. A newer method, directed sampling, is based on spatial patterns defined by some prior knowledge about a field. Sampled areas are divided into homogeneous soil units of varying size. Factors such as field management history, soil maps, soil color, yield maps, topography, and past soil tests are combined and analyzed using a geographic information system (GIS) to determine optimal sampling patterns.

Sampling equipment for grid sampling includes four-wheelers and trucks equipped with global positioning system (GPS) capabilities and mechanized sampling arms (Pocknee and Boydell, 1995). Costs for custom service range from $7 to $15 per acre, including soil sampling, analysis of standard elements, and mapping.

Recommendations regarding sampling frequency range from once a year to once every 4 years. In Arizona, soil sampling for residual nitrate content analysis is recommended prior to planting annual crops (Doerge et al., 1991). For sandy soils in North Carolina, sampling is recommended once every 2 to 3 years; testing once every 4 years is suitable for silt and clay loam soils (Baird et al., 1997). A minimum frequency of once every 4 years is generally recommended in the central United States (Hirschi et al., 1997). In Mississippi, soil samples should be taken once every 3 years or once per crop rotation (Crouse and McCarty, 1998).

Application and Performance: Soil sampling is a practice that applies to all farms and all land to which nutrients are applied. The farmer or trained consultants can conduct the sampling.

Soil sampling does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: Soil analysis is the only way in which the actual nutrient content can be determined. Nitrogen testing has not been consistently reliable because N is highly mobile in soil, but drier parts of the Corn Belt have had some success with both the early spring nitrate-N test and the pre-sidedress N test (Hirschi et al., 1997). There is also some evidence that the pre-sidedress test is most helpful on soils to which manure has been applied.

A late spring N test ensures that the proper amount of N was applied to the crops. Because this test is used to make site-specific adjustments of application rates, following the recommendations provided by this test can help achieve expected crop yields. For example, where N is too high, the late spring N test will indicate that additional N application is not needed by the crop and may contaminate water supplies. Records should be kept and adjustments made to N applications on future crops.

Without soil analysis, farmers might buy more commercial fertilizer than is needed or spread too much manure on their fields (USDA NRCS, 1996a). Either practice can result in overfertilization, which, in turn, can depress crop yields and cut profits. Improper spreading of manure also can pollute surface and ground water.

Convenient laboratory reports allow farmers to easily determine the pounds of nutrients per acre of soil (McFarland et al., 1998). Recommendations based on soil testing results are developed using crop response data from within a state or region with similar soils, cropping systems, and climate (Sims et al., 1998). For this reason, it is important to send samples to a laboratory that is familiar with the crops, soils, and management practices that will be used on the particular farm. The better the information provided to laboratories for each soil sample—such as previous fertilizer use, management plans, and soil series—the greater the potential for receiving a better recommendation. Laboratories are available at universities in most states, and lists of service providers can be obtained from county offices and the Internet.

Operational Factors: Soil samples can be taken with a probe, auger, or spade and collected in a clean bucket. Probes and augers are preferred because they provide an equal amount of soil from each depth (Crouse and McCarty, 1998). For uniform fields, one sample is satisfactory, but most fields are not uniform in treatment, slope, soil type, or drainage, and so should be divided into small areas of 5 to 10 acres each for sampling (USDA NRCS, 1996a). It is recommended that a soil map be used to guide sampling, and a separate, composite soil sample should be taken for each distinct kind of land, soil texture, soil organic matter, fertility level, and management unit (Crouse and McCarty, 1998). The samples should be taken from 20 or more places in the field, using a zig-zag pattern (USDA NRCS, 1996a). Samples should not be taken from unusual areas such as turn rows, old fence rows, old roadbeds, eroded spots, areas where lime or manure have been piled, or in the fertilizer band of row crops. A soil auger, soil tube, or spade can be used for sampling at the plow depth for cropland (6 to 8 inches or more) and at 2 to 4 inches for pasture. Samples should be placed in a clean plastic pail, mixed thoroughly with all clods broken up, and then sent to a laboratory in a 1/2-pint box for analysis.

Recommendations regarding the appropriate field size to be sampled vary somewhat, as shown in Table 8-24.

Table 8-24. Recommended Field Size for Soil Sampling

Location	Field Size	Comments	Source
Arizona	40 acres or less	15-20 subsamples	Doerge et al., 1991
Hawaii	2-5 acres	5-10 subsamples	Hue et al., 1997
Minnesota	5-20 acres	15-20 subsamples	Rosen 1994
North Carolina	20 acres or less	15-20 subsamples	Baird et al., 1997
Texas	10-40 acres	10-15 subsamples	McFarland et al., 1998
U.S.	20-30 acres	20-25 subsamples	Sims et al., 1998
U.S.	5-10 acres	20 or more subsamples	USDA NRCS, 1996a

Sampling for the early spring nitrate-N test involves taking soil samples in 1-foot increments down to a depth of 2 to 3 feet in early spring, while the pre-sidedress N test calls for sampling from the top 1 foot of soil when corn is 6 to 12 inches tall (Hirschi et al., 1997). Guidelines on interpretation of early spring nitrate tests vary across states.

Phosphorus soil tests are based on the chemical reactions that control P availability in soils (Sims et al., 1998). These reactions vary among soils, so a range of soil tests is available in the United States, including the Bray P1 (used in the North Central and Midwest Regions), Mehlich 3 (in widespread use in the United States), Mehlich 1 (Southeast and Mid-Atlantic), Morgan and Modified Morgan (Northeast), and Olsen and AB-DTPA (West and Northwest).

Demonstration Status: Soil testing is widely practiced in the United States. In a national survey of corn, soybeans, wheat, and cotton growers, 32 to 60 percent of respondents said that they perform soil testing (Marketing Directions, 1998).

8.3.2.5 Manure Application Rates and Land Requirements

Practice: Determining Manure Application Rates and Land Requirements

Description: The final step of a nutrient management analysis is to determine the amount of manure that can be applied to field crops to meet crop needs while simultaneously preventing excessive nutrient losses. This step involves using the information developed in the nutrient budget analysis to compare crop nutrient requirements with the supply of nutrients provided per unit volume of animal waste. Soil testing helps in determining the rates at which manure should be applied by establishing which nutrients are already present in the soil and available to the crop. Testing manure identifies the amount and types of nutrients it contains and helps to ensure that nutrients are not overapplied to the land. Depending on the cropping system, different amounts of nutrients will be required for optimum production. This final analysis allows the operator to determine how much land acreage is required to apply the animal manure generated or, conversely, how much manure can be applied to the available acreage. These final calculations are illustrated in Figures 8-13 and 8-14.

Figure 8-13 illustrates that two possible strategies for determining the correct agronomic application rate of manure are (1) applying enough manure to ensure the proper amount of N is available to the crop and (2) applying manure based on desired amounts of P, then adding commercial N and K to make up the differences in crop needs. Depending on the frequency of application, the first method might increase the risk of oversupplying P and K, thereby potentially adversely affecting soil and water quality (Dick et al., 1999). For this reason, the strategy requiring the greater land area for spreading is selected in the analysis illustrated by Figure 8-13.

Application and Performance: Determining manure application rates and land requirements applies to all farms and all land to which manure is applied. This analysis does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Determine land area needed for manure application.
Total pounds of usable nutrients available and pounds of nutrients available to plants in each gallon have been calculated. This information should be used to calculate the number of acres you need for manure application.

From nitrogen planning:
Net usable nitrogen available ____________ lb
Net nitrogen amount ÷ ____________ lb N/acre
Land area needed for spreading nitrogen: = ____________ acres

From phosphorus planning:
Net usable P_2O_5 available: ____________ lb
Total P_2O_5 needs: ÷ ____________ lb P_2O_5/acre
Land area needed for spreading P_2O_5: = ____________ acres

Acres required:
Greater of the two above values (a or b): ____________

Adapted from Iowa State University, 1995.

Figure 8-13. Example Procedure for Determining Land Needed for Manure Application

Determine manure volume to apply.

Total annual volume of manure:		____________	gal or T
Land area required for spreading:	÷	____________	acres
Manure volume used on field:	=	____________	gal or T/acre

If the field is smaller than the acres calculated above, calculate the manure to apply to this field:

Land area in field:		____________	acres
Manure volume to apply :	x	____________	gal or T/acre
Manure volume used on field:	=	____________	gal or T

Determine the number of gallons or tons of manure remaining to be spread:

Total annual volume of manure:		____________	gal or T
Manure volume used on field:	–	____________	gal or T
Manure volume remaining:	=	____________	gal or T

Manure volume remaining:		____________	gal or T
Manure volume to apply :	÷	____________	gal or T/acre
Additional land area for spreading:	=	____________	acres

Adapted from Iowa State University, 1995.

Figure 8-14. Example Calculations for Determining Manure Application Rate

Advantages and Limitations: Without this analysis, farmers may buy more commercial fertilizer than is needed or spread too much manure on their fields (USDA NRCS, 1996a). Either practice can result in overfertilization, which, in turn, can depress crop yields and cut profits. Improper spreading of manure also can pollute surface and ground water.

In cases where there is inadequate land to receive manure generated on the farm, alternative approaches to handling the manure, described elsewhere in this document, need to be considered.

Operational Factors: Although the correct manure application rate is determined by soil and manure nutrient composition, as well as the nutrient requirements for the crop system, further consideration should be given to soil type and timing of application. Attention to these factors aids in determining which fields are most appropriate for manure application. Before applying manure, operators should consider the soil properties for each field. Coarse-textured soils (high sand content) accept higher liquid application rates without runoff because of their increased permeability; however, manure should be applied frequently and at low rates throughout the growing season because such soils have a low ability to hold nutrients, which creates a potential for nitrate leaching (NCSU, 1998). Fall applications of animal manure on coarse-textured soils are generally not recommended. Fine-textured soils (high clay content) have slow water infiltration rates, and therefore application rates of manure should be limited to avoid runoff. Application on soils with high water tables should be limited to avoid nitrate leaching into ground water (Purdue University, 1994).

Demonstration Status: A 1995 survey of 1,477 swine producers showed that 92 percent of operations had not had their manure tested for nutrients within the past 12 months (USDA APHIS, 1995). Approximately 6 percent had tested their manure for nutrients once during the past 12 months, while another 1.5 percent had tested it twice. These findings are supported by a crop nutrient management survey in which only 2 to 17 percent of respondents in various regions stated that they factored manure nutrient value into their nutrient management plans (Marketing Directions, 1998). Like manure testing, analysis of land requirements and application rates is practiced widely across the United States, but many farmers still do not test manure or employ a N credit from manure when determining commercial fertilizer needs (Stevenson, 1995).

8.3.3 Record Keeping

The key to a successful nutrient management system is sound record keeping. Such a record-keeping regime should include the following:

Practice: Record Keeping

Description: Record keeping for a CNMP includes recording manure generation; field application (amount, rate, method, incorporation); the results and interpretation of manure, soil, and litter analysis; visual inspections of equipment and fields; manure spreader calibration worksheets; manure application worksheets (nutrient budget analyses); and related information on a monthly or more frequent basis.

Application and Performance: Record keeping applies to all farms and all land to which nutrients are applied. Record keeping does not address direct treatment or reduction of any pollutants, but is essential to tracking the results of activities associated with nutrient management.

Advantages and Limitations: Without record keeping, farmers will have little ability to determine what works and does not work with regard to on-farm nutrient management. Failure to learn from past successes and mistakes may cause farmers to continue in an endless loop of buying more commercial fertilizer than is needed, spreading too much manure on their fields, and realizing smaller profits than would otherwise be obtainable. For example, tracking manure sampling locations, dates, and methods will help establish a firm basis for adjusting sampling frequencies to provide an accurate assessment of manure nutrient content (Busch et al., 2000).

Record keeping can seem to be nothing but a burden unless tools are provided with which farmers can analyze the information for their own benefit. Fortunately, a great number of tools are currently available from universities and industry to help farmers use their records to make better business decisions. For example, MAX (Farming for Maximum Efficiency Program) is a program designed to help farmers look at their profit margins, rather than just their yields (CTIC, 1998b). MAX software is provided to cooperators to help them document their savings.

Operational Factors: Record keeping can be performed using pencil and paper, personal computers, portable computers, or GIS-based systems.

Demonstration Status: Record keeping of some form is conducted on all farms as a matter of business.

8.3.4 Certification of Nutrient Management Planners

Practice: Training and Certification for Nutrient Management Planners

Description: CNMPs should be developed or modified by a certified specialist. Certified specialists are persons who have a demonstrated ability to develop CNMPs in accordance with applicable USDA and state standards and are certified by USDA or a USDA-sanctioned organization. Certified specialists would include individuals who have received certifications through a state or local agency, third-party organization approved by NRCS, or NRCS personnel. In addition, USDA develops agreements with third-party vendors similar to the 1998 agreement with the Certified Crop Advisors (CCAs) and consistent with NRCS standards and specifications (or state standards if more restrictive).[1] CCAs provide technical assistance to producers in nutrient management, pest management, and residue management. The purpose of using a certified specialist is to ensure that CNMPs are developed, reviewed, and approved by persons who have the appropriate knowledge and expertise to ensure that plans fully and effectively address the core components of CNMPs, as appropriate and necessary, and that plans are appropriately tailored to the site-specific needs and conditions of the farm. Because of the multidisciplinary nature of CNMPs, it is likely that a range of expertise will be needed to develop an effective CNMP (e.g., professional engineer, crop specialist, soil specialist).

Application and Performance: Certification of nutrient management planners applies to all farms and all land to which nutrients are applied. Farmers may seek certification themselves or choose to seek assistance from certified professionals when developing their nutrient management plans.

Certification provides no direct treatment or reduction of any pollutants, but is essential to ensuring that CNMPs developed and implemented are effective in preventing pollution.

Advantages and Limitations: Without certification, those who develop CNMPs might not have the skills or knowledge necessary to develop cost-effective plans. This could result in both water pollution and less-than-optimal farm profits.

---

[1] Third-party vendor certification programs may include, but are not limited to, (1) the American Society of Agronomy's certification programs, including Certified Crop Advisors (CCA) and Certified Professional Agronomists (CPAg), Crop Scientists (CPCSc), and Soil Scientists (CPSSc) (2) land grant university certification programs (3) National Alliance of Independent Crop Consultants (NAICC); and (4) state certification programs.

If a producer chooses to attain certification, a time commitment is required, and training and travel expenses may be incurred. Course fees of $25 and 1 day of time lost are considered reasonable estimates of costs based on a review of both state training programs for nutrient management and pesticide certification costs provided by various state extension services. The major advantage of becoming certified is that the farmer will be able to develop his or her own CNMPs without the need for outside technical assistance. Certification would ultimately provide benefits with regard to time commitments, convenience, and expense.

Farmers who choose not to obtain certification will need to purchase services from those who are certified.

Operational Factors: Producers might need to travel within their state to attain certification.

Demonstration Status: Some states already have certification programs in place for nutrient management planning, which can provide an excellent foundation for CNMP certification programs. In addition, USDA develops agreements with third-party vendors similar to the 1998 agreement with the Certified Crop Advisors (CCAs).

8.4 Land Application and Field Management

Two important factors that affect nutrient loss are field application timing and application method.

8.4.1 Application Timing

The longer manure remains in the soil before crops take up its nutrients, the more likely those nutrients will be lost through volatilization, denitrification, leaching, erosion and surface runoff. Timing of application is extremely important. To minimize nitrogen losses, a good BMP is to apply manure as near as possible to planting time or to the crop growth stage during which nitrogen is most needed. Because of regional variations in climate, crops grown, soils, and other factors, timing considerations vary across regions.

Spring is the best time for land application to conserve the greatest amount of nutrients. Available nutrients are used during the cropping season. Nutrient losses are still possible, however, because the likelihood of wet field conditions may result in export by surface runoff or leaching. Spring applications result in less time for organic decomposition of manure (an issue for manure with a low percentage of moisture) and the release of some nutrients. Four main considerations often prevent manure application in the spring. First, a livestock producer might not have sufficient storage capacity for an entire year of manure and might be forced to apply at multiple times during the year. Second, time constraints and labor availability for farmers and applicators during the spring season make it difficult to complete manure application. Third, time constraints are complicated further if there are wet field conditions. Finally, applying manure in the spring creates a potential for greater soil compaction which can cause yield loss. Field equipment, such as heavy manure tanks, compacts the soil and can alter soil structure and reduce water movement. Tillage to break up this compaction is not a viable option in reduced-till cropping systems. Freezing and thawing cycles in winter months lessen the effect of compaction caused during fall application.

Conversely, fall application usually results in greater nutrient losses (25 to 50 percent total nitrogen loss) than spring application, especially when the manure is not incorporated into the soil (MWPS, 1993). These nitrogen losses are a result of ammonia volatilization and conversion to nitrate, which may be lost by denitrification and leaching. Fall applications allow soil microorganisms time to more fully decompose manure and release previously unavailable nutrients for the following cropping season. This is especially advantageous for solid manure, which contains high levels of organic matter. When temperatures are below 50 °F, microbial action of the soil slows and prevents nitrification, thereby immobilizing some of the nutrients. In the fall, manure is best applied to fields to be planted in winter grains or cover crops. If winter crops are not scheduled to be planted, manure should be applied to fields that require nutrients in the subsequent crop year or have the most existing vegetation or crop residues, or to sod fields to be plowed the next spring.

Summer application is suitable for small-grain stubble, noncrop fields, or little-used pastures. Manure can also be applied effectively to pure grass stands or to old legume-grass mixtures, but not on young stands of legume forage. Summer application allows a farmer or applicator to spread out the workload of a busy spring and fall.

Winter is the least desirable application time, for both nutrient utilization and pollution prevention. Late fall or winter applications might be desirable because of greater labor availability and better soil trafficability. Although there may be significant losses of available nitrogen, the organic nitrogen fraction will still contribute to the plant-available nitrogen pool. The potential for nutrient runoff is an environmental concern for applications that cannot be incorporated, especially during winter. Winter applications of manure should include working the manure into the soil either by tillage or by subsurface injection, thereby reducing runoff. In northern areas, frozen soil surfaces prevent rain and melting snow from carrying nutrients into the soil and make incorporation and injection impossible. Where daily winter spreading is necessary, manure should be applied first to fields that have the least runoff potential. Application on frozen or snow-covered ground should be avoided because of the possibility of runoff.

8.4.2 Application Methods

Manure can be handled as a liquid (less than 4 percent solids), semisolid or slurry (4 to 20 percent solids), or solid (greater than 20 percent solids). The amount of bedding and water dilution influence the form, as do the species and production phase of the animals. Consequently, the manure form dictates the way manure will be collected, stored, and finally applied to land (MWPS, 1993).

Liquid manure and slurry manure are applied using similar methods, but equipment needs for the two manure forms may vary depending on percentage of solids content. Chopper pumps may be necessary to reduce the particle size of bedding or feed. Agitation of liquid manure is extremely important prior to land application. Inadequate agitation results in inconsistent nutrient content and makes the manure difficult to credit as a valuable fertilizer source. A lack of uniform application can also lead to nutrient excesses and deficiencies, yield loss, and increased incidence of ground and surface water contamination. Furthermore, insufficient agitation can cause a buildup of solids in the storage tank and lead to decreased capacity. A disadvantage to liquid manure handling systems is that they may require the addition of water for collection of the manure, increasing the amount of material that must be handled and applied.

The liquid-based manure is applied to fields by means of tank wagons, drag-hose systems, or irrigation systems. Tank wagons can either broadcast manure (surface apply) or inject it into the soil. The method of injection, and the corresponding level of disturbance to the soil surface, is extremely variable. With the proper implement type, disruption to the soil surface and residue cover can be minimal and appropriate for reduced-tillage operations. Depending on the specific implement chosen, injection is the preferred method in reduced-till or no-till cropping systems.

Soil incorporation occurs immediately and crop residues are left on the surface to act as a mulch. The amount of exposed soil surface is minimized, resulting in reduced erosion. Injection systems can reduce odor by 20 to 90 percent (Hanna, 1998). There is less nutrient loss to air and diminished runoff as well. For injection, a liquid manure spreader or “umbilical” system and equipment to deposit manure below the soil surface are necessary. Injection requires more horsepower, fuel, and time than broadcasting. Liquid-based manure can also be pumped from a tanker or storage facility located adjacent to the field through a long flexible hose. This umbilical or drag-hose system is feasible for both broadcasting and injecting manure. Irrigation equipment applies liquid manure pumped directly from storage (usually lagoons). Wastewater and manure can be applied by means of sprinkler or surface (flood) irrigation.

Solid manure is broadcast using box-type or open-tank spreaders. Spreader mechanisms include paddles, flails, and augers. Rate calibration of box spreaders is often difficult, resulting in less uniform application, difficulty crediting fertilizer values, nutrient excesses and deficiencies resulting in yield loss, and increased potential for ground and surface water contamination.

Surface application, or broadcasting, is defined as the application of manure to land without incorporation. Simply applying manure to the soil surface can lead to losses of most of the available nitrogen, depending on soil temperature and moisture. Nitrogen is lost through volatilization of ammonia gas, denitrification of nitrates, and leaching. Volatilization losses are greatest with lower humidity and with increases in time, temperature, and wind speed. High-moisture conditions can carry water-soluble nitrates through the soil profile and out of the plant root zone, potentially causing ground water contamination. University extension services generally recommend a certain correction factor (Table 8-25). Environmental conditions such as temperature, wind, and humidity influence this factor. Generally, phosphorus and potassium losses are negligible, regardless of application method. However, some phosphorus and potassium is lost through soil erosion and runoff.

Table 8-25. Correction Factors to Account for Nitrogen Volatilization Losses During Land Application of Animal Manure

Application Method	Correction Factor
Direct injection	0.98
Broadcast and incorporation within 24 hours	0.95
Broadcast and incorporation after 24 hours	0.80
Broadcast liquid, no incorporation	0.75
Broadcast dry, no incorporation	0.70
Irrigation, no incorporation	0.60

Source: Adapted from Iowa State University Extension PM-1811, November 1999.

Solid and liquid manures can be incorporated into the soil by tillage in a row-crop system. Incorporation increases the amount of nitrogen available for crops by limiting volatilization, denitrification, and surface runoff. Incorporation also reduces odor and encourages mineralization of organic nitrogen by microbial action in the soil, thereby increasing the amount of nitrogen readily available to the plants. Although incorporation by tillage makes the nutrients less susceptible to runoff, the resulting reduction in crop residue can increase sediment runoff. If manure nutrients are to be fully used, incorporation should be performed within 12 to 24 hours of land application.

8.4.3 Manure Application Equipment

Livestock producers and custom manure applicators consider six predominant criteria when choosing an application system: (1) the amount of land to be covered/fertilized; (2) the amount of manure to be spread; (3) water content and consistency of the manure; (4) the frequency of application and importance of timeliness; (5) soil trafficability; and (6) distance between storage and the field to be treated. The fundamental classes of application equipment are solid waste spreaders, liquid waste tankers, umbilical systems, and liquid waste irrigation systems. Table 8-26 presents the advantages and disadvantages of the different application systems.

Table 8-26. Advantages and Disadvantages of Manure Application Equipment

Application Method	Description	Advantages	Disadvantages
Solid			
Box spreader	Common box spreader with aprons, paddles, or hydraulic push system. Depending on size, can be pulled by as small as a 15-hp tractor.	Equipment readily available. Mobile. Equipment relatively inexpensive. High solids content allows less total volume to be handled.	Limited capacity. High labor and time requirement. Fairly difficult to achieve uniform application. Significant nutrient loss and odor if not incorporated immediately. Moderate risk of soil compaction. Uneven applications when conditions are windy.
Flail spreader	V-bottom spreader with chains attached to a rotating shaft to sling the manure out of the top or side of the tank. Can be pulled by 30- to 90-hp tractor.	Wide, even application. Spreads solid, frozen, chunky, slurry, semisolid, or bedded manure. Low maintenance because of few moving parts.	Moderate risk of soil compaction. Higher cost and power requirements than box spreader. Significant nutrient loss and odor if not incorporated immediately. Uneven applications when conditions are windy.

Application Method	Description	Advantages	Disadvantages
Hopper spreader	V-bottom spreader with large auger across bottom of spreader. Manure spread by impeller on side.	Wide, even application.	Moderate risk of soil compaction. Higher cost and power requirements than box spreader. Significant nutrient loss and odor if not incorporated immediately. Uneven applications when conditions are windy.
Liquid (Broadcast)			
Tank spreader	Mounted tank shoots manure in widespread pattern. Can be on one side, both sides, or directly behind spreader. Also can have drop hoses. Spreading width of 15 to 25 feet. Capacity of 1,000 to 5,000 gallons.	Simple to manage. Less costly than injectors. Requires less horsepower than injectors.	Great nutrient loss and odor possibilities. Uneven applications when conditions are windy. Air contact results in some nutrient loss. High risk of soil compaction.
Tractor-pulled flexible hose (drag-hose)	Manure is pumped from the storage facility or tanker at the edge of the field through hose pulled by tractor. Tractor-mounted unit consists of pipe, nozzle, and deflector plate. Spread pattern similar to that of broadcast tank spreader.	Simple design. Relatively inexpensive. Low power required to pull hose. Low risk of soil compaction.	Great nutrient loss and odor possibilities. Uneven applications when conditions are windy. Air contact results in some nutrient loss. May be limited by distance from storage to fields and by terrain.
Liquid (Injection)			
Tank spreader	Front- or rear-mounted tank. Soil is opened and manure deposited below surface by variable methods. Capacity of 1,000 to 5,000 gallons.	Odor is minimized. Nutrients not lost to atmosphere. Nutrients can be placed near plant's root zone in a standing crop. Depending on implement type, soil surface and residue disturbed minimally.	Pulling injectors requires more horsepower. Operation difficult in stony soil. More expensive than broadcasting. High risk of soil compaction. Increased application time as compared with broadcasting.
Tractor-pulled flexible hose (drag-hose)	Manure is pumped from storage facility or tanker at the edge of the field through hose pulled by tractor and fed into injectors. Injectors must be lifted from ground to turn. Rigid, swinging pipe on equipment prevents hose damage by tractor. 150- to 200-hp tractor needed.	Odor controlled during spreading. Nitrogen retained. Requires less power than tanker injection systems. Low soil compaction risk.	Some manure may be spilled at end of runs. May be limited by distance from the storage to fields and by terrain. Increased application time as compared with broadcasting by drag-hose.
Irrigation			

Application Method	Description	Advantages	Disadvantages
Surface irrigation	Manure transported to application site through rigid irrigation pipes. Manure spread on field via gated pipes or open ditches.	Low initial investment. Low energy requirements. Little equipment needed. Little soil compaction. Few mechanical parts. Timely manure application.	Moderate labor requirement. High degree of management skill needed. Limited to slopes of less than 2%. May be limited by distance to field. High odor levels possible. Difficult to control runoff and achieve uniform application. Significant nutrient loss if not incorporated immediately.
Hand-moved sprinklers	Manure transported through rigid irrigation pipes, including a mainline and one or more aluminum pipe laterals. One parcel irrigated at a time. Pipe is disassembled and moved by hand to next parcel.	Low initial investment. Few mechanical parts. Low power requirement. Adapts to field shape. Little soil compaction. Timely manure application.	High labor requirement. Sprinklers can clog. Significant nutrient loss if not incorporated immediately. High odor levels possible. Uneven distribution in windy conditions.
Towline sprinklers	Manure transported through rigid irrigation pipes, including a mainline and one or more al uminum pipe laterals. One parcel irrigated at a time. Laterals are stronger and are moved using a tractor.	Low initial investment. Requires less labor than hand-move sprinklers. Few mechanical parts. Low power requirement. Little soil compaction. Timely manure application.	Not adaptable to irregular field shapes because of fixed laterals. Sprinklers can clog. Require tractor lanes for towing in tall crops. Significant nutrient loss if not incorporated immediately. High odor possible. Uneven distribution in windy conditions.
Stationary big gun	Manure transported through rigid irrigation pipes. Single large gun sprays manure in a circle. Must be moved by hand.	Moderate labor requirement. Few mechanical parts. Adaptable to irregular land area. Requires less pipe than small sprinklers. Big nozzle allows spreading of manures with more solids. Little soil compaction. Timely manure application.	Moderate to high initial investment. High power requirement. Uneven distribution in windy conditions. Significant nutrient loss if not incorporated immediately. High odor possible.
Towed big gun	Manure transported through rigid irrigation pipes. Functions like a towline system with the laterals replaced by a big gun.	Few mechanical parts. Requires less labor than hand-move or stationary gun systems. Requires less pipe than small sprinklers. Big nozzle allows spreading of manures with more solids. Little soil compaction. Timely manure application.	Moderate to high initial investment. High power requirement. Uneven distribution in windy conditions. Less adaptable to land area. Requires tractor driving lanes. Significant nutrient loss if not incorporated immediately. High odor possible.

Application Method	Description	Advantages	Disadvantages
Traveling gun	Manure transported through rigid irrigation pipes. Irrigation gun travels across field, spreading manure in semicircular pattern. Hard or soft hose types available. Soft hose system is less expensive.	Lowest labor requirement of all sprinkler systems. Big nozzle allows spreading of manures with more solids. Little soil compaction. Less energy required than tank spreader. Timely manure application.	High initial costs. May be limited by distance to field. Uniform application difficult in very windy conditions. Possibility of high odor levels. Significant nutrient loss if not incorporated immediately. Environmental damage likely if not supervised. High odor possible.

Sources: Adapted from MWPS, 1993, and Bartok, 1994.

Practice: Solid Manure Application with Spreaders

Description: Solid and semisolid manure can be applied to land using box, V-bottom, or flail spreaders. Spreaders are either tractor-pulled or mounted on trucks, depending on the load capacity. The manure is discharged from the rear, side, or bottom of the spreader with the aid of paddles, flails, chains, or augers (MWPS, 1993).

Application and Performance: Solid waste application methods are appropriate for manure containing 20 percent or more solids (MWPS, 1993). Spreaders are most appropriate for smaller operations with frequent manure removal from small areas (USDA NRCS, 1996a).

Advantages and Limitations: Spreaders are relatively inexpensive but have a limited load capacity. They require power to operate and, because of the open-air application method, often present odor problems during and after application. In addition, calibration can be difficult and create a problem with uniform application and nutrient crediting. Most spreaders must be filled using a tractor front-end loader. Smaller spreaders require a greater time investment because of the number of return trips to the manure source for refilling. Increasing spreader capacity reduces the time investment but increases the risk of soil compaction. V-box bottom spreaders can achieve a more uniform application than box spreaders but require more power and investment.

Operational Factors: Spreaders are constructed of treated wood or steel and include a plastic or fiberglass interior lining to assist with loading and unloading. The spreaders can rot or rust, depending on the construction material, and tractor front-end loaders can damage the spreader and lining during loading. To prevent deterioration and damage, operators should load the spreader carefully, clean and lubricate it regularly, and protect it from the weather.

Demonstration Status: Of grower-finisher swine operations that dispose of waste on owned or rented land, 57.8 percent use broadcast/solid spreader methods. Only 13.7 percent of large grower-finisher operations (marketing more than 10,000 head) use broadcast/solid spreader methods (USDA APHIS, 1996a).

On dairy farms with fewer than 100 milk cows, 90.6 percent broadcast manure with a solid spreader. As herd size increases, solid handling is less common. Solid handling is most common in the northeastern and midwestern areas of the United States (USDA APHIS, 1997).

Fewer than 1 in 7 producers with fewer than 100 milk cows incorporates manure into soil within 24 hours of application. This ratio increases with herd size to more than one-third of producers with more than 500 cows incorporating manure into the soil in less than 24 hours (USDA APHIS, 1997).

Practice: Liquid Manure Application With Tankers

Description: Manure is applied to the soil surface or injected into the soil using spreader pump tankers or vacuum tankers. The spreader pump tanker is composed of a tank and pump mounted on a truck or wagon and requires a separate pump to load the manure. The vacuum tanker is mounted in a similar fashion but includes a pump that both loads and unloads the manure. Tankers usually include an agitating device (either auger or pump type) to keep solids suspended. Chopper pumps may be needed to prevent malfunctions caused by clogging with manure solids or fibrous material. A gated opening at the rear bottom of the tank either discharges the manure into a spinner for broadcasting or directs it through hoses to an injection device.

Application and Performance: Tankers are used for spreading slurry and liquid manure with less than 10 percent solids. Tankers are appropriate for moderate- to large-sized operations. Thorough agitation prior to and during tanker loading is necessary to limit inconsistency of manure.

Tankers using injection systems can decrease runoff by causing minimal soil surface disturbance and maintaining a residue cover.

Advantages and Limitations: Broadcast tankers use less power and are less expensive than injector tankers but result in greater nutrient loss and odor problems. Tankers with injector systems decrease the loss of nitrogen and odorous gases to the atmosphere and place nutrients near the plant's root zone where they are needed; furthermore, depending on the specific injector system, there is a significant decrease in disturbance to the soil surface and residue, limiting the potential for erosion. The weight of both types of tanker spreaders can cause soil compaction.

Operational Factors: Tankers must be cleaned and repaired regularly and should be protected from the weather. Vacuum pumps, moisture traps, pipe couplers, tires, and power shafts must be maintained regularly. Sand, often used in dairy freestall barns, can cause damage to the pumps. A vacuum tanker used for swine manure typically lasts 10 years (USDA NRCS, 1996a).

Demonstration Status: Slurry surface application is practiced at 46.0 percent of all grower-finisher operations that apply wastes to land, while subsurface injection of slurry is practiced at 21.9 percent of these operations (USDA APHIS, 1996a).

Slurry surface application is practiced at 44.6 percent of dairy farms having more than 200 milk cows. Subsurface slurry application is practiced at only 8.6 percent of dairy operations of the same size (USDA APHIS, 1997).

Practice: Liquid Manure Application With a Drag-Hose System

Description: The drag-hose system pumps manure from the manure storage tank, or from a portable tank adjacent to the field, through a supply line that can be up to 3 miles long. The supply line attaches to a flexible hose that is pulled across the field by a tractor. Manure is fed through the hose to applicator implements similar to the types found on tankers. The manure can be broadcast or injected.

Application and Performance: Drag-hose systems are used for spreading slurry and liquid manure with less than 10 percent solids. They are appropriate for moderate- to large-sized operations. Up to 40 acres of a field can be covered before the hoses must be repositioned. Thorough agitation prior to and during pumping is necessary to limit inconsistency of manure.

Use of certain injection systems can decrease runoff and erosion by causing minimal soil surface disturbance and maintaining residue cover.

Advantages and Limitations: The drag-hose system eliminates the need for repeated trips with a wagon or tanker to the manure storage site. It takes more initial setup time, but overall it has a smaller fuel and labor requirement than other spreader systems. Another benefit is decreased soil compaction and decreased road traffic. The weight of the liquid-based manure is dispersed over a much greater surface area and there is less equipment weight.

The person using a drag-hose system must be careful to not cut the line or break the umbilical cord during manure application.

For application rates under or around 2,000 gallons per acre, a drag-hose may not be practical because a certain amount of pressure is needed to keep the hose from collapsing.

Operational Factors: The application of drag-hose systems is limited by the distance the supply lines can travel, as well as by terrain.

Demonstration Status: Drag-hose systems are becoming increasingly popular as consolidation takes place in livestock production. It should be noted that the demonstration figures given in the tanker section also pertain to and include swine and dairy operations using the drag-hose system for slurry application.

Practice: Liquid Waste Application by Irrigation

Description: Irrigation systems use pipes to transfer liquid manure and wastewater from the containment facility (usually a lagoon) to the field. Wastewater can be transferred to the field through portable or stationary pipes or through an open ditch with siphon tubes or gated pipe. Manure is applied to the land using either a sprinkler or surface irrigation system.

Sprinkler systems most often used for manure disposal include handmove sprinklers, towlines, and big guns (MWPS, 1993). Surface irrigation systems include border, furrow, corrugation, flood, and gated pipe irrigation (MWPS, 1993). Descriptions of individual irrigation systems are included in Table 8-26.

Application and Performance: Irrigation systems are increasingly used by hog operations that spread over a million gallons of wastewater per year (USDA NRCS, 1996a). Most irrigation systems can handle manure that contains up to 4 percent solids (MWPS, 1993). Solid separation practices may be necessary to achieve this level.

Irrigation system selection varies according to the percentage of solids present in the manure, the size of the operation, the labor and initial investment available, field topography, and crop height.

Advantages and Limitations: Irrigation systems minimize soil compaction, labor costs, and equipment needed for large operations, and they spread the manure more quickly than tank spreaders. Also, irrigation makes it possible to move large quantities of manure in a short time period. Finally, irrigation systems can be used to transport water during dry periods, and they are especially effective if crop irrigation systems are already in place.

However, nitrogen is easily lost to volatilization and denitrification if not incorporated into the soil. Odor from the wastewater can create a nuisance. Other problems that might alter the viability of the irrigation system include windy conditions that reduce the uniformity of spreading and increase odor problems off-site, the fact that soils might not be permeable enough to absorb the rapidly applied liquid, and a crop height that prevents application (MWPS, 1993; USDA NRCS, 1996a).

Although irrigation systems can reduce the overall labor cost of large spreading operations, labor communication and coordination are needed for initiating, maintaining, and ceasing an irrigation cycle. System operators must agitate manure before and during pumping to keep solids in suspension. Surface irrigation application must be closely monitored to control runoff and application uniformity. Pipes must be flushed with clean water after manure is applied to prevent clogs. Irrigation pipes are susceptible to breakage and should be regularly inspected.

Operational Factors: Single-nozzle sprinklers perform better where wind is a problem. Also, one large nozzle is less likely to plug than two smaller nozzles with the same flow capacity.

Demonstration Status: Irrigation of swine wastewater is practiced at 12.8 percent of grower-finisher operations which dispose of their waste on owned or rented land. Nearly 80 percent of grower-finisher operations with more than 10,000 head use irrigation for land application of manure.

Land application of wastewater by irrigation is also common at large dairy operations; 40.5 percent of producers with more than 200 cows used irrigation for manure application.

Practice: Center Pivot Irrigation

Description: Center pivots are a method of precisely irrigating virtually any type of crop (with the exception of trees) over large areas of land. In a center pivot, an electrically driven lateral assembly extends from a center point where the water is delivered, and the lateral circles around this point, spraying water. A center pivot generally uses 100 to more than 150 pounds of pressure per square inch (psi) to operate and therefore requires a 30- to 75-horsepower motor.

The center pivot system is constructed mainly of aluminum or galvanized steel and consists of the following main components:

> Pivot: The central point of the system around which the lateral assembly rotates. The pivot is positioned on a concrete anchor and contains various controls for operating the system, including timing and flow rate. Wastewater from a lagoon, pond, or other storage structure is pumped to the pivot as the initial step in applying the waste to the land.
>
> Lateral: A pipe and sprinklers that distribute the wastewater across the site as it moves around the pivot, typically 6 to 10 feet above the ground surface. The lateral extends out from the pivot and may consist of one or more spans depending on the site characteristics. A typical span may be from 80 to 250 feet long, whereas the entire lateral may be as long as 2,600 feet.
>
> Tower: A structure located at the end point of each span that provides support for the pipe. Each tower is on wheels and is propelled by either an electrically driven motor, a hydraulic drive wheel, or liquid pressure, which makes it possible for the entire lateral to move slowly around the pivot.

The center pivot is designed specifically for each facility, based on wastewater volume and characteristics, as well as site characteristics such as soil type, parcel geometry, and slope. The soil type (i.e., its permeability and infiltration rate) affects the selection of the water spraying pattern. The soil composition (e.g., porous, tightly packed) affects tire size selection as to whether it allows good traction and flotation. Overall site geometry dictates the location and layout of the pivots, the length of the laterals, and the length and number of spans and towers. Center pivots can be designed for sites with slopes of up to approximately 15 percent, although this depends on the type of crop cover and methods used to alleviate runoff. Figure 8-15 presents a schematic of a central pivot irrigation system.

Application and Performance: Using a center pivot, nutrients in the wastewater, such as nitrogen and phosphorus, can be efficiently applied to the cropland to meet crop needs. With a known nutrient concentration in the wastewater, the animal waste can be agronomically applied to cropland very precisely by appropriately metering the flow based on crop uptake values. Agronomic application helps reduce runoff of pollutants from cropland and overapplication of nutrients to the soil.

Center pivot irrigation does not provide wastewater treatment. Nutrients, pathogens, and other pollutants simply pass through and are distributed by the center pivot.

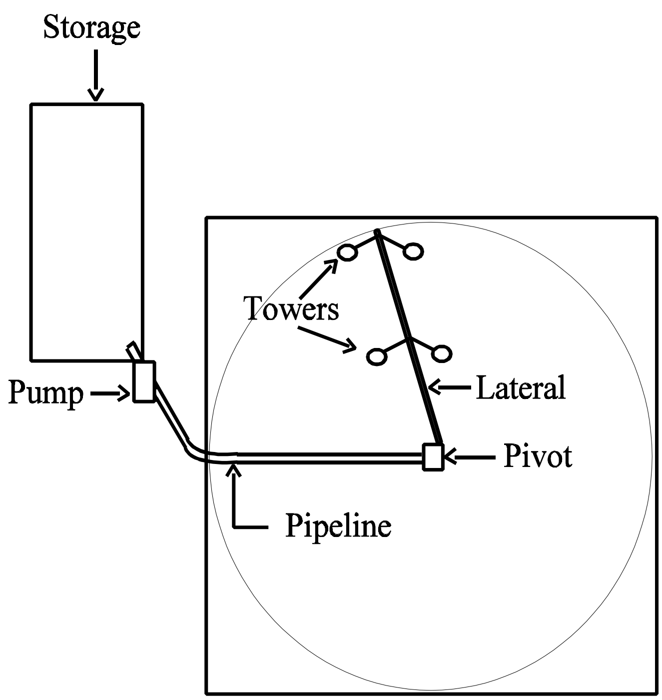


Figure 8-15. Schematic of a Center Pivot Irrigation System

Operational Factors: According to one manufacturer (Valley Industries), center pivot systems can be designed to handle wastes containing up to 5 percent solids. Thus, it may be necessary to have a solids removal step (e.g., settling basin or mechanical separator) prior to wastewater storage and subsequent land application. It is also a good practice to flush the pipes with clean water following waste application to prevent clogging of pipes and sprinkler nozzles.

Salt accumulation in the soil may be an issue, especially in drier climates. Salt concentrations in the wastewater and soil should be monitored to determine if salinity is a problem at a particular site.

Odor may also be a problem when using a center pivot to apply liquid animal wastewater to the land. However, techniques can be implemented to reduce the dispersion of the waste stream into the wind, such as positioning the sprinklers closer to the ground, using low trajectory sprinklers, and using low pressure sprinklers. Proper timing of application based on environmental conditions (i.e, monitoring wind velocity and direction) can also help reduce odor problems.

Application efficiency (i.e., the percentage of the total water pumped that reaches the ground or plant surface) depends primarily on climatic factors such as ambient temperature, relative humidity, and wind velocity and direction. A typical application efficiency is about 90 percent, provided that at least 1 inch of water is applied.

Advantages and Limitations: As noted above, a center pivot is an effective means of distributing liquid animal waste and supplying nutrients to cropland at agronomic rates. The center pivot design is fairly flexible and can be adapted to a wide range of site and wastewater characteristics. Center pivots are also advantageous because they can distribute the wastewater quickly, uniformly, and with minimal soil compaction. Center pivots have low operating labor costs compared with manual application methods.

One limitation of a center pivot system is the relatively high capital investment it entails. Other limitations may result from sloped lands, high solids content of waste, and potential odor problems. Center pivots are also vulnerable to high winds and lightning. Additionally, swine waste is fairly corrosive so the waste either needs to be treated to reduce its corrosivity or system components such as piping need to be corrosion-resistant (e.g., galvanized or lined pipe). Another concern with center pivot spraying is nitrogen loss through volatilization, which is estimated to be as high as 25 percent (USDA NRCS, 1996a).

Demonstration Status: Center pivots have been in operation in the United States since the 1950s. In the 1970s, center pivots started to become popular as a means of land-applying wastewater from municipal, industrial, and agricultural sources. Today, center pivots are widely used in agriculture, including land application of wastewater from swine, beef, and dairy facilities.

Practice: Calibration of Application Equipment

Description: Three conditions must be addressed to ensure that application rates are accurate (Schmitt and Rehm, 1998). First, analysis of a properly collected manure sample is needed to quantify nutrient content. Second, the rate of manure being applied to the field must be known and kept constant; calibration must be conducted for all manure applications. Third, the application or spread pattern of the manure must be uniform throughout the field.

Manure spreaders can discharge manure at varying rates, depending on forward travel speed, power take-off speed, gear box settings, discharge opening, width of spread, overlap patterns, and other parameters (USDA NRCS, 1996a). Calibration defines the combination of settings and travel speed needed to apply manure at a desired rate.

The actual rate at which a spreader applies manure will differ from the manufacturer's estimates, so calibration is necessary to ensure accurate manure application (Hirschi et al., 1997). Two basic methods, the load-area method and weight-area method, can be used for calibration (USDA NRCS, 1996a). In the load-area method, the amount of manure in a loaded spreader is measured and the rate is determined based on the number of loads needed to cover a known area of land. In the weight-area method, manure spread over a small surface is weighed, and the weight per unit area is calculated. Although there are only two basic calibration methods, a variety of specific calibration procedures are available, many of which require knowledge of the tank's or spreader's load size (Hirschi et al., 1997).

For solid systems, the spreader can be weighed before and after going to the field to determine the weight of manure spread (Schmitt and Rehm, 1998). Using the width of the spread manure and the distance traveled per load, the weight of manure applied per acre can be calculated. Alternatively, the rate per acre can be estimated using the weight of a full load as determined with a scale, the number of loads per field, and the field acreage. A third method is to lay a tarp or sheet of strong plastic in a field and make a pass over it with the spreader. The manure deposited on the tarp or sheet of plastic is then collected and weighed. Using the area of the tarp or plastic sheet, the weight of manure applied per unit area can be determined. Because of the small area involved in this method, there is high variability, so multiple samples should be collected. Knowledge of the variability in application rate, however, is useful information when one considers that uniform application is desired.

For liquid systems, calibration requires that the manure be measured in gallons per acre. The best way to determine the volume applied is to weigh the tank before and after spreading the manure and then to divide by the density of liquid manure (8.3 lb/gallon) (Schmitt and Rehm, 1998). Combining this information with the width of the spread pattern and the distance the tank travels before emptying the tank will provide the data necessary to determine the application rate. A second option for liquid systems that does not involve a scale is to fill the tank, count the number of loads applied uniformly per unit area of field, and then calculate the volume per acre using the known volume of a filled tank.

Manure application rates must often be adjusted to match the recommended rate (Schmitt and Rehm, 1998). The most common method of changing the application rate is to change the speed at which the spreader is driven across the field. Solid manure equipment may also have an adjustment that changes the chain speed in the box, thereby changing the application rate. Liquid manure application equipment may have valve opening adjustments to alter the rate. Because the flow rate may change from the beginning to the end of a tank of liquid manure, some equipment uses pressurized tanks, flow pumps, and newer distributor designs to address the problem of variable flow. Once equipment is adjusted or driving rates are changed to achieve new application rates, recalibration is necessary to maintain the accuracy in calculating application rates.

A wide range of water measurement devices is available, including some that primarily measure rate or volume of flow and some that primarily measure rate of flow (USDA NRCS, 1997). A suitable measuring device, calibrated in the laboratory or field, can be used to determine total application volume, which, combined with the measured nutrient concentration in the applied liquid, can be used to determine the quantity of nutrients applied to the receiving land. Dividing the quantity of nutrients by the land acreage provides the nutrient application rate. Rain gauges can be used in the field to check the uniformity of application of sprinkler systems.

Application and Performance: Calibration is a practice that applies to all farms and all land on which manure is applied, and it can be performed by the producer with little training.

Calibration of manure application equipment provides no direct treatment or reduction of any pollutants, but it is essential to accurate application of manure.

Advantages and Limitations: Calibrating manure applicators helps to ensure that applications are adequate for crop needs, but not excessive and a source of water quality problems (USDA NRCS, 1995).

Calibration of spreaders should take less than 1 hour (Hirschi et al., 1997).

Operational Factors: Agitation of liquid manure is extremely important prior to land application. Inadequate agitation results in inconsistent nutrient content and makes the manure difficult to credit accurately as a valuable fertilizer source. A lack of uniform application can also lead to nutrient excesses and deficiencies, yield loss, and increased incidence of ground and surface water contamination.

Solid manure is broadcast using box-type or open-tank spreaders. Spreader mechanisms include paddles, flails, and augers. Rate calibration of box spreaders is often difficult, resulting in less uniform application, difficulty crediting fertilizer values, nutrient excesses and deficiencies resulting in yield loss, and increased potential for ground and surface water contamination.

Windy conditions can affect the uniformity of applications with sprinklers. System operators must agitate manure before and during pumping to keep solids in suspension. Surface irrigation application must be closely monitored to control runoff and application uniformity.

Demonstration Status: Calibration of manure spreaders is a topic that has been addressed in technical guidance and extension service publications across the United States. Information regarding the extent to which farmers calibrate manure applicators was not found, but information regarding the extent to which manure is sampled is probably indicative of the maximum extent to which calibration is practiced.

Manure sampling is practiced widely across the United States, but many farmers still do not test manure or employ a nitrogen credit from manure when determining commercial fertilizer needs (Stevenson, 1995). A 1995 survey of 1,477 swine producers showed that 92 percent of operations had not had their manure tested for nutrients within the past 12 months (USDA NAHMS, 1999). Approximately 6 percent had tested their manure for nutrients once during the past 12 months, while another 1.5 percent had tested it twice. These findings are supported by a crop nutrient management survey in which only 2 to 17 percent of respondents in various regions stated that they factored manure nutrient value into their nutrient management plans (Marketing Directions, 1998).

Practice: Transportation of Waste Off Site

Description: Animals at an animal feeding operation generate a large amount of liquid and semi-solid waste every day. This waste is rich in nutrients and can be applied to cropland as fertilizer. Often, there are more nutrients present in the waste than can be used by the crops on site. In this case, or in the case where the operation has no cropland, the waste must be transported off site to a facility that can manage the waste properly.

Application and Performance: At an agronomic application rate, some facilities will be able to apply all produced animal waste to on-site cropland. However, some animal feeding operations do not have sufficient land to accommodate all of the waste on site. These facilities must transport the waste off site using farm equipment or by hiring a contractor to haul the waste away. Hiring a contractor is a viable option for operations that do not have the capital to purchase their own trucks to haul excess waste.

Transportation does not "treat" the waste; however, it does move the waste off the farm. By transporting the waste off site, the operation prevents potential pollution by limiting the time that waste remains on the feedlot, and thereby reduces the likelihood of nutrients, pathogens, and other pollutants being carried from the stockpile by rainfall, runoff, seepage, or volatilization.

The cost of transporting waste off site is determined by the quantity and consistency of the waste as well as the distance the waste must be transported to be managed properly. Semisolid or liquid manure can be more expensive to haul because it requires a tanker truck for transport and is heavier due to a higher moisture content. Solid waste is easier to handle and is therefore less expensive to transport. Because the amount of manure transported off site is dictated by the amount that is applied to on-site cropland, it is expected that facilities will apply semisolid waste to fields before they apply solid waste. The distance manure must be hauled to be properly managed depends on the proximity of crops that need additional nutrients.

Advantages and Limitations: One advantage of transportation as a waste management practice is not having to treat and dispose of the waste on site. Excess waste at one operation can be transported to and used as fertilizer at another operation, distributing the nutrient load among cropland at multiple facilities. In addition, in some cases the operation owner is able to sell the waste to a compost or fertilizer facility or another farm operation. This income can potentially offset the cost of the transportation.

It is important to consider the potential non-water-quality impacts that result from increased diesel truck traffic. EPA assumes that some facilities do not currently apply at agronomic rates, and therefore, there will be an increase in excess waste once operations begin applying agronomically. This increase in excess waste requires an increase in truck traffic, causing an increase in exhaust emissions from the trucks transporting the waste.

Operational Factors: There are three operational factors considered in determining transportation practices: the amount of waste to be transported, type of waste to be transported (semisolid or liquid), and the distance from the operation to the off-site destination. The amount of waste to be transported per year determines the size of the trucks that are required and the time that is spent hauling the waste. The consistency of the waste determines the type of truck that is used and the cost of handling that waste. The distance of the off-site facility from the operation determines how far the waste must be hauled and the cost of transporting the waste. The regional location of the operation also plays a role in determining how frequently the waste needs to be transported (e.g., if there are seasons in which the waste is not applied, due to climate or crop cycles).

Demonstration Status: It is not known what portion of animal feeding operations have their waste hauled by contractors and what portion opt to own and operate their own vehicles. It is assumed that each operation chooses the most economically beneficial option, which in most cases is to contract-haul the waste off site.

Beef: Eleven percent of beef feedlots across the country currently sell excess manure waste, and 27 percent give away their manure waste. Approximately 3 percent of beef operations currently pay to have manure waste hauled off site (USDA APHIS, 2000).

Dairy: In 1997, 23 percent of dairies with more than 200 head give away some portion of their manure waste, and 18 percent sold or received compensation for their manure waste (USDA APHIS, 1997).

Poultry: Most poultry operations are currently transporting their waste off site. Nationwide, broiler operations transport about 95 percent of their waste. The percentage of layer operations transporting waste varies by region: 40 percent in the Central region, 100 percent in the Midwest region, 75 percent in the Mid-Atlantic region, 95 percent in the Pacific region, and 50 percent in the South region (USDA NAHMS, 2000).

Swine: Four to six percent of swine operations currently transfer some manure off site (USDA APHIS 1995), while 23 percent of small swine operations and 54 percent of large swine operations do not have enough land to apply agronomically under an N-based application scenario (Kellogg et al., 2000).

8.4.4 Runoff Control

Fields to which manure is to be applied should have an appropriate conservation management system in place to prevent nutrients from leaving the landscape. In the event of mismanaged manure application, such as applying manure prior to an unexpected rainfall, conservation practices that reduce soil erosion and water runoff, including grassed waterways, sediment basins, and buffers, can help to minimize the transport of nutrients off-site.

Susceptibility to erosion and the rate at which it occurs depend on land use, geology, geomorphology, climate, soil texture, soil structure, and the nature and density of vegetation in the area. Soil erosion can be caused by wind or water and involves the detachment of soil particles, their transport, and their eventual deposition away from their original position. Movement of soil by water occurs in three stages: (1) soil particles, or aggregates, are detached from the soil surface when raindrops splash onto the soil surface or are broken loose by fast-moving water; (2) the detached particles are removed or transported by moving water; and (3) the soil particles fall out of suspension when the water velocity slows, and are deposited as sediment at a new site.

Soil erosion caused by water is generally recognized in four different forms: sheet erosion, rill erosion, ephemeral erosion, and gully erosion. Erosion occurs during or immediately after rainstorms or snowmelt. Sheet erosion is the loss of a uniform, thin layer of soil by raindrop splash or water runoff. The thin layer of topsoil, about the thickness of a dime, disappears gradually, making soil loss visibly imperceptible until numerous layers are lost.

Rill erosion often occurs in conjunction with sheet erosion and is a process in which numerous channels, a few inches deep, are formed by fast-flowing surface water. The detachment of soil particles results from the shear stress that water exerts on the soil. The shear stress is related to the velocity of water flow. Therefore, when water gains velocity on steeper and longer slopes, rill erosion increases. Sheet and rill erosion carry mostly fine-textured small particles and aggregates. Fine-textured particles contain the bulk of plant-available nutrients, pesticides, and other absorbed pollutants because there is more surface area per given volume of soil.

Ephemeral erosion occurs when concentrated water flows through depressions or drainage areas. The water forms shallow channels that can be erased by tillage practices. Ephemeral erosion is a precursor to gully erosion if left untreated.

Once rills become large enough to restrict vehicular access, they are referred to as gullies. Gully erosion results from the removal of vast amounts of topsoil and subsoil by fast-flowing surface water through depressions or drainage areas. Gully erosion detaches and transports soil particles that are the size of fine to medium sand. These larger soil particles often contain a much lower proportion of absorbed nutrients, organic material, and pollutants than the fine-textured soil particles from sheet and rill erosion.

It is not practical to prevent all erosion, but the preferred strategy is to reduce erosion losses to tolerable rates. In general terms, tolerable soil loss, sometimes referred to as T, is the maximum rate of soil erosion that can occur while still maintaining long-term soil productivity. These tolerable soil loss levels determined by USDA NRCS are based on soil depth and texture, parent material, productivity, and previous erosion rates. The levels range from 1 to 5 tons/acre/year (2 to 11 metric tons/hectare/year). The strategies for controlling erosion involve reducing soil detachment and reducing sediment transport.

Surface water runoff contains pollutants, including nutrients (e.g., nitrogen and phosphorous) and some pathogens. Excessive manure application can cause increased nitrate concentration in water. If the rate of manure application exceeds plant or crop nitrogen needs, nitrates may leach through the soil and into ground water. Nitrates in drinking water are the cause of methemoglobinemia ("blue baby syndrome").

Agricultural nonpoint source pollutants, such as those contained in manure, can migrate off the field and into surface water through soil erosion. Excessive nutrients attached to the sediment and carried into surface water bodies can cause algae blooms, fish kills, and odors. Combinations of BMPs can be used to protect surface water by reducing the amount of nutrient-rich sediment that is detached and transported away from a field.

A BMP is a practical, affordable strategy for conserving soil and water resources without sacrificing profitability. BMPs that reduce soil erosion are part of a broader integrated soil management system that improves overall soil health and water quality. In addition, BMPs benefit crop production in a variety of ways, such as improved drainage, improved moisture-holding capacity, pest management, and ultimately, long-term profitability.

Runoff Control Practices

Livestock manure can be a resource if managed correctly. A large proportion of livestock manure is returned to the land as organic fertilizer. Unfortunately, if manure is handled incorrectly, it can become a source of pollution that ends up in streams or lakes. The nutrients in animal manure, especially phosphorus and nitrogen, can cause eutrophication of water.

Eutrophication is a natural process that takes place in all surface water bodies. The natural process is accelerated by increased sediment and nutrient loading in the water. It is characterized by an aquatic environment rich in nutrients and prolific plant production (algae). As a result of nutrient enrichment, the biomass of the water body increases and eventually produces a noxious environment that accelerates algae growth, leading to a reduction in water quality.

The transport of manure nutrients to streams and lakes is very similar to the transport of nutrients from commercial fertilizers. Nitrogen is water-soluble and moves largely with the flow of water. Injecting or incorporating manure into the land however, significantly reduces the amount of nitrogen transported with runoff. Yet nitrogen can still move with ground water or subsurface water flow.

Reducing phosphorous levels in surface water is the best way to limit algae growth. Most of the phosphorous transported by surface water is attached to sediment particles. Therefore, reducing soil erosion is essential to protecting water quality.

Manure from properly managed grazing animals has little detrimental effect on water quality. In a grazing system, 100 percent of the manure generated by the grazing animal is applied to the land daily. In addition, the runoff from a well-managed grazing system carries very little sediment or nutrients; however, manure from feedlots or overgrazed pastures is more susceptible to runoff and sediment delivery (Hatfield, 1998).

Practices to Reduce Soil Detachment

The most effective strategy for keeping soil on the field is to reduce soil detachment. Crop canopy and crop residue on the soil surface protect against soil detachment by intercepting falling raindrops and dissipating their energy. In addition, a layer of plant material on the ground creates a thick layer of still air next to the soil to buffer against wind erosion. Keeping sufficient cover on the soil is therefore a key factor to controlling both wind and soil erosion.

Conservation practices, such as no-tillage, preserve or increase organic matter and soil structure. No-tillage reduces soil detachment and transport and results in improved water infiltration and surface stability. No-tillage also increases the size of soil aggregates, thereby reducing the potential of wind to detach soil particles.

Combinations of the following practices can be used to effectively reduce soil detachment by wind or water erosion:

- Conservation tillage (including mulch-tillage, no-tillage, strip-tillage, and ridge-tillage)
- Cover crops
- Contour stripcropping/contour buffer strips
- Crosswind trap strips
- Crosswind ridges
- Crosswind stripcropping
- Crop rotation, including small grains, grasses, and forage legumes
- Chemical fallow or no fallow
- Grassed waterways
- Pasture management
- Shelterbelts/field windbreaks

Practices to Reduce Transport Within the Field

Sediment transport can be reduced in several ways, including the use of vegetative cover, crop residue, and barriers. Vegetation slows runoff, increases infiltration, reduces wind velocity, and traps sediment. Strips of permanent vegetation (e.g., contour strip cropping and contour grass strips) slow runoff and trap sediment. Contour farming creates rough surfaces that slow surface water velocity and reduce transport of sediment.

Reductions in slope length and steepness reduce sediment-carrying capacity by slowing velocity. Terraces and diversions are common barrier techniques that reduce slope length and slow, or stop, surface runoff.

By decreasing the distance across a field that is unsheltered from wind, or by creating soil ridges and other barriers, sediment transport by wind can be reduced.

Combinations of the following practices can be used to effectively reduce soil transport by wind or water erosion:

- Buffers
  - Shelterbelts/field windbreaks
  - Contour strip cropping/contour buffer strips
  - Riparian buffers
  - Filter strips
  - Grassed waterways
  - Field borders
  - Crosswind trap strips
  - Contour or cross slope farming
- Conservation tillage, (including mulch-tillage, no-tillage, strip-tillage, and ridge-tillage)
- Crop rotation including grains, grasses and forage legumes
- Chemical fallow or no fallow
- Cover crops
- Crosswind ridges
- Crosswind stripcropping
- Diversions
- Ponds
- Sediment basins
- Terraces

Practices to Trap Sediment Below the Field or Critical Area

Practices are also typically needed to trap sediment leaving the field before it reaches a wetland or riparian area. Deposition of sediment is achieved by practices that slow water velocity and increase infiltration. Combinations of the following practices can be used to effectively trap sediment below the field or critical area:

- Contour strip cropping/contour buffer strips
- Crosswind traps strips
- Crosswind stripcropping
- Diversions
- Filter strips
- Grassed waterways
- Ponds
- Riparian buffers
- Sediment basins

- Shelterbelts/field windbreaks
- Terraces
- Wetlands

Practices That Have Multiple Functions to Reduce Detachment, Transport, and Sediment Delivery

Many conservation practices have multiple functions. Table 8-27 identifies the primary functions of each practice.

Considerations in BMP Selection

The selection of the most effective BMPs to protect water quality depends on the objectives of the farmer and the specific site conditions of individual fields. The best combination of BMPs for any specific field depends on factors such as the following:

- Rainfall—more rainfall means more erosion potential.
- Soil type—some soils erode more easily than others.
- Length of slope—a longer slope has increased potential for erosion due to increased runoff energy.
- Steepness of slope—steep slopes erode more easily than gradual slopes.
- Ground cover—the more the soil is covered with protective grasses, legumes, or crop residues, the better the erosion control.

Other factors to consider include:

- Type of farm operation
- Size of the field or farm
- Nutrient levels of manure
- Nutrient requirements of crops
- Proximity to a waterway (stream, lake), water source (drinking water well), or water of the state
- Relationship of one erosion control practice to other supporting conservation practices
- Conservation plan if required by USDA NRCS
- Economic feasibility

Table 8-27. Primary Functions of Soil Conservation Practices

Conservation Practice	Detachment	Transport	Sedimentation
Chemical fallow or no fallow	O	O	
Conservation Tillage (mulch-till, ridge-till, strip-till, and no-till)	X / O	X / O	
Contour or Cross Slope		X	
Contour Stripcropping/Contour Buffer Strips	X	X	X
Cover Crops	X	X	
Crop Rotation, including small grains, grasses, and forage legumes	X	X	
Crosswind Trap Strips	O	O	O
Crosswind Ridges	O	O	
Crosswind Stripcropping	O	O	O
Diversions		X	X
Field Borders		X	
Filter Strips		X	X
Grassed Waterways	X	X	X
Ponds		X	X
Riparian Buffers		X	X
Sediment Basins		X	X
Shelterbelts/Field Windbreaks	O	O	O
Terraces		X	X
Wetlands			X

Note: X = water erosion; O = wind erosion

Agricultural nonpoint source runoff management practices that protect natural resources generally have two principal goals: (1) to reduce runoff volume and (2) to contain and treat agricultural runoff. An effective runoff control system meets both of these goals by integrating several practices in a way that meets the needs of the particular management system. Strategies for controlling erosion involve reducing soil detachment, reducing sediment transport, and trapping sediment before it reaches a water body.

Soil erosion can be reduced by using a single conservation practice or a combination of practices. The following section explains conservation practices that can be used separately or in combination to reduce manure runoff and improve water quality.

Practice: Crop Residue Management

Description: Tillage operations influence the amount and distribution of plant residues on or near the soil surface. In the past, the preferred system, conventional tillage, was designed to bury as much residue and leave the soil surface as smooth as possible, which unfortunately led to significant soil erosion. In contrast, residue management systems are designed to leave residue on top of the soil surface to increase infiltration and reduce erosion. In general, the more residue left on the soil surface, the more protection from erosion the soil has. The amount of crop residue left after planting depends on the original amount of residue available, the tillage implements used, the number of tillage passes, and the depth and speed at which tillage was performed.

Crop residue management has been designated by many terms since its inception. The Natural Resources Conservation Service (NRCS) and the Conservation Technology Information Center (CTIC) have adopted the following terms and definitions.

- Conventional-till: Tillage types that leave less than 15 percent residue cover after planting. Generally this involves plowing or intensive (numerous) tillage trips.

- Reduced-till: Tillage types that leave 15 to 30 percent residue cover after planting.

- Conservation tillage: Any tillage and planting system that leaves 30 percent, or more, of the ground covered after planting with the previous year's crop residues. Conservation tillage systems include mulch-till, no-till, strip-till, and ridge-till.

    - Mulch-till: Full-width tillage that disturbs the entire soil surface is performed prior to and during planting. Tillage tools such as chisels, field cultivators, discs, sweeps, or bands are used. Weed control is accomplished with herbicides and/or cultivation.

    - No-till and strip-till: The soil is left undisturbed from harvest to planting except strips up to one-third of the row width (strips may involve only residue disturbance or may include soil disturbance). Planting or drilling is accomplished using disc openers, coulter(s), row cleaners, in-row chisels, or roto-tillers. Weeds are controlled primarily with herbicides. Cultivation may be used for emergency weed control. Other common terms used to describe no-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

    - Ridge-till: The soil is left undisturbed from harvest to planting except for strips up to one-third of the row width. Planting is completed on the ridge and usually involves the removal of the top of the ridge. Planting is completed with sweeps, disc openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weeds are controlled with herbicides (frequently banded) and/or cultivation. Ridges are rebuilt during cultivation (CTIC, 1998a).

No-till, strip-till, and ridge-till provide the most soil conservation protection.

Application and Performance: Plant residues can aid in soil erosion control. Residues can protect the soil from the time of rowcrop harvest through the time the succeeding crop has developed sufficiently to provide adequate canopy protection. Conservation tillage reduces soil erosion by reducing detachment. It also reduces transport by minimizing soil crusting and increasing infiltration, which reduces runoff. The residue acts as small dams, slowing the movement of water across the field and reducing its ability to carry soil particles.

Conservation tillage increases the size of soil aggregates, which reduces the potential of wind to detach soil particles and thereby reduces wind erosion. The residue also slows the wind speed at ground level, reducing its ability to carry soil particles.

Advantages and Limitations: Benefits other than soil conservation that can be gained include the following:

- Reduced tillage costs
- Reduced labor
- Reduced runoff
- Reduced fuel use
- Reduced machinery wear
- Reduced particulate matter in air from wind erosion
- Increased soil moisture
- Improved surface water quality
- Increased water infiltration
- Decreased soil compaction
- Improved soil tilth
- Increased populations and diversity of wildlife
- Increased sequestration of greenhouse gases (carbon dioxide)

Normally, the cost of changing from a conventional tillage system to a conservation tillage system is minimal if current equipment can be adapted. The cost of changing is associated with the purchase of additional attachments for equipment and depends on the type of conservation tillage to be done (no-till, ridge-till, mulch-till, and so forth). The incremental cost of these attachments may range from $1.00 to $3.00/acre/year. However, if equipment is impossible to adapt or needs extreme adaptations, the investment in changing to a conservation tillage system can become significant.

Intensive overall management is critical to the success of a no-tillage or ridge-tillage system. Constraints and challenges within the system should be considered before choosing a no-tillage or ridge-tillage method. The most successful system needs a strong commitment from a knowledgeable manager. Management considerations and system constraints include the following:

- Manure application and the need to incorporate
- Alternative methods or equipment modifications for nutrient placement
- The need to apply and/or incorporate lime
- Planter and harvesting attachments need to be correctly installed and maintained
- Critical timing of field operations
- Greater reliance on herbicides for weed control
- Shifts in weed populations and weed varieties
- Increased nitrogen requirements due to an increase in residue that has a high carbon-to-nitrogen ratio
- Delays in spring field operations due to cold, wet soils
- Delayed seed germination due to cold, wet soils

Conservation tillage can be used on cropland fields where excess sheet and rill erosion and wind erosion are a concern. Conservation tillage is most effective when used with other supporting conservation practices such as grassed waterways, contouring, and field borders.

Operational Factors: In the northern areas of the United States where soil temperatures stay colder for longer periods of time, no-till may not be as well adapted as some of the other conservation tillage systems. In these areas strip-till or ridge-till may be better options.

Demonstration Status: Conservation tillage is used across the United States and in conjunction with all the major crops.

Practice: Crop Rotation

Description: Crop rotation is the practice of alternating high-residue crops with low-residue crops on the same piece of land, from year to year. Although crop rotations can vary significantly, a typical rotation giving significant erosion protection could include high-residue-producing crops like small grains and hay, and low-residue-producing row crops like corn and soybeans. A typical rotation using these crops would be corn-soybeans-corn-small grain-hay-hay.

Application and Performance: The soil conservation purpose of a crop rotation is to alternate crops that have high erosion potential with crops that have low erosion potential because it is the average soil loss over time that is critical. It is expected that in those years when low-residue crops are planted, significant erosion may occur. However, in years when high-residue crops are planted, very little erosion will occur. Therefore, the average rate of soil erosion throughout the rotation sequence will be significantly lower than it would be if only low-residue crops had been planted. A rotation of corn-soybeans-corn-small grain-hay-hay could be expected to reduce soil erosion by 50 percent as compared with just corn and soybeans, depending on the tillage system (Renard et al, 1997).

Advantages and Limitations: Weather conditions, unexpected herbicide carryover, and marketing considerations may result in a desire to change a scheduled crop rotation. Since most farmers want to balance production acres of different crops, they need to have the flexibility of changing the rotations in one field because of an unexpected condition in another field.

Operational Factors: Crop rotation can be used where sheet and rill erosion is a problem on cropland. Crop rotation works best with other supporting conservation practices such as conservation tillage, contouring, and grassed waterways. A market or use for the small grains or hay is needed before farmers will adopt the use of crop rotation.

Demonstration Status: The use of crop rotations is generally adopted in those regions that have dairy herds because of the need for hay.

Practice: Contouring and Cross-Slope Farming

Description: Contour farming is the practice of tilling, planting, and cultivating crops around a slope on a nearly level line that slowly grades water to a nonerosive area that can handle concentrated flow. In gentle rains, the contoured rows are able to slowly grade the water to a nonerosive area such as a grassed waterway or field border. In heavier rains, when the water runs over the tops of the rows, the rows serve as mini-dams to slow the water. Slowing the water allows for more infiltration of water into the soil profile and reduces sediment transport in the field.

On some slopes, strict contour farming that results in sharp turns and endless point rows is impractical. Farm machinery may be too large to accommodate the tight turns and numerous point rows and increases the amount of time required to complete field operations. In this case, an alternative to contouring is cross-slope farming, which allows greater deviation from the contour line. Although cross-slope makes farming easier, it is generally only half as effective as contouring in reducing soil erosion.

In some areas of the country, using a rollover plow on the contour is beneficial to turn the soil uphill while performing conventional tillage. By using a rollover plow on the contour, soil is mechanically moved up-slope.

To allow for the removal of water in a concentrated flow, waterways need to be seeded, or shaped and seeded.

Application and Performance: Contouring can reduce soil erosion by 25 to 50 percent and cross-slope farming can reduce soil erosion by 10 to 25 percent depending on slope length, slope steepness, field roughness, and row grade (Renard et al, 1997).

Advantages and Limitations: Because contouring and cross-slope farming slow the runoff of water, water infiltration is increased and soil erosion is reduced. The increased water infiltration may also mean more available subsoil moisture during the growing season. Horsepower requirements may also be lower when farming on the contour or cross-slope.

On longer slopes, both contouring and cross-slope farming become less effective and should then be used in combination with a supporting conservation practice such as terraces or contour strip cropping.

The major disadvantage of contouring, and to a lesser extent cross-slope farming, is the increased time needed to perform the tilling, planting, spraying, cultivating, and harvesting operations. Contouring may require 25 to 50 percent more time as compared with farming straight rows. Cross-slope farming may require 10 to 25 percent more time as compared to farming straight rows. This increased time leads to higher labor, fuel, and equipment costs on a per acre basis.

Operational Factors: Contouring or cross-slope farming can be used on most slopes on which row crops are planted.

Demonstration Status: Contouring or cross-slope farming is widely adopted across the United States.

Practice: Contour Stripcropping/Contour Buffer Strips

Description: Contour stripcropping is a system of growing crops in approximately even-width strips or bands on the contour. The crops are arranged so that a strip of meadow or close-growing crop is alternated with a strip of row crop. Contour stripcropping combines the soil protection of both contouring and crop rotation. The widths of rowcrop strips should equal the widths of the hay or small grain strips. The strips of hay or small grain slow water flow and trap sediment from the row crop strips above them.

Contour buffer strips can be used when a higher percentage of row crop acres are needed. A contour buffer strip system allows for the hay or small grain strips to be narrower than the strips of row crop. Because a contour buffer strip system results in more row crop acres, it is less effective than contour strip cropping in reducing soil erosion.

The strip width depends on the steepness of the slope and the management practices being used. It is also designed to accommodate the width of equipment (planters, sprayers, and harvesters). An even number of equipment passes along each strip improves field operation efficiency by starting and finishing a pass at the same end of the field. Grassed field borders and grassed waterways are an integral part of any stripcropping system. They provide access lanes and safe areas for concentrated water runoff.

Application and Performance: Contour stripcropping is very effective in reducing sheet and rill erosion. It can reduce soil loss by as much as 75 percent, depending on the type of crop rotation and the steepness of the slope. Depending on the width of the grass strip and the row crop strip and the steepness of the slope, contour buffer strips can reduce sheet and rill erosion by as much as 75 percent or as little as 20 percent (Renard et al., 1997).

Advantages and Limitations: Choosing to use contour stripcropping or contour buffer strips is an excellent conservation practice for a farmer who can use small grains or hay. Instead of planting one entire field to small grains or hay and another entire field to row crops, strips of hay or grain can be alternated, thereby reducing soil erosion.

Effective stripcropping systems require strips that are wide enough to be farmed efficiently. If possible, consolidation of fields may be necessary. The major disadvantage of using contour stripcropping or contour buffer strips as an erosion control practice is the same as that of contouring: increased time to perform the field operations (e.g., tillage, planting, spraying, and harvesting). These practices may require 25 to 50 percent more time than farming straight rows. Increased time used in field operations leads to higher labor, fuel, and equipment costs on a per acre basis.

Operational Factors: Contour stripcropping and contour buffer strips can be used where sheet and rill erosion are a problem in cropland, and they work best with other supporting conservation practices such as conservation tillage and grassed waterways. The use of contour stripcropping and contour buffer strips is practical only if there is a market or use for the small grains or hay.

Demonstration Status: The use of crop rotations is generally adopted in those regions that have dairy herds, beef cattle, or sheep because of the need for hay.

Practice: Grassed Waterways

Description: Grassed waterways are areas planted to grass or other permanent vegetative cover where water usually concentrates as it runs off a field. They can be either natural or man-made channels. Grass in the waterway slows the water as it leaves the field. Grassed waterways can serve as safe outlets for graded terraces, diversions, and contour rows. They can also serve as passageways for water that enters a farm from other land located higher in the drainage basin. Grassed waterways significantly reduce gully erosion and aid in trapping sediment.

Application and Performance: Grassed waterways protect the soil from erosion at points of concentrated water flow. They are designed to safely carry runoff water from the area that drains into them to a stable outlet. Small waterways are designed in a parabolic shape and are built wide enough and deep enough to carry the peak runoff from a 24-hour storm that would be expected to occur once every 10 years.

The decision to mow or not to mow grassed waterways depends on supporting conservation practices and other management concerns. To increase the lifespan of the waterway, it is best to mow or clip the grass in the waterway. If grasses are allowed to grow, the flow rate of the waterway is slowed, increasing the rate of sedimentation in the waterway, which in turn increases the cost of maintaining the waterway. If waterways are clipped, however, water flows faster and the sediment is carried farther down slope before being dropped out. If manure is applied in the waterway drainage area, grassed waterways should not be mowed. To prevent excessive sedimentation in the unmowed waterways, other supporting conservation practices, such as contouring, conservation tillage, or barrier systems, should be in place.

Advantages and Limitations: The goal of a waterway design is to protect against soil loss while minimizing siltation and gullying in the waterway. Gullies can form along the side of a waterway if the water does not enter the waterway or if the runoff spills out of the waterway and runs parallel to it. This can be caused by inadequate design (too shallow or too narrow) or inadequate maintenance, and in some cases by flooding. Even under the best conditions, grassed waterways tend to either silt in or develop channels or gullies. Timely maintenance and repairs can prevent major reconstruction. Silt can be cleaned out and small gullies can be filled in. However, if the waterway is damaged too badly, it will need to be completely reshaped and reseeded. Often heavy equipment such as a bulldozer or a scraper is required.

Grassed waterways permanently take land out of cereal and row crop production, but they can be harvested for forage production if the farmer has a use and/or market for the forage and the equipment to harvest the forage.

The cost of waterway construction depends on the depth and width of the waterway. It ranges from $1.50 to $3.50 per linear foot, with mulch and seed. In addition to the construction cost, there is a maintenance cost. The cost to maintain a waterway is highly variable depending on drainage area size, soil type, grade of the waterway, and level of control of soil erosion above the waterway. Some waterways can function for 10 years without maintenance, whereas others need maintenance on a yearly basis.

Operational Factors: Grassed waterways can be used where ephemeral erosion and gully erosion are a problem.

Demonstration Status: Grassed waterways are used across the United States and in conjunction with all the major crops.

Practice: Terraces

Description: Terraces are earthen structures that run perpendicular to the slope and intercept runoff on moderate to steep slopes. They transform long slopes into a series of shorter slopes. On shorter slopes, water velocity is slower and therefore has less power to detach soil particles. Terraces slow water, catch water at intervals down slope, and temporarily store it in the terrace channel.

Depending on the soil type, the water can either infiltrate into the ground or be delivered into a grassed waterway or an underground tile. Terraces are spaced to control rill erosion and to stop ephemeral gullying. Terrace spacing is determined by several factors, including soil type, slope, and the use of other supporting conservation practices such as conservation tillage and crop rotation. When more than one terrace is placed on a hillside, it is best to construct the terraces parallel to each other and at spacings that are multiple widths of field equipment. This approach helps eliminate short rows and improves the efficiency of field operations.

Application and Performance: Terraces reduce the rate of runoff and allow soil particles to settle out.

Advantages and Limitations: One of the biggest advantages of terraces is that they are permanent conservation practices. A farmer usually does not adopt terracing one year and decide the next year not to use it, unlike such management practices as conservation tillage or contouring. In almost all cases, terraces will not be removed until they have exceeded their life expectancy of 20 years.

A disadvantage of terraces is that they are built with heavy construction equipment and the soil structure around the terrace can be permanently altered. Terraces are built by pushing soil up, and they usually require a bulldozer. Compaction on the lower side of the terrace is always a concern and can last for years after the terrace is constructed.

Terraces can permanently remove land from production. The amount of land removed from production depends on the terrace system installed, but it normally ranges from 0 to 5 percent of the overall land base. The cost to install terraces ranges between $0.75 and $3.00 per linear foot, including seeding. In many cases terraces also require either a tile line or a waterway as an outlet for the water. The cost of installing tile can range from $.75 to $1.50 per linear foot. Waterway costs are covered in the section on grassed waterways. It can cost in the range of $100 to $165 to protect 1 acre of land with terraces and suitable outlets. In addition to construction costs, there are always maintenance costs. If excessive rains occur, terraces will overtop and require maintenance. The sediment collected in terrace channels should be cleaned out periodically, at least every 10 years, or sooner, depending on the sedimentation rate. Maintenance also includes removing trees and shrubs from the terrace and repairing rodent damage.

In addition to the loss of cropland and cost of construction and maintenance, terraces are laid out on the contour, which can increase the time, fuel, and equipment costs associated with field operations. See the section on contouring and cross-slope farming for costs associated with contouring.

Operational Factors: Terraces can be used when sheet, rill, or ephemeral erosion are a concern.

Demonstration Status: Terraces are widely adopted across the United States.

Practice: Field Borders

Description: A field border is a band or strip of perennial vegetation, usually grass and/or legume, established at the edge of a field. From a soil conservation standpoint, field borders are used to replace end rows that run up and down a hill. Sometimes field borders replace end rows all the way around the field, and other times they are used where slope length and steepness present a concern for soil erosion. Field borders can be used in fields that are contoured, cross-sloped, contour stripcropped, contour buffer stripped, or terraced.

Application and Performance: Field borders reduce detachment, slow transport, and help reduce sediment load in water.

Advantages and Limitations: Field borders reduce acres of cereal crops or row crops in production. However, if the field border is planted to forage, it can be harvested, as long as the farmer has the proper equipment and a use or market for the crop. The cost of seeding an acre of field borders is approximately $50 to $70 per acre.

Operational Factors: Field borders can be used with all crops and in all regions of the United States.

Demonstration Status: Field borders are commonly used as a conservation practices in combination with other practices.

Practice: Sediment Basin

Description: A sediment basin is a barrier structure constructed to collect and store manure, sediment, or other debris.

Application and Performance: Sediment basins are constructed to accumulate and temporarily store water runoff. For controlling manure runoff, sediment basins may be used in two types of settings: to capture feedlot runoff or to capture field runoff. As runoff accumulates and water is slowly discharged through an outlet, soil particles settle out and are trapped in the basin. Frequently, a filter strip is positioned as a secondary treatment practice below the sediment basin to catch the additional sediment flowing through the outlet. Sediment basins reduce the transport of soil and manure by flowing water.

Advantages and Limitations: The construction cost of sediment basins is quite variable, depending on the steepness of the land and the size of the drainage area flowing into the basin. However, basins are normally a cost-effective practice to capture sediment.

On-site erosion control cannot be achieved with sediment basins, because they do little to stop detachment and transport of soil.

Operational Factors: Sediment basins can be used with all crops and in all regions of the United States.

Demonstration Status: Sediment basins are commonly used as a conservation practices in all cropland systems.

Practice: Cover Crops

Description: A cover crop is a crop of close-growing grass, legumes, or small grain grown primarily for seasonal protection and soil improvement. These crops are also known as green manure crops. Cover crops are usually grown for 1 year or less, except where there is permanent cover (e.g., orchards). They increase vegetative and residue cover during periods when erosion energy is high, and especially when primary crops do not furnish adequate cover. Cover crops may be established by conventional or conservation tillage (no-till or mulch-till) methods or by aerial seeding.

Cover crops should be planted immediately after harvest of a primary crop to maximize the erosion control benefits. Recommended seeding dates vary from year to year and depend on soil type, local climatic conditions, field exposure, and the species of cover crop being grown.

Application and Performance: Cover crops control erosion during periods when the major crops do not furnish adequate cover. Since cover crops provide a quick canopy, they reduce the impact of raindrops on the soil surface, thereby reducing soil particle detachment. Cover crops also slow the surface flow of water, reducing transport of sediment and increasing water infiltration. Cover crops can add organic material to the soil; they improve water infiltration, soil aeration, and soil quality. In addition, cover crops can control plant nutrients and soil moisture in the root zone. If a legume crop is used as a cover crop, it will provide nitrogen for the next year's crop.

Actively growing cover crops use available nutrients in the soil, especially nitrogen, thus preventing or decreasing leaching or other loss. These nutrients may then become available to the following crop during the decaying process of the green manure.

Advantages and Limitations: Cover crops increase transpiration. In areas of the United States where moisture is limited, cover crops may use up too much of the available soil moisture. Loss of available soil moisture may reduce the yield of the primary crop planted after the cover crop, reducing profits.

Preparing a seedbed and drilling in a winter cereal crop costs $40 to $45 per acre. Broadcast seeding after harvest, followed by a tillage pass that levels the soil surface, costs $35 per acre. Broadcast seeding prior to harvest costs $15 per acre.

Operational Factors: Cover crops can be used when major crops do not furnish adequate cover and sheet and rill erosion is a problem.

Demonstration Status: Cover crops are used throughout the United States.

Practice: Filter Strip/Riparian Buffer

Description: Filter strips are strips of grass used to intercept or trap field sediment, organics, pesticides, and other potential pollutants before they reach a body of water.

Riparian buffers are streamside plantings of trees, shrubs, and grasses that can intercept contaminants from both surface water and ground water before they reach a stream.

Application and Performance: Filter strips and riparian buffers are designed to intercept undesirable contaminants such as sediment, manure, fertilizers, pesticides, bacteria, pathogens, and heavy metals from surface and subsurface flows of water to a waterbody. They provide a buffer between a contaminant source and waterbodies. Buffers and filter strips slow the velocity of water, allowing soil particles to settle out.

Advantages and Limitations: Buffer strips and riparian buffers reduce the acreage in cereal crops or row crops, but they can be harvested for forage production if the farmer has a use or market for the forage and the equipment to harvest the forage. Depending on whether the filter strip or riparian buffer strip is seeded to grass or planted to trees, the cost of seeding can range from $50 to $500 per acre.

Operational Factors: Buffer strips and riparian buffers can be used with all crops and in all regions of the United States.

Demonstration Status: Filter strips and riparian buffers have been widely promoted and adopted throughout the United States with programs like the Conservation Reserve Program (CRP).

Practice: Crosswind Trap Strips, Crosswind Ridges, Crosswind Stripcropping, and Shelterbelts/Field Windbreaks

Description: Crosswind trap strips are rows of perennial vegetation planted in varying widths and situated perpendicular to the prevailing wind direction. They can effectively prevent wind erosion in cropping areas with high, average annual wind speeds.

Crosswind ridges are formed by tillage or planting and are aligned across the prevailing wind erosion direction. The ridges reduce wind velocity near the ground, and the soil particles that do start to move are trapped in the furrows between the ridge crests.

Crosswind stripcropping is growing crops in strips established across the prevailing wind direction and arranged so that the strips susceptible to wind erosion are alternated with strips having a protective cover that is resistant to wind erosion.

A shelterbelt or field windbreak is a row (or rows) of trees, shrubs, or other plants used to reduce wind erosion, protect young crops, and control blowing snow. Shelterbelts also provide excellent protection from the elements for wildlife, livestock, houses, and farm buildings. Field windbreaks are similar to shelterbelts but are located along crop field borders or within the field itself. In some areas of the country, they may also be called hedgerow plantings.

Application and Performance: These practices are designed to reduce soil erosion by increasing the soil roughness and reducing the wind speed at the soil surface.

Advantages and Limitations: The same practices that reduce wind erosion also reduce moisture loss. Snow is more likely to stay on the field than to blow off, thereby increasing soil moisture. A drawback to crosswind trap strips, shelterbelts, and field windbreaks is that they take cropland out of production. Also, they are a physical barrier to operations such as manure application with an umbilical cord system.

Operational Factors: These practices can be used anywhere that wind erosion is a concern in row crops.

Demonstration Status: These practices are used where row crops are planted in the Plains states.

8.5 References

AAC. 2000. Farming for Tomorrow: Conservation Facts. Rotational Grazing: The Rest and Recovery Method of Pasture Management. <http://aceis.agr.ca/pfra/land/fft10.htm> Accessed 2/11/00. Agriculture and Agri-Food Canada.

ASAE. 1998. Standards, 45th Edition, Standards, Engineering Practices and Data. American Society of Agricultural Engineers, St. Joseph, MI.

Baird, J.V., S.C. Hodges, and M.R. Tucker. 1997. Careful soil sampling—the key to reliable soil test information. Publication AG-439-30, North Carolina Cooperative Extension Service, North Carolina State University, Raleigh, North Carolina.

Barker, J.C. 1996. Livestock waste sampling, analysis, and calculation of land application rates. Publication Number EBAE 111-84, North Carolina Cooperative Extension Service, North Carolina State University, Raleigh, North Carolina.

Barker, J.C., and J.P. Zublena. 1996. Components of a complete manure management plan. Publication Number EBAE 185-93, North Carolina Cooperative Extension Service, North Carolina State University, Raleigh, North Carolina.

Barth, C.L. and J. Kroes. 1985. Livestock Waste Lagoon Sludge Characteristics, In: Agricultural Waste Utilization and Management, Proceedings of the Fifth International Symposium on Livestock Wastes, St. Joseph, MI, ASAE, p.660-671.

Bartok, J.W. 1994. Fertilizer and manure application equipment. NRAES-57. Northeast Regional Agricultural Engineering Service, Cooperative Extension, Ithaca, New York. April.

Beal, J.D., P.H. Brooks, and H. Schulze. 1998. The effect of the addition of a protease enzyme to raw or autoclaved soya bean on the growth performance of liquid fed grower/finisher pigs. Abstract submitted for the Brit. Soc. Anim. Sci. meetings.

Berry, J.T., and N. Hargett. 1984. Fertilizer summary data. Tennessee Valley Authority, National Fertilizer Development Center, Mussel Shoals, Alabama.

Bicudo, J., D. Schmidt, C. Jacobson, K. Janni. 1999. Nutrient Content and Sludge Volumes in Single Cell Recycle Anaerobic Swine Lagoons in North Carolina, Transactions of the ASAE. Vol.42(4): 1087-1093, 1999.

Bonner, J., R.B. Moore, and J. Thomas. 1998. Managing animal waste nutrients. Mississippi State University Extension Service, Mississippi State University, Jackson, Mississippi.

Brady, N.C., and R.R. Weil. 1996. The nature and properties of soils. 11th ed. Macmillan Publishing Company, New York, New York.

Bridges, T.C.; L.W. Turner, G.L. Cromwell, and J.L. Pierce. 1995. Modeling the effects of diet formulation on nitrogen and phosphorus excretion in swine waste. Applied Engineering in Agriculture 11: 5, 731-739.

Brown, K.W. 1995. Agronomy 616-Land disposal of waste. Vol.1. Texas A&M University, College Station, Texas.

Brumm, M.C., J. D. Harmon, M. C. Honeyman, and J. Kliebenstein. 1997. Hoop Structures for Grow-Finish Swine. Agricultural Engineers Digest 41: 1-16. February 1997.

Busch, D., T. Wagar, and M. Schmitt. 2000. Livestock manure sampling. FO-6423-GO, College of Agricultural, Food, and Environmental Sciences, University of Minnesota Extension Service, St. Paul, Minnesota.

CAST. 1996. Integrated animal waste management. Task Force Report No. 28. Council for Agricultural Science and Technology, Ames, Iowa. November.

Chase, L. E. 1998. "Phosphorus nutrition of dairy cattle" Mid-South Ruminant Nutrition Conference, Dallas, Texas, sponsored by Texas Animal Nutrition Council and the Texas Agricultural Extension Service. May 7-8.

Chastain, J., W. Lucas, J. Albrecht, J. Pardue, J. Adams, and K.Moore. 1998. Solids and Nutrient Removal from Liquid Swine Manure using a Screw Press Separator. Paper No. 98-4110. American Society of Agricultural Engineers, St. Joseph, MI.

Cheng, J., J. Pace, K. D. Zering, J. C. Barker, K. F. Roos, and L. M. Saele. 1999. Evaluation of Alternative Swine Waste Treatment Systems in Comparison with Traditional Lagoon System. Paper to be presented at Livestock Waste Management Symposium, American Society of Agricultural Engineers, Des Moines, IA, October 2000.

CIAS. 2000. Dairy Grazing Can Provide Good Financial Return. Center for Integrated Agricultural Systems. <http://www.wisc.edu/cias/pubs/resbrief/050.html> Accessed 5/29/00.

Conner, M. 1994. Update on alternative housing for pigs. Manitoba Swine Seminar Proceedings 8: 93-96.

Conner, M. 1993. Evaluation of a biotech housing for feeder pigs. Manitoba Swine Update. July 1993. 5(3)1.

Crouse, K., and W. McCarty. 1998. Soil testing for the farmer. Extension Agronomy, Mississippi

State University, Jackson, Mississippi.

CTIC. 1998a. Crop Residue Management Survey Executive Summary. <http://www.ctic.purdue.edu/Core4/CT/CTSurvey/Method.PDF>. Accessed 3/31/00.

CTIC. 1998b. The 1998 MAX report. Conservation Technology Information Center, Purdue University, West Lafayette, Indiana.

Culotta, C. P., and G. H. Schmidt 1988. An Economic Evaluation of Three Times Daily Milking of Dairy Cows. Journal of Dairy Science 71: 1960.

Cummings, R.J., and W.J. Jewell. 1977. Thermophilic Aerobic Digestion of Dairy Waste. In Food, Fiber, and Agricultural Residues, ed. R.C. Loehr. pp. 637-657. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan.

Dahl, G. E., J. P. Chastain and R. R. Peters. 1998. Manipulation of photoperiods to increase milk production in cattle: biological, economic and practical considerations. In Proceedings of the Fourth International Dairy Housing Conference, J. P. Chastain ed., American Society of Agricultural Enginineers, St. John's, Michigan.

Dahl, G.E., T.H. Elsasser, A.V. Capuco, R.A. Erdman and R.R. Peters. 1996. Long day photoperiod that stimulates milk yield and also increases circulating insulin-like growth factor-1 (IGF-1). FASEB J. 10: A751.

Dick, W.A., D.J. Eckert, J.W. Johnson. 1999. Land application of poultry litter. ANR-4-98. Ohio State University Extension Fact Sheet, School of Natural Resources, Columbus, Ohio.

Dierick and Decuypere. 1994: referenced by Close, W.H. 1996. Nutritional management of swine is ever-evolving challenge. Feedstuffs, 22 Jan.:16-19,46-47

Dinn, N. E. , L. J. Fisher, J. A. Shelford and J. Paul. 1996. The use of the Cornell net carbohydrate and protein system and rumen protected lysine and methionine to reduce nitrogen excretion of lactating dairy cows. J. Dairy Sci. 79: (Suppl 1) 129.

Doerge, T.A., R.L. Roth, and B.R. Gardner. 1991. Nitrogen fertilizer management in Arizona. College of Agriculture, University of Arizona, Tucson, Arizona.

Dunlap, T. F., R. A. Kohn and K. F. Kalscheur. 1997. Effect of animal grouping strategies on nutrient losses from the dairy farm. J. Dairy Sci. 80: (Suppl. 1) 246.

Edens F. and C. Simons. 1998. Use of Phytase in Poultry diets to Reduce Phosphorus Excretion. North Carolina State University, Department of Poultry Sciences, and Center for Applied

Poultry Research, Netherlands.

Emmicx, D.L. 2000. State Grasslands Specialist, New York State. ABC's of Rotational Grazing: Questions and Answers. Accessed from the Internet 2/11/00. <http://www.kingcd.org/stewardship/Ag%20Pr...ces/Pastures/ABCsofRotationalGrazing.html>

Envirologic Corporation. 2000. High-Rise™ Hog Facilities. Informational packet distributed by Fort Recovery Equipment Systems, Inc. Received March 27, 2000.

Erdman, R. A. and M. Varner. 1995. Fixed yield responses to increased milking frequency. J. Dairy Sci. 78: 1199.

Ferguson, J. D. 1999. Typical concentrations of urea found in milk. in More MUN Research (web site) <http://www.dhia.psu.edu/munnews>. Accessed (date).

Fox, D.G., M.C. Barry, R.E. Pitt, D.K. Roseler and W.C. Stone. 1995. "Application of the cornell net carbohydrate and protein system for cattle consuming forage" J. Anim. Sci. 73: 267.

Fulhage C. 1998. Gaseous Emissions from Manure Management Systems - An Overview. Presented at 1998 American Society of Agricultural Engineers Annual Meeting, Orlando, Florida. 1998.

Fulhage, C. and J. Hoehne. 1999. Manure Nutrient Content and Variability in Missouri Swine Lagoons. Presented at 1999 American Society of Agricultural Engineers Mid-Central Meeting, St. Joseph, MO. April 20-May 1, 1999. Paper. No. MC99-104

Fulhage, C.D., and D.L. Pfost. 1993. Flushing Systems for Dairies. WQ308. Department of Agriculture Engineering, University of Missouri-Columbia, Columbia, MO. July 15.

Garber, L. 1999. USDA NAHMS Center for Animal Health Monitoring facsimile sent August 1999.

Graham, H. and J. Inborr. 1993. Feed enzymes: mode of action and application to heat processed poultry feeds. Amandus Kahl Seminar

Graves, R. 2000. Department of Agriculture Engineering, Penn State University, University Park, PA. E-mail correspondence. April 2.

Hallberg, G.R.. 1991. A progress review of Iowa's agricultural-energy-environmental initiatives: nitrogen management in Iowa. Technical Information Series 22, Iowa Department of Natural Resources, Iowa City, IA.

Halverson, M. 1998. Management in Swedish Deep-Bedded Swine Housing System: Background and Behavioral Considerations. Managing Manure in Harmony with the Environment Conference and Proceedings, February 10-12 1998, Ames, Iowa: 155-158.

Hanna, M. 1998. Incorporate manure to reduce odor and maintain residue cover. Iowa Manure Matters Odor Nutrient Management Newsletter. Summer 1998. Iowa State University, Ames, Iowa.

Hannawale, J. 2000. Telephone conversation with Jim Hannawale, USDA, on April 4, 2000.

Harmon, J., H. Xin. 1997. Thermal Performance of a Hoop Structure for Finishing Swine. ASL-R1391. 1996 Swine Research Reports: 104-106. Iowa State University Extension, Ames, IA.

Harmon, J., M. Honeyman. 1997. Hoop Structures- Research on Performance and Operation. Iowa State University Agriculture and Biosystems Engineering, Ames, IA. <http://www.ae.iastate.edu/aen189.htm> Accessed March 15, 2000.

Hatfield, J.L. 1998. Evaluation of the potential environmental implications of animal manure. National Soil Tilth Laboratory, Ames, Iowa.

Hirschi, M., R. Frazee, G. Czapar, and D. Peterson. 1997. 60 ways farmers can protect surface water. North Central Regional Extension Publication 589, University of Illinois, Urbana-Champaign, Illinois..

Honeyman, M. 1999. An Overview of Swine System Options. Proceedings: Swine System Options For Iowa 1999, February 17, 1999. Iowa State University, Ames, Iowa.

Honeyman, M. 1996. Hoop Structures with Deep Bedding for Grow-finish Pigs. ASL-R1392. 1996 Swine Research Reports: 107:110. Iowa State University Extension, Ames, Iowa.

Honeyman, M., J. Harmon, D. Lay, and T. Richard. 1997. Gestating Sows in Deep-bedded Hoop Structures. ASL-R1496. 1997 Swine Research Reports. Iowa State University Extension, Ames, Iowa.

Honeyman, M., J. Harmon, A. Penner, and C. Jorgenson. 1999. Performance of Finishing Pigs in Hoops and Confinement During Summer and Winter. ASL-R1682. 1999 Swine Research Reports. Iowa State University Extension, Ames, Iowa.

Hue, N.V., R. Uchida, and M.C. Ho. 1997. Testing your soil—why and how to take a soil-test sample. AS-4. Agronomy and Soils, Cooperative Extension Service, College of Tropical Agriculture & Human Resources, University of Hawaii at Manoa, Hawaii.

Humenick, F. , A.A. Szogi, P.G. Hunt, J.M. Rice, and G.R. Scalf. 1972. Constructed Wetlands for Swine Wastewater Treatment. Waste Management Research, Proceedings of the 1972 Cornell Agricultural Waste Management Conference. Cornell University and USEPA. P341-353.

Hutchinson, L.J. 1988. Animal Health, Pest Management and Environment U.S. Department of Agriculture, Soil Conservation Service, Northeast National Technical Center, Chester, Pennsylvania. Proceedings of the Pasture in the Northeast Region of the United States. April 1988.

Iowa State University. 1999. Managing Nutrients for Crop Production. PM-1811. Iowa State University Extension, Ames, IA. November.

Iragavarapu, R., and T. Doerge. 1999. Manure Phosphorus - Problems Regulations, and Crop Genetic Solutions. Crop Insights 9(6). <http://www.pioneer.com/usa/nutrition/ manure_phosphorus _availability_99.html>. Accessed September 20, 1999

ISU. 1995. Iowa State University. Land application for effective manure nutrient management. Pm-1599. October 1995. Iowa State University Extension, Ames, Iowa.

Jeffery, R. 1996. Nitrogen and Phosphorus Accumulation in the Soil Profile Beneath an Alternative Housing System for Pigs, Report No 2. Pig Research and Development Corporation, Medina Research Centre, February 27, 1996, Greenwood, W.A.

John, R.E. 1991. Alternative Animal Products: The Industry. University of Maryland National Dairy Database. Updated September 21, 1991. Accessed September 24, 1999. <http://www.inform.umd.edu/EdRes/Topic/AgrEnv/ndd/feeding/ALTERNATIVE_ANIMAL_PRODUCTS_THE_INDUSTRY.html>

Johnson, D.E., G.M. Ward and J. Torrent. 1992. "The environmental impact of bovine somatotropin use in dairy cattle" J. Environ. Qual. 21: 157.

Johnson, Kerstin P., and Montemagno, Carlo D. 1999. An Analysis of Dairy Waste Treatment Using Sequencing Batch Reactors. Cornell University, Department of Agricultural and Biological Engineering, 1999.

Jones, D.D. 2000. Department of Agriculture and Biosystems, Purdue University, West Lafayette, IN. E-mail correspondence. March 31.

Jonker, J.S., R.A. Kohn and R.A. Erdman. 1998. Using Milk Urea Nitrogen to Predict Nitrogen Excretion and Utilization Efficiency in Lactating Dairy Cows. J. Dairy Sci. 81:2681.

Kalscheur, K.F., R.A Kohn, R.A. Erdman, and J.H. Vandersall. 1997. Evaluation of Diet

Formulation Models Using Low Protein Corn-based Diets. J. Dairy Sci. 80: (Suppl. 1) 162.

Keener, H., D. Elwell, T. Menke, and R. Stowell. 1999. Design and Management of High-Rise™ Hog Facility Manure Drying Bed. ASAE Paper 994108. ASAE, St. Joseph, MI.

Keplinger, K. 1998. Cost savings and environmental benefits of dietary P reductions for dairy cows in the Bosque river watershed. Working paper, Texas Institute for Applied Environmental Research.

Knowlton, K. F., and R. Kohn. 1999. "We've got to stop overfeeding phosphorus" Hoard' Dairyman, Vol. 144, no. 11, June.

Koelsch, R. 1997. Determining crop available nutrients from manure. G97-1335A. NebGuide, Cooperative Extension Publication. Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, Lincoln, Nebraska. September.

Kohn, R. A., K. F. Kalscheur and M. Hanigan. 1998. "Evaluation of Models for Balancing the Protein Requirements of Dairy Cows" J. Dairy Sci. 81: 3402.

Kohn, R.A. 1999. "The Impact of Dairy Herd Management on Nutrient Losses to Water Resources" In Manurenet (website), <http://www.inform.umd.edu/ManureNet/herdeffic>.

Kroodsma, W. 1985. Separation as a Method of Manure Handling and Odours Reduction in Pig Buildings. In: Odour Prevention and Control of Organic Sludge and Livestock Farming. Elsevier Applied Science Publishing, London, England.

Langland, M.J., and D.K. Fishel. 1996. Effects of agricultural best-management practices on the Brush Run Creek headwaters, Adams County, Pennsylvania, prior and during nutrient management. U.S. Geological Survey, Water Resources Investigations Report 95-4195, Lemoyne, Pennsylvania.

Lee, A. 2000. What Is Pastured Poultry? By Farmer/Author/Instructor, Andy Lee. Accessed from the Internet on 12/04/00 <http://www.lionsgrip.com/pastured.html>

Lei, X.G., P.K. Ku, E.R. Miller, and M.T. Yokoyama. 1993. Supplementing corn-soybean meal diets with microbial phytase linearly improves phytate phosphorus utilization by weaning pigs. Journal of Animal Science 71(12): 3359-3367.

Lemunyon, J.L., and R.G. Gilbert. 1993. The concept and need for a phosphorus assessment tool. *Journal of Production Agriculture*: 6(4): 483-486.

Lenis, N.P., and J.B. Schutte. 1990. Aminozuurvoorziening van biggen en vleesvarkens in relatie tot stikstofuitscheiding. In: Mestproblematiek: aanpak via de voeding van varkens en pluimvee (A.W. Jongbloed and J. Coppoolse, eds.), pp. 79-89. Onderzoek inzake de mest en ammoniakproblematiek in de veehouderij 4, Dienst Landbouwkundig Onderzoek, Wageningen.

Liskey, R.K., J.B. Franzini, D.L. Freyberg, and G. Tchobanoglous. 1992. Water Resources, 4^{th} ed. McGraw-Hill, New York, New York.

Loehr, R. 1977. Pollution Control for Agriculture, Academic Press, Inc., New York, NY.

Lorimor, J. 2000. Department of Agriculture and Biosystems Engineering, Iowa State University, Ames, IA. E-mail correspondence. April 4.

Lusk, P. 1998. Methane Recovery from Animal Manures: The Current Opportunities Casebook. National Renewable Energy Lab, Golden, CO. NREL/SR-580-25145. September 1998

Marketing Directions. 1998. Nutrient management research. Conservation Technology Information Center, West Lafayette, Indiana.

Martin, J.H., Jr. 1999. Pathogen Reduction-Temperature Relationships. Unpublished report prepared for the Engineering Analysis Division, U.S. Environmental Protection Agency, Washington, DC by ICF, Inc., (need to insert City, State).

McClure, T.J. 1994. Nutritional and Metabolic Infertility in the Cow, CAB International, Oxon, UK.

McFarland, M.L., T.L. Provin, and S.E. Feagley. 1998. Managing crop nutrients through soil, manure and effluent testing. L-5175, Texas Agricultural Extension Service, Texas A&M University System, College Station, Texas.

Meals, D.W., J.D. Sutton, and R.H. Griggs. 1996. Assessment of progress of selected water quality projects of USDA and state cooperators, U.S. Department of Agriculture, National Resources Conservation Service, Washington, DC.

Menke, T., R. Mackin, H. Keener, M. Veenhuizen, and Organic Resource Technologies, Inc. 1996. An Integrated Method of Managing the Residuals of Swine Production. A demonstration project/study proposal. March 21, 1996.

Mescher, T., T. Menke, R. Stowell, M. Veenhuizen, and H. Keener. 1999. Design, Performance, and Economics of a High-Rise™ Swine Finishing Building. ASAE Paper 994107. ASAE, St. Joseph, MI.

Metcalf & Eddy, Inc. 1991. edited by G. Tchabanoglous. Wastewater Engineering: Treatment, Disposal, And Reuse, Third Edition. McGraw-Hill Book Co., New York, NY.

Michele, D., J.R. Bacon, C.M. Gempesaw, and J.H. Martin. 1986. Nutrient management by Delmarva poultry growers: A survey of attitudes and practices. University of Delaware, Newark, Delaware.

Monge, H., P.H. Simmins, and J. Weigel. 1998. Reduction du taux proteique alimentaire combinee avec differents rapports methionine:lysine. Effet sur le bilan azote du porc maigre en croissance et en finition. Journees de la Recherce Porcine en France 29:293-298.

Moser, M., Dr. J. Martin, A. Martin, R.P. Mattocks. 1999. Pig Manure Solids Separation. Unpublished report prepared by ICF Inc. for the Engineering Analysis Division, United States Environmental Protection Agency, Washington DC.

Moser, M.A., and A. Martin. 1999. Anaerobic Manure Management. Unpublished report prepared for the Engineering Analysis Division, United States Environmental Protection Agency, by ICF Inc.

Mroz, Z., A.W. Jongbloed, and P.A. Kemme. 1994. Apparent digestibility and retention of nutrients bound to phytate complexes as influenced by microbial phytase and feeding regimen in pigs. J. Anim. Sci. 72:126-132.

Murphy, B. 1988. Voisin Grazing Management in the Northeast. U.S. Department of Agriculture, Soil Conservation Service, Northeast National Technical Center, Chester, Pennsylvania. Proceedings of the Pasture in the Northeast Region of the United States. April 1988.

MWPS. 1993. Livestock Waste Facilities Handbook. 3rd ed. MidWest Plan Service, Iowa State University, Ames, IA.

NCSU. 1998. EPA national guidelines for swine and poultry waste management. North Carolina State University, Raleigh Durham, North Carolina.

NCSU. 1999. Nitrogen and Phosphorus Excretion in Poultry Production. Unpublished. February 1999. North Carolina State University, Animal Waste Management Program

Oldham, L. 1999. Nutrient management. Mississippi State University Extension Service, Mississippi State University, Jackson, Mississippi.

Pennsylvania State University. 1992. Nonpoint source database. Department of Agricultural and Biological Engineering, Pennsylvania State University, University Park, Pennsylvania.

Pocknee, S., and B. Boydell. 1995. Soil sampling for precision farming. National

Environmentally Sound Production Agriculture Laboratory, College of Agricultural and Environmental Sciences, University of Georgia, Athens, Georgia.

PPRC. 1996. Impacts of Intensive Rotational Grazing on Stream Ecology and Water Quality. September 1996. Accessed from the Internet 2/11/00. <http://www.pprc.org/pprc/rpd/fedfund/usda/sare_nc/impactsi.html> Pollution Prevention Resource Center, Seattle, WA.

Purdue Research Foundation. 1994. Manure Storage - Storage Facilities. Purdue Research Foundation, West Lafayette, IN. <http://abe.www.ecn.purdue.edu/~epados/farmstead/manure/src/credits.htm> Accessed September 15, 1999

Purdue University. 1994. Poultry Manure Management Planning. Purdue University, Cooperative Extension Service, West Lafayette, Indiana.

RCM, Inc. 2000. File date. RCM Inc., Berkeley, CA.

RCM, Inc. 1999. File date. RCM Inc., Berkeley, CA.

Reeves, P.L., K.P. Johnson, and C.D. Montemagno. 1999. Biological treatment of dairy manure using sequencing batch reactors: Improving profitability through innovative design. Cornell University, Ithaca, New York

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting soil erosion by water: A guide to conservation planning with the revised universal soil loss equation (RUSLE). Agricultural Handbook No. 703. U.S. Department of Agriculture, Washington, DC.

Richard T., S. Smits. 1998. Management of Bedded-Pack Manure from Swine Hoop Structures: 1998 Results. ASL-R1595. 1998 Swine Research Reports. Iowa State University Extension, Ames, IA.

Richard, T., J. Harmon, M. Honeyman, and J. Creswell. 1997. Hoop Structure Bedding Use, Labor, Bedding Pack Temperature, Manure Nutrient Content, and Nitrogen Leaching Potential. ASL-R1499. 1997 Swine Research Reports. Iowa State University Extension, Ames, IA.

Ross, C.C., et al. 1996. Handbook of Biogas Utilization, 2nd ed, U.S. Department of Energy, Southeastern Regional Biomass Energy Progam, Tennessee Valley Authority, Muscle Shoals, AL.

Sansinena, M., L.D. Bunting, S.R. Stokes, and E.R. Jordan. 1999. "A survey of trends and rationales for dietary phosphorus recommendations among mid-south dairy nutritionists"

Mid-South Ruminant Nutrition Conference, Irving, TX.

Schmitt, M., and G. Rehm. 1998. Fertilizing Cropland with Poultry Manure. FO-5881-GO. University of Minnesota, St. Paul, Minnesota.

Schmitt, M.A. 1999. Manure management in Minnesota. FO-3553-GO. College of Agricultural, Food, and Environmental Sciences, University of Minnesota Extension Service, St. Paul, Minnesota.

Sharpley, A.N. 1995. Identifying sites vulnerable to phosphorus loss in agricultural runoff. *Journal of Environmental Quality*, 24(5): 947-951.

Sharpley, A.N., S.C. Chapra, and R. Wedepohl. 1994. Managing agricultural phosphorus for protection of surface waters: Issues and options. *Journal of Environmental Quality*, 23(3): 437-446.

Sharpley, A.N., T.Daniel, T. Sims, J. Lemunyon, R. Stevens, and R. Parry. 1999. Agricultural phosphorus and eutrophication. ARS-149. U.S. Department of Agriculture, Agricultural Research Service, Pasture Systems & Watershed Management Research Laboratory, University Park, Pennsylvania.

Shih, J. 2000. North Carolina Department of Poultry Science, North Carolina State University, Raleigh, NC. E-mail correspondence. April 6.

Sims, J.T., S. Hodges, and J. Davis. 1998. Principles of soil testing for phosphorus. In *SERA-17, Soil testing for phosphorus: Environmental uses and implications*, Southern Cooperative Series Bulletin #389.

Sniffen, C.J., J.D. O'Connor, P.J. Van Soest, D.G. Fox and J.B. Russell. 1992. "A Net Carbohydrate and Protein System for Evaluating Cattle Diets: Ii. Carbohydrate and Protein Availability" J. Anim. Sci. 70: 3562.

Sohail S. and D. Roland. 1999. Phytase Enzyme Proving Helpful to Poultry Producers and Environment. Highlight of Agricultural Research. 46(1), Spring 1999. <http://www.ag.auburn.edu /aaes/information/highlights/spring99/phytase.html>. Accessed September 21, 1999.

Steevens, B.J., L.J. Bush, J.D. Stout, and E.I. Williams. 1971. "Effects of varying amounts of calcium and phosphorus in rations for dairy cows" J. Dairy Sci. 54:655.

Stevenson, G.R. 1995. Watershed management and control of agricultural critical source areas. In *Animal waste and the land-water inteface*, K. Steele ed., pp. 273-281, CRC Press, Inc., Baton Rouge, Louisianna.

Stokes, S.R. 1999. Addressing Environmental Concerns Associated with the Dairy Industry, Report to the Bosque River Advisory Council, personal collection, July 8.

Stowell, R., D. Elwell, B. Strobel, H. Keener, and T. Menke. 1999. Airflow and Air Quality within a High-Rise™ Hog Facility.

Sutton, A., D. Jones, E. Collins, L. Jacobs, and S. Melvin. 1996. Swine Manure as a Plant Resource. PIH-25. Oklahoma State University Cooperative Extension Service, Stillwater, OK. February.

Tammiga, S. 1992. Nutrition management of dairy cows as a contribution to pollution control. J. Dairy Science. 75:345.

Tengman, C.L., H.L. Person, and D.R. Rozeboom. Undated Draft. Immediate liquid-solid separation of swine manure below slats using sloped pit floors to concentrate phosphorus in the solids. Michigan State University, Department of Animal Science, East Lansing, Michigan.

Terwillger, A.R., and L.S. Crauer. 1975. Liquid Composting Applied to Agricultural Wastes. In Managing Livestock Wastes, pp. 501-505. American Society of Agricultural Engineers, St. Joseph, MI.

UD. 1999. Changes for chicken? New Hybrid Corn Helps Reduce Phosphorus in Poultry Litter. UD scientists report. University of Delaware, August 1999. <http://www.eurekalert.org/releases/udel-cfc0824999.html>. Accessed September 10, 1999.

USDA APHIS. 1995. Swine '95 Part I: Reference of 1995 Grower/Finisher Health and Management. U.S. Department of Agriculture, animal and Plant Health Inspection Service, Washington DC. <http://www.aphis.usda.gov/vs/ceah/cahm/>. File sw95des2.pdf accessed October 15, 1998.

USDA APHIS. 1997. Waste Handling Facilities and Manure Management on U.S. Dairy Operations. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington DC. <http://www.aphis.usda.gov/vs/ceah/cahm/>. Accessed April 4, 2000.

USDA APHIS. 1996a. Environmental Practices/Management by U.S. Pork Producers. Swine '95 Part II: Reference of 1995 Grower/Finisher Health and Management. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington DC. <http://www.aphis.usda.gov/vs/ceah/cahm/>. Accessed April 4, 2000.

USDA APHIS. 1996b. *National Animal Health Monitoring System, Part III: Reference of 1996 Dairy Health and Health Management Practices*. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. Washington, D.C.

USDA APHIS. 1996c. *APHIS Info Sheet: Waste Handling Facilities and Manure Management on U.S. Dairy Operations*. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. Washington, D.C.

USDA NAHMS. 2000. Part I: Baseline Reference of Feedlot Management Practices: National Animal Health Monitoring System. May 2000.

USDA NRCS. 1995. Nutrient management for better crops, more profit, and clean water. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC.

USDA NRCS. 2000. Field Office Technical Guide No. IA-208. IA-208. U.S. Department of Agriculture, Natural Resources Conservation Service. Des Moines, IA. January.

USDA NRCS. 1999. National Handbook of Conservation Practices. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC.

USDA NRCS. 1998a. Nutrients available from livestock manure relative to crop growth requirements. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington DC.

USDA NRCS. 1998b. Nutrient Management. Natural Resources Conservation Service Conservation Practice Standard, Code 590.

USDA NRCS. 1996a. Agricultural waste management field handbook, Part 651. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC.

USDA. 1997. National Range and Pasture Handbook. Chapter 5: Management of Grazing Lands. U.S. Department of Agriculture. September 1997.

USEPA. 1999. Unified National Strategy for Animal Feeding Operations. U.S. Department of Agriculture and U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2000. Cost Model Report for Beef and Dairy Operations Developed for the Effluent Limitations Guidelines. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

Van der Peet-Schwering, C. 1993. Effect microbieel fytase in het voer op de opfokresultaten van gespeende biggen. Praktijkonderzoek varkenshouderij. Proefstation voor de Varkenshouderij, Rosmalen.

Van Horn, H.H., G.L. Newton and W.E. Kunkle. 1996. "Ruminant nutrition from an environmental perspective: factors affecting whole-farm nutrient balance" J. Anim. Sci.

74: 3082.

Van Horn, H.H., G.L. Newton, R.A. Nordstedt, E.C. French, G. Kidder, D.A. Graetz, and C.F. Chambliss. 1998. Dairy Manure Management: Strategies for Recycling Nutrient to Recover Fertilizer Value and Avoid Environmental Pollution. Florida Cooperative Extension Service, Institute of Food and Agricultural Services, University of Florida, Gainesville.

Van Horn, H.H. 1999. "Options in Managing Manure Phosphorus" Florida Ruminant Nutrition Symposium, Gainesville, Florida, Jan 14-15.

Vanschoubroeck, F., L. Coucke, and R. van Spaendonck. 1971. The quantitative effect of pelleting feed on the performance of piglets and fattening pigs. Nutr. Abstr. Rev. 41:1-9.

Veenhuizen, M.A., D.J. Eckert, K. Elder, J. Johnson, W.F. Lyon, K.M. Mancl, and G. Schnitkey. 1999. Ohio livestock manure and wastewater management guide, Bulletin 604, Extension Service, Ohio State University, Columbus, Ohio.

Vetsch, J. Fertility and Management Issues. Lecture Notes. June 23, 1999. Rippey, Iowa.

Wheaton, H.N. and J.C. Rea. 1999. Forages for Swine. University Extension, University of Missouri-Columbia, Publication No. G2360.

Wilkinson, S.R. 1992. Nitrogen carryover from broiler litter applied to coastal bermudagrass, IN: National livestock, poultry and aquaculture waste management - proceedings of the national workshop 29-31 July 1991, Westin Crown Center Hotel, Kansas, Missouri, ASAE publication 03-92, American Society of Agricultural Engineers, St. Joseph, MI, pp. 166-170.

Zhang, Ruihong, Li, Xiujing, Tao, Jun. 1999. Treatment of Dairy Wastewater with Sequencing Batch Reactor Systems (ASAE Paper No. 994069), written for presentation at the 1999 ASAE Annual International Meeting in Toronto, Canada, July 1999.

CHAPTER 9

NPDES REGULATORY OPTIONS

9.0 INTRODUCTION TO NPDES PROGRAM

Under the National Pollutant Discharge Elimination System (NPDES) permit program, all point sources that discharge pollutants to waters of the United States must apply for an NPDES permit and may discharge pollutants only under the terms of that permit. Such permits include nationally established technology-based effluent discharge limitations. In the absence of national effluent limitations, NPDES permit writers must establish technology-based limitations and standards on a case-by-case basis, based on the permit writer's best professional judgment.

In addition to the technology-based effluent limits, permits may also include water quality-based effluent limits where technology-based limits are not sufficient to ensure compliance with the water quality standards or to implement a Total Maximum Daily Load (TMDL). Permits may include specific best management practices to achieve effluent limitations, typically included as special conditions. In addition, NPDES permits normally include monitoring and reporting requirements, as well as standard conditions that apply to all permits (such as duty to properly operate and maintain equipment).

Under the existing NPDES regulations, a facility must first be defined as an Animal Feeding Operation (AFO). An AFO is a "lot or facility" where animals "have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period" and where "crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility." The existing NPDES program then has a three-tier structure, based primarily on facility size, under which an AFO is either defined or designated as a Concentrated Animal Feeding Operations (CAFO). The size of an AFO, based on numbers of animals, is expressed in terms of animal units, or AU. Each major livestock type, except poultry, is assigned a multiplication factor to determine the number of AU at the facility. Facilities with more than 1,000 AU are automatically defined as CAFOs. Facilities with more than 300 AU are also defined as CAFOs if they either discharge pollutants into navigable waters through a man-made ditch, flushing system, or other similar device or discharge pollutants directly into waters that originate outside of and pass over, across, or through the facility or come into direct contact with the confined animals. However, no AFO is defined as a CAFO if the facility discharges only in the event of a 25-year, 24-hour storm. Finally, where an operation does not meet the definition of a CAFO (including those with fewer than 300 AU), the permitting authority may still designate it a CAFO on a case-by-case basis after an inspection and based on the finding that the facility "is a significant contributor of pollution to the waters of the United States."

The current NPDES permit program for CAFOs is being revised to more effectively address water pollution problems. Currently, several scenarios are being considered to revise the structure of the NPDES rule. EPA is also proposing changes to strengthen, clarify, and simplify the NPDES regulation. The purpose of this section is to:

- Describe industry compliance with existing regulations
- Describe the permit scenarios under consideration
- Estimate the number of AFOs that would be affected under the different scenarios
- Estimate the administrative burden
- Describe additional changes to the NPDES regulation
- Cost these additional changes to the NPDES regulation

9.1 Industry Compliance with Existing Regulations

EPA promulgated the current NPDES regulations for CAFOs in 1976. For the purposes of this analysis, EPA assumes that all operations are currently fully complying with the existing regulatory program. This assumption represents the "baseline," and the costs EPA is attributing to the proposed regulatory revisions consist of the increment between these baseline costs and the costs of new regulatory requirements.

More specifically, EPA assumes that all operations are fully complying with the existing regulations because they fall into one of two categories. The first category consists of those operations that are defined or designated as CAFOs and that have in fact obtained a permit. EPA assumes, for purposes of costing the new regulations, that these CAFOs are in full compliance with their existing permits. The second category consists of all of the other unpermitted AFOs. EPA assumes that these operations do not need a permit because they fall outside the definition of a CAFO. For example, they might not meet the basic terms for being defined as a CAFO, or they might meet those terms but are excluded from the definition because they do not discharge except in the event of a 25-year, 24-hour storm. This second group of operations are also complying with the regulations in the sense that they are assumed not to be subject to the CAFO regulations in the first instance. In reality, however, there probably are a number of unpermitted operations that <u>are</u> subject to the regulations and <u>should</u> have a permit (for example, they incorrectly claim they are a "no discharge" facility, <u>as discussed in the preamble</u>). Consequently, EPA's assumptions are conservative: they tend to <u>underestimate</u> the number of facilities that should be subject to baseline costs today as permitted facilities, and therefore they <u>overestimate</u> the incremental costs of the new regulatory revisions.

This section presents EPA's approach and assumptions for identifying the population of AFOs that are subject to permitting under the <u>existing</u> CAFO permitting regulations. The universe of AFOs and CAFOs is discussed in this section by livestock category, size of operation, and production region. EPA's assumptions about what is needed to comply with the current CAFO regulations are consistent with the Agency's views as stated in its 1995 CAFO guidance manual, *Guidance Manual on NPDES Regulations for Concentrated Animal Feeding Operations* (USEPA, 1995; USEPA, 1999).

To be authorized by EPA to implement the NPDES program, states must adopt requirements that are at least as stringent as those set forth in the federal regulations. Many states have adopted stricter requirements that either lower the size threshold for animal feedlots or require additional controls designed to prevent water quality impairment. Note that the costs presented in Chapter 11 also account for individual state requirements that are more stringent than those of the federal NPDES program.

9.1.1 Approach and Assumptions for Identifying AFOs That Are Currently Subject to Regulation

The primary livestock sectors have been divided into five production regions consistent with development of the Cost Models. The designation and use of production regions allows for the aggregation of critical data on the number of facilities, production quantities, and financial conditions, which might otherwise not be possible because of concerns about disclosure.[1] The production regions are defined in Table 4-1.

The numbers of AFOs by livestock category, facility size, and region were generally obtained from the 1997 U.S. Census of Agriculture, from NASS bulletins (such as Cattle: Final Estimates and Layers), and from additional census analysis requested by EPA; they were supplemented by data and comments from industry. See Chapter 3 for more information on data collection. Swine, layer, and dairy operation data were estimated from "farms with inventory." All other livestock operation data were estimated from "farms with sales" and were divided by an assumed turnover rate—broilers = 5.5, swine = 2.8, turkeys = 3, beef = variable depending on size—but were assumed to be 2.2 for facilities with 301 to 1,000 AU. See Chapter 4: Industry Profiles for more details regarding EPA estimates of turnovers.

Livestock numbers were converted to EPA animal units assuming 1,000 AU are equal to 2,500 swine over 55 pounds, 55,000 turkeys, 30,000 laying hens using wet manure systems, 100,000 laying hens or broilers using dry manure systems, 700 mature dairy, or 1,000 beef cattle. Where data were not available for swine and poultry in the desired size ranges, the data were linearly interpolated to estimate the size group needed (e.g., 301 to 1,000 AU). For the beef and dairy sectors, the interpolation assumes for any given size range of farm, the smaller farms are the more numerous. Table 9-1 provides a summary of the number of facilities with animal inventories (or livestock sales as described above) by livestock sector, all production regions, and size of operation. See Chapter 4: Industry Profiles for more details regarding EPA estimates of numbers of farms.

---

[1] For example USDA Census of Agriculture data are not typically released unless there is a sufficient number of observations to ensure confidentially. Consequently, if data were aggregated on a state basis (instead of a regional basis), many key data points needed to describe the industry segments would be unavailable.

Table 9-1. Total 1997 Facilities With Confined Animal Inventories by Livestock Sector and Size*

	Region	<300 AUs	300 to 499 AUs	500 to 999 AUs	≥1,000 AUs
BEEF	Central	10,000	110	110	510
	Midwest	68,340	750	750	1,450
	MidAtlantic	15,370	90	90	20
	Pacific	3,940	20	30	80
	South	4,350	30	20	10
	Total	102,000	1,000	1,000	2,070
DAIRY	Central	9,690	610	410	410
	Midwest	59,680	860	590	90
	MidAtlantic	32,490	820	560	80
	Pacific	2,870	840	580	790
	South	5,000	260	170	80
	Total	109,730	3,390	2,310	1,450
SWINE	Central	8,270	80	90	130
	Midwest	63,750	540	3,710	2,440
	MidAtlantic	14,950	4,990	460	1,260
	Pacific	8,270	30	20	20
	South	8,270	180	180	240
	Total	95,240	5,820	4,460	3,850
LAYERS	Central	15,460	40	80	70
	Midwest	18,600	100	250	210
	MidAtlantic	24,610	120	210	120
	Pacific	6,950	30	120	110
	South	7,500	130	340	130
	Total	73,120	420	1,000	640

	Region	<300 AUs	300 to 499 AUs	500 to 999 AUs	≥1,000 AUs
BROILERS	Central	3,050	290	450	350
	Midwest	7,920	140	160	180
	MidAtlantic	5,110	1,440	1,720	940
	Pacific	1,240	30	50	110
	South	3,400	2,460	3,460	2,360
	Total	20,720	4,360	5,840	3,940
TURKEYS	Central	2,300	30	40	30
	Midwest	4,020	290	320	140
	MidAtlantic	3,260	360	380	80
	Pacific	1,020	50	70	50
	South	1,020	80	100	70
	Total	10,600	810	910	370
	Grand Total	420,700	15,800	12,520	12,560

*Numbers rounded to nearest 10. Numbers may not add due to independent rounding.

The numbers in Table 9-1 must be further adjusted to account for operations that have multiple livestock inventories (e.g., swine and layers at the same facility). EPA's analysis of 1992 Census data indicates that approximately 20 percent of facilities with fewer than 1,000 AU maintain multiple animal types. Hence, the number of small and medium facilities with livestock inventories is reduced by 20 percent to arrive at the actual number of AFOs. Thus for every 100 AFOs reported in the Census with fewer than 1,000 AU, 20 have multiple animal types, leaving only 80 unique facilities that are potentially permitted. For large facilities, EPA's analysis indicates 200 facilities have multiple livestock types that have more than 1,000 AU only when all animal types are summed; at these facilities no single animal type is present at more than 1,000 AU. A corresponding reduction in large facility numbers is necessary to arrive at the total number of AFOs in this size category. Note this reduction in facility counts applies only to the potential number of permits; industry costs of compliance discussed elsewhere in this document are assessed for all animal types that might be present at a given facility.

Table 9-2 displays the adjusted total number of AFOs by livestock category, production region, and facility size based on the estimates presented in Table 9-1. The adjusted numbers of AFOs presented in Table 9-2 are used throughout this section.

Table 9-2. Total Adjusted AFOs by Size and Livestock Sector*

	Region	<300 AUs	300 to 499 AUs	500 to 999 AUs	≥1,000 AUs
BEEF	Central	8,000	80	90	510
	Midwest	54,660	600	600	1,430
	MidAtlantic	12,290	80	70	20
	Pacific	3,150	20	20	70
	South	3,480	20	20	10
	Total	81,580	800	800	2,040
DAIRY	Central	7,750	490	330	400
	Midwest	47,750	690	470	90
	MidAtlantic	25,990	650	450	80
	Pacific	2,300	670	460	770
	South	4,000	200	140	80
	Total	87,780	2,700	1,850	1,420
SWINE	Central	6,620	60	70	120
	Midwest	50,990	3,990	2,970	2,400
	MidAtlantic	11,960	440	370	1,240
	Pacific	6,620	30	10	20
	South	6,620	150	140	240
	Total	82,810	4,670	3,560	4,020
LAYERS	Central	12,370	30	70	70
	Midwest	14,880	80	200	210
	MidAtlantic	19,690	90	170	110
	Pacific	5,560	30	90	110
	South	6,000	100	270	130
	Total	58,500	330	800	630
BROILERS	Central	2,440	230	360	350
	Midwest	6,340	110	130	180
	MidAtlantic	4,090	1,160	1,370	930
	Pacific	990	20	40	100
	South	2,720	1,970	2,770	2,320
	Total	16,580	3,490	4,670	3,880

	Region	<300 AUs	300 to 499 AUs	500 to 999 AUs	≥1,000 AUs
TURKEYS	Central	1,840	30	30	30
	Midwest	3,220	240	250	140
	MidAtlantic	2,610	280	310	80
	Pacific	820	40	60	50
	South	820	70	80	60
	Total	9,310	660	730	360
	Grand Total	336,570	12,650	12,410	12,350

*Numbers rounded to nearest 10. Numbers may not add due to independent rounding.

9.1.2 Livestock Categories

The following subsections describe many of the livestock categories that would be affected by the revised rule, including beef, dairy, swine, broilers, layers, and turkeys. Operations with 300 to 999 AU may be either defined or designated as a CAFO. Operations under 300 AU must be designated as a CAFO.

9.1.2.1 Beef

The beef industry is concentrated in the Central and Midwest production regions. Smaller concentrations of beef feeding operations exist in the MidAtlantic, South, and Pacific production regions.

Large AFOs. All large beef AFOs are assumed to be in full compliance, being either permitted or exempt because they have no discharges except in the event of a 25-year, 24-hour storm.

Medium AFOs. EPA assumes approximately 7 percent of medium-sized AFOs in the Midwest, Mid Atlantic, Pacific, and South production regions are CAFOs because at direct contact with waters of the United States (WOUS) or discharge through a man-made device (MMD); 3 percent of the AFOs in the Central region are CAFOs because of direct contact or discharge through MMD (Bracht, 1999; Bryon, 1999; Wilson, 1999; Funk, 1999; Gunter, 1999). Additionally, EPA assumes that 5 percent of all medium-size AFOs are designated as CAFOs because of the potential to discharge based on their infrequent use of effluent control systems and the topography of the facilities in relation to nearby WOUS (Bredencamp, 1999; Harrelson, 1999). EPA believes 5 percent is a conservative estimate based on how many operations should be designated and also because many operations are incurring costs under separate State regulatory (non-NPDES) and voluntary programs. Thus, based on the proposed new regulations, the formula used to estimate medium-sized facilities that are CAFOs is

> (Total AFOs × percentage that meet the CAFO definition, e.g., direct contact/conveyance via MMD) + (Total AFOs × percentage that would be designated)

Small AFOs. EPA assumes the same estimates as in the medium size category regarding direct contact/discharge via MMD are applied (7 and 3 percent, depending on region), however, the potential for significant discharge is estimated at approximately 0.1 percent. In general, EPA and States have not focused on facilities with fewer than 300 AU. Consequently, the number of small facilities designated as CAFOs has been very small for all livestock categories. Thus, the calculation used to estimate small regulated facilities is

(Total AFOs × percentage with direct contact or conveyance via MMD × designation rate)

Table 9-3 presents the number of beef feeding operations estimated to be in full compliance by region and size. These estimates were derived by multiplying numbers of AFOs by the direct contact/conveyance and designation rates discussed above.

Table 9-3. Regulated Beef Feeding Operations by Size Category Assuming Full Compliance*

Region	Total	<300 AU	300 to 999 AU	≥1,000 AU
Central	520	0	10	510
Midwest	1,570	0	140	1,430
Mid Atlantic	40	0	20	20
Pacific	70	0	0	70
South	10	0	0	10
Total	2,210	0	170	2,040

*Numbers rounded to nearest 10.

Estimates of the number of facilities with direct contact or with an MMD were derived based on conversations with USDA Extension personnel, state water quality staff, industry representatives, and others. (Bracht, 1999; Bredenkamp, 1999; Byron, 1999; Funk, 1999; Gunter, 1999; Harrelson, 1999; Wilson, 1999). The estimate of the number of small facilities that would be designated CAFOs is based on best professional judgment.

9.1.1.2 Dairy

The largest number of dairies assumed to be in compliance are in the Midwest and MidAtlantic production regions, as described in Chapter 4. Smaller numbers of dairies in compliance are located in the Central, Pacific, and South production regions. Note that although there are more dairies in the Midwest and MidAtlantic, the Central and Pacific regions actually have the most large dairies.

Large AFOs. EPA assumes all large dairy AFOs are in compliance, being either permitted or exempt because they have no discharges except in the event of a 25-year, 24-hour storm.

Medium AFOs. The dairy industry is dominated by medium and small operations in the Midwest and MidAtlantic regions. Many of these dairies were designed and built on or near WOUS and therefore have direct contact; others have some type of MMD. Estimates for the percentage of dairies in these two regions with direct contact or MMD range from less than 20 percent to 75 percent (Bickert, 1999; Groves, 1999; Holmes, 1999). Based on this information, it is estimated that 40 and 50 percent of the dairies in the Midwest and MidAtlantic regions, respectively, have direct contact or use an MMD, and are thus defined as CAFOs. In the other production regions, 10 to 20 percent of the dairies are assumed to be CAFOs because direct contact or use of an MMD[2] (Johnson, 1999). The designation rates in this size class range from 5 percent (Midwest, MidAtlantic, Pacific) to 10 percent (Central) to 15 percent (South) (Bickert, 1999; Orth, 1999).

Small AFOs. The same estimates as in the medium size category regarding direct contact/discharge via MMD are applied to the small category. Of these dairies, it is estimated that less than 0.1 percent would be subject to designation as CAFOs based on their potential to significantly contribute pollution to WOUS (designation rate = 0.1 percent). Table 9-4 provides estimates of the number of regulated dairies by size category for the various regions under the assumption of full compliance.

Table 9-4. Regulated Dairy Operations by Size Category Assuming Full Compliance With Existing Regulations*

Region	Total	<300 AUs[1]	300 to 999 AUs[2]	≥1000 AUs
Central	560	0	160	400
Midwest	620	10	520	90
MidAtlantic	690	0	610	80
Pacific	1,050	0	280	770
South	200	0	120	80
Total	3,120	10	1,690	1,420

*Numbers rounded to nearest 10.

9.1.2.3 Swine

The swine industry is concentrated in the Midwest and MidAtlantic production regions. The remaining swine facilities are in the Pacific region, emergent areas in the South Central region, and to a lesser extent in the South region.

[2]Central = 10 percent; South and Pacific = 20 percent.

Large AFOs. All large swine AFOs are assumed to be in compliance, being either permitted or exempt because they have no discharges except in the event of a 25-year, 24-hour storm.

Medium AFOs. Based on contacts with USDA Extension personnel, approximately 10 percent of facilities in this size category (across all regions) are assumed to have direct contact or use an MMD (Greenless,1999; Steinhart, 1999); all of these facilities are defined as CAFOs. Additionally, it is estimated (based on best professional judgment) that an additional 5 percent of the facilities have been designated.

Small AFOs. Estimates from a number of USDA Extension specialists concerning direct contact or use of an MMD by small operations range from 0 to 15 percent (Funk, 1999; Jacobson, 1999; Steinhart, 1999); 10 percent is assumed for all regions based on best professional judgment. Of these facilities, it is assumed that less than 0.1 percent are designated as CAFOs. Table 9-5 provides estimates of the number of regulated swine operations by size category under assumptions of full compliance.

Table 9-5. Regulated Swine Operations by Size Category Assuming Full Compliance*

Region	Total	<300 AU	300 to 999 AU	≥1000 AU
Central	140	0	20	120
Midwest	3,440	0	1,040	2,400
MidAtlantic	1,360	0	120	1,240
Pacific	30	0	10	20
South	280	0	40	240
Total	5,250	0	1,230	4,020

*Numbers rounded to nearest 10.

9.1.2.4 Layers

A layer operation is defined as a CAFO if it maintains more than 30,000 birds and uses a wet manure management system (a technology that has fallen out of favor in the industry and is not being used by new operations) or if it maintains more than 100,000 birds using continuous overflow watering and has the potential to discharge pollutants to WOUS. EPA recognizes that continuous overflow watering is an outdated technology that has fallen out of favor in both the layer and broiler industries.

Currently, as many as 60 percent of the operations in the South and Central production regions use a wet manure handling system, whereas only 0 to 5 percent of the facilities use a wet system in the other regions. These estimates are further discussed in Chapter 4 of this document. Of these operations, EPA assumes the large facilities have either been defined as CAFOs and are permitted or are in compliance, not having any discharge.

As noted in EPA’s 1995 permitting guidance, dry poultry operations are subject to the NPDES regulations if they establish a “crude liquid manure system” by stacking manure or litter in an outside area unprotected from rainfall and runoff. This analysis assumes that 10 percent of large operations and 5 percent of medium operations would be defined as CAFOs for this reason. This assumption is based on conversations with industry personnel, who indicate that layer facilities generally have long-term (> 6 months) storage, after which the manure is either sold or land applied (Funk, 1999; Jacobson, 1999; Patterson, 1999; Thomas, 1999; Tyson, 1999; York, 2000). The number of regulated layer operations is presented in Table 9-6 under assumptions of full compliance.

Table 9-6. Regulated Layer Operations by Size Category Assuming Full Compliance*

Region	Total	<300 AU	300 to 999 AU	≥1,000 AU
Central	110	0	60	50
Midwest	20	0	10	10
MidAtlantic	10	0	10	0
Pacific	10	0	0	10
South	300	0	220	80
Total	450	0	300	150

*Numbers rounded to nearest 10.

9.1.2.5 Broilers

Broiler operations with more than 30,000 birds are defined as CAFOs only if they use a liquid manure handling system. Because few, if any, broiler operations use a liquid manure handling system, the only way by which a broiler operation is defined as a CAFO currently is if, through its manure handling practices, it creates a form of liquid manure handling system (Carey, 1999). As noted, dry poultry operations may establish a “crude liquid manure system” by stacking litter in an outside area unprotected from rainfall or runoff. This analysis assumes that at least 10 percent of the large broiler operations and 5 percent of the medium operations stack litter temporarily, in a manner consistent with EPA’s interpretation of a liquid manure handling system and therefore would be defined as CAFOs (York, 2000). Furthermore, it is assumed that no broiler operations have direct contact with WOUS or an MMD (Carey, 1999; Gale, 1999; Lory, 1999; Patterson, 1999; Thomas, 1999; Tyson, 1999). No small broiler operations are assumed to be designated as CAFOs because this size category falls below the size that would typically be of concern to the permitting authorities. Table 9-7 presents regulated broiler operation numbers.

9.1.2.6 Turkeys

EPA assumes turkey operations with more than 55,000 birds (1,000 AUs) are in compliance, being either permitted or exempt because they have no discharges except in the event of a 25-year, 24-hour storm. The only other turkey AFOs subject to the NPDES program are those which discharge to WOUS. Because virtually all turkey operations use dry litter systems (Battaglia, 1999; Carey, 1999; Jones, 1999), the only operations that have the potential to discharge are those operations which have established a liquid manure system through the use of waste management practices that allow contact between manure and rainwater. It is estimated that 5 percent of the medium facilities in the South production region and 2 percent in the other regions are defined as CAFOs for this reason. As with broiler operations, it is assumed that no turkey facilities have direct contact or an MMD. Table 9-8 presents the number of turkey feeding operations in full compliance by region and size.

Table 9-7. Regulated Broiler Operations by Size Category Assuming Full Compliance*

Region	Total	<300 AU	300 to 999 AU	≥1,000 AU
Central	60	0	30	30
Midwest	30	0	10	20
MidAtlantic	220	0	130	90
Pacific	10	0	0	10
South	470	0	240	230
Total	790	0	410	380

*Numbers rounded to nearest 10.

Table 9-8. Regulated Turkey Operations by Size Category Assuming Full Compliance*

Region	Total	<300 AU	300 to 999 AU	≥1,000 AU
Central	30	0	0	30
Midwest	150	0	10	140
MidAtlantic	90	0	10	80
Pacific	50	0	0	50
South	70	0	10	60
Total	390	0	30	360

*Numbers rounded to nearest 10.

9.1.3 Summary of Feeding Operations in Compliance by Size and Type

The estimated number of regulated animal feeding operations based on an assumption of full compliance with the existing regulations is presented in Table 9-9.

Table 9-9. Summary of Effectively Regulated Operations by Size and Livestock Sector*

Livestock	Total	≥ 1,000 AU	300 to 999 AU	<300 AU
Beef	2,210	2,040	170	0
Dairy	3,120	1,420	1,690	10
Swine	5,250	4,020	1,230	0
Layers	450	150	300	0
Broilers	790	410	380	0
Turkeys	390	360	30	0
Total	12,210	8,400	3,800	10

*Numbers rounded to nearest 10.

This summary of animal operations that should currently have NPDES permits does not correspond with the number of NPDES permits issued to date. Most sources place the estimate of the number of facilities covered by NPDES permits at approximately 2,500 (SAIC, 1999).

Several reasons explain the large disparity between these numbers. First, many of the large facilities opt out of the NPDES program because they claim they do not discharge except in the event of a 25-year, 24-hour storm. Second, many authorized states have declined to issue NPDES permits for CAFOs, relying instead on regulatory mechanisms other than the NPDES program to regulate CAFOs. The balance between the NPDES program and the other state programs is discussed in more detail in following sections.

9.2 Affected Entities Under Proposed Scenarios for Revised NPDES CAFO Rule

EPA is proposing to revise the current three-tier structure in 40 CFR 122.23 for determining which facilities are CAFOs that are subject to NPDES requirements. Five scenarios are under consideration. Scenarios 1 through 3 have a three-tier structure similar to the current rule. Tier 1 is 1,000 AU and greater; Tier 2 is 300 to 999 AU; Tier 3 is fewer than 300 AU. Scenarios 4a and 4b have a two-tier structure. Under Scenario 4a, Tier 1 is 500 AU and greater; Tier 2 is fewer than 500 AU. Under Scenario 4b, Tier 1 is 300 AU and greater; Tier 2 is fewer than 300 AU. The following sections discuss the universe of AFOs that would be affected by the proposed scenarios by livestock category, size of operation (which varies by scenario), and production region. The tables for each of the scenarios give both the tier and the corresponding animal units. Note that Tier 1 of the three-tier structure is not the same as Tier 1 of the two-tier structure.

9.2.1 Regulatory Scenarios

In this section EPA identifies the five regulatory scenarios for the NPDES permit rule. These scenarios, briefly described below, consider different facility size thresholds and variations in regulatory requirements. Under all five regulatory scenarios, the following conditions apply:

- Clarify the definition of an AFO.
- Eliminate the 25-yr/24-hr storm exemption.
- Include dry poultry operations.
- Duty to apply: If the AFO meets the definition of a CAFO, it must apply for a permit.
- Include stand-alone immature swine and heifer operations.
- Eliminate use of the term “Animal Unit.”
- Eliminate the mixed animal multiplier.
- Include facility closure requirements.

More details on the above conditions are provided in sections 9.3 and 9.4.

9.2.2 Scenario 1: Three-Tier Structure

Scenario 1 maintains the current rule structure but adds the conditions listed in Section 9.2.1 (eliminate 25-yr/24-hr storm exemption, include dry poultry operations, etc.). The primary effect as far as the number of facilities which would be impacted is the addition of dry poultry operations, stand- alone immature operations, and facilities previously exempt due to the 25-yr/24-hr storm provisions. Tier 2 facilities would still be defined as CAFOs if pollutants are discharged through a man-made ditch, flushing system or other similar man-made device or if pollutants are discharged directly into WOUS that originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation. Facilities can also be designated CAFOs if they are significant contributors of pollutants through any other means of conveyance. Small facilities (Tier 3) can be designated only if pollutants are discharged into navigable waters through a man-made ditch, flushing system or other similar man-made device or pollutants are discharged directly into WOUS that originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation. A summary of the number of AFOs that would be defined as CAFOs under this scenario is presented in Table 9-10. In total, 16,520 facilities would have to apply for a permit under Scenario 1.

EPA assumes that nationwide there are only a small number (estimated as 10) of AFOs in Tier 3 that have been designated as CAFOs. Because Scenario 1 maintains the same conditions for designation, EPA assumes that the same number of operations will be designated under this scenario. For purposes of presentation, it is assumed that five of these small CAFOs are dairies and five are swine; in reality, they are spread across the various livestock categories.

Table 9-10. Scenario 1: Summary of AFOs by Livestock Sector Required to Apply for Permit

Livestock Sector	Region	Total CAFOs	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Beef	Central	520	510	10	0
	Midwest	1,570	1,430	140	0
	MidAtlantic	40	20	20	0
	Pacific	70	70	0	0
	South	10	10	0	0
	Total	2,210	2,040	170	0
Dairy	Central	560	400	160	0
	Midwest	620	90	520	5
	MidAtlantic	690	80	610	0
	Pacific	1,050	770	280	0
	South	200	80	120	0
	Total	3,120	1,420	1,690	5
Heifers	Central	100	80	20	0
	Midwest	90	20	70	0
	MidAtlantic	100	20	80	0
	Pacific	200	160	40	0
	South	40	20	20	0
	Total	530	300	230	0
Veal	Central	0	0	0	0
	Midwest	0	0	0	0
	MidAtlantic	0	0	0	0
	Pacific	20	10	10	0
	South	0	0	0	0
	Total	20	10	10	0

Livestock Sector	Region	Total CAFOs	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Swine	Central	140	120	20	0
	Midwest	3,440	2,400	1,040	5
	MidAtlantic	1,360	1,240	120	0
	Pacific	30	20	10	0
	South	280	240	40	0
	Total	5,250	4,020	1,230	5
Layers	Central	100	70	30	0
	Midwest	230	210	20	0
	MidAtlantic	130	110	20	0
	Pacific	120	110	10	0
	South	240	130	100	0
	Total	820	630	180	0
Broilers	Central	360	350	10	0
	Midwest	180	180	0	0
	MidAtlantic	980	930	50	0
	Pacific	100	100	0	0
	South	2,560	2,320	240	0
	Total	4,180	3,880	300	0
Turkeys	Central	30	30	0	0
	Midwest	150	140	10	0
	MidAtlantic	100	80	20	0
	Pacific	40	50	0	0
	South	70	60	10	0
	Total	390	360	40	0
	Grand Total	16,520	12,660	3,850	10

*Numbers rounded to nearest 10. Numbers may not add due to independent rounding.

9.2.3 Scenario 2: Three-Tier Structure with Revised Criteria for Defining a Middle-Tier CAFO

Scenario 2 specifies that any Tier 2 AFO (i.e., 300 to 1,000 AU) that meets any one of the following criteria is <u>defined</u> as a CAFO and is required to apply for an NPDES permit:

- Operation has insufficient storage capacity to contain all manure and wastewater from a 25-year, 24-hour storm event. (Also see Chapter 4)
- Operation has animals in direct contact with WOUS.
- Operation has a feedlot or storage area within 100 feet of WOUS.
- Operation has been the subject of an enforcement action in the past 5 years.
- Operation does not have or is not implementing a nutrient management plan.
- Operation transports manure off-site for land application and there is no nutrient management plan at the recipient's site. This also reflects operations that do not have any cropland, as described in Chapter 4.

The case-by-case designation of facilities as CAFOs is maintained as in Scenario 1.

<u>Who Must Apply for a Permit</u>

Estimating the number of total AFOs that will have to apply for a permit under Scenario 2 is difficult because the defining criteria are not mutually exclusive (e.g., many facilities without adequate storage may also transport manure off-site for land application, etc.). While estimates of the individual criteria have been obtained, determining how many facilities would be defined as CAFOs under all of the criteria is a judgement based on available data and contacts with industry representatives.

Tables 9-11 through 9-19 indicate the number of CAFOs that would be required to apply for a permit, by livestock category and region. While facilities may change operating practices in order to avoid the permit requirements, it is assumed that the following six categories of facilities will be required to apply for a permit:

- Facilities with insufficient storage.
- Facilities that have been the subject of enforcement actions in the past 5 years.
- Facilities that do not have a nutrient management plan.
- Facilities that transport manure off-site to land without a nutrient management plan.
- Facilities that have animals in direct contact with WOUS.
- Facilities where the production areas are within 100 feet of WOUS.

Estimates of facilities that would be included because of enforcement actions in the past 5 years were made by using data on recent enforcement actions in individual states. Data on enforcement actions are reported in the State Compendium (SAIC, 1999). Data obtained for eight states (Illinois, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Carolina, and

Ohio) indicate there were approximately 119 enforcement actions annually, or 595 when extrapolating over a 5-year period. The total number of Tier 1 and 2 AFOs in these states is approximately 15,380. Thus, it is estimated that nearly 4 percent (595/15,380 = 0.04) of the AFOs had an enforcement action in the past 5 years. However, it is not known how many of the enforcement actions were taken against Tier 2 AFOs. Further, it is not known if the eight states are representative of the nation. Consequently, the assumption used in this analysis is that only 1 percent of the Tier 2 AFOs have been the subject of enforcement actions in the past 5 years.

Beef CAFOs required to apply for a permit are presented in Table 9-11. These include facilities where cattle have direct contact with water, facilities that have been the subject of enforcement actions, and facilities with insufficient waste storage. In total it is estimated that approximately 57 percent of the Tier 2 beef facilities nationwide are assumed to be defined as CAFOs under this scenario.[3] Many of the Tier 2 beef feedlots have limited controls for effluents, principally storm water discharges, which EPA considers insufficient storage (Funk, 1999; Harrelson, 1999). Most of these facilities are thus defined as CAFOs because the lack of available land for manure application and inadequate storage.

Table 9-11. Scenario 2: Beef CAFOs Required to Apply for a Permit

Region	**Total**	**Tier 1 (≥1,000 AU)**	**Tier 2 (300-999 AU)**	**Tier 3 (<300 AU)**
Central	610	510	100	0
Midwest	2,110	1,430	680	0
MidAtlantic	110	20	90	0
Pacific	90	70	20	0
South	30	10	20	0
Total	2,950	2,040	910	0

Dairy CAFOs required to apply for a permit are presented in Table 9-12. Dairies were historically located such that they are within 100 feet of water, especially in the MidAtlantic and Midwest production regions. Facilities within 100 feet of water are estimated at 60 percent in the MidAtlantic and 50 percent in the Midwest; other regions range from 15 percent (Central) to 25 percent (South) (Bickert, 1999; Groves, 1999; Johnson, 1999; Holmes, 1999). Additionally, many of the dairies, estimated at 50 percent nationally (Bickert, 1999; Holmes, 1999), have

[3] This calculation is made step by step, with each factor considered incrementally. For illustration purposes, assume there are only two reasons why a facility would be defined as a CAFO: inadequate storage (a characteristic of 40 percent of facilities) and close proximity to water (a characteristic of 30 percent of facilities). Assuming there are 300 AFOs, the calculation for the number of CAFOs would be 300 × 40% = 120, *plus* (300-120) × 30% = 54, for a total of 174 (120 + 54).

inadequate manure storage. Various sources indicate that these dairies practice daily spreading of manure (Holmes, 1999; Bickert, 1999), including applications on frozen and potentially saturated ground. It is estimated that approximately 88 percent of the Tier 2 dairies would be defined as CAFOs under Scenario 2.

Table 9-12. Scenario 2: Dairy CAFOs Required to Apply for a Permit

Region	Total	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Central	1,090	400	690	0
Midwest	1,145	90	1,050	5
MidAtlantic	1,100	80	1,020	0
Pacific	1,740	770	970	0
South	370	80	290	0
Total	5,445	1,420	4,020	5

Heifer CAFOs required to apply for a permit are shown in Table 9-13. The assumptions regarding the percentage of dairy heifers with direct contact with water and inadequate manure storage were based on information obtained on dairy facilities discussed above.

Table 9-13. Scenario 2: Heifer CAFOs Required to Apply for a Permit

Region	Total	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Central	170	80	90	0
Midwest	160	20	140	0
MidAtlantic	160	20	140	0
Pacific	290	160	130	0
South	60	20	40	0
Total	840	300	540	0

Veal CAFOs required to apply for a permit are shown in Table 9-14. The assumptions regarding the percentage of veal operations with direct contact with or a man-made conveyance to water, facilities that have been the subject of enforcement actions, and facilities with inadequate manure storage were based on information obtained on beef facilities. Although EPA recognizes that the veal feeding industry is markedly different from the beef cattle industry, little information specific to veal is available.

Table 9-14. Scenario 2: Veal CAFOs Required to Apply for a Permit

Region	Total	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Central	20	0	20	0
Midwest	20	0	20	0
MidAtlantic	20	0	20	0
Pacific	40	10	30	0
South	10	0	10	0
Total	110	10	100	0

Swine CAFOs required to apply for a permit are summarized in Table 9-15. Only a limited number of Tier 2 facilities are added because of inadequate storage. Nationally, it is estimated that approximately 41 percent of the Tier 2 facilities would be defined as CAFOs, primarily because of the lack of available land on which to apply manure and wastewater.

Table 9-15. Scenario 2: Swine CAFOs Required to Apply for a Permit

Region	Total	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Central	170	120	50	0
Midwest	5,255	2,400	2,850	5
MidAtlantic	1,600	1,240	360	0
Pacific	40	20	20	0
South	360	240	120	0
Total	7,425	4,020	3,400	5

Layer AFOs required to apply for a permit under Scenario 2 are presented in Table 9-16. Very few of the Tier 2 facilities are located within close proximity to water (Patterson, 1999; Ernst, 1999) or have inadequate storage (Funk, 1999; Patterson, 1999). However, based on the analysis of Census of Agriculture data summarized in Chapter 4, very few of the operations have adequate land on which to apply manure. Consequently, 97 percent of the Tier 2 AFOs would be defined as CAFOs under Scenario 2.

Table 9-16. Scenario 2: Layer CAFOs Required to Apply for a Permit

Region	Total	Tier 1 (≥1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Central	170	70	100	0
Midwest	480	210	270	0
MidAtlantic	360	110	250	0
Pacific	230	110	120	0
South	490	130	360	0
Total	1,730	630	1,100	0

Broiler AFOs required to apply for a permit are presented in Table 9-17. As with layers, very few of the operations have adequate land on which to apply manure and would be defined as CAFOs for this reason. Regarding storage, numerous contacts indicated that storage was usually adequate, especially since the litter is removed only on an annual basis (Malone 1999; Patterson, 1999; Ramsey, 2000). However, as some contacts indicated, there is a high incidence of improper storage stemming from the fact that when litter is removed from the houses it may be temporarily stacked outside prior to land application (Johnson, 1999). Nationally, an estimated 96 percent of the Tier 2 broiler facilities would be defined as CAFOs under this scenario.

Table 9-17. Scenario 2: Broiler CAFOs Required to Apply for a Permit

Region	Total	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Central	920	350	570	0
Midwest	410	180	230	0
MidAtlantic	3,360	930	2,430	0
Pacific	160	100	60	0
South	6,870	2,320	4,550	0
Total	11,720	3,880	7,840	0

Table 9-18 presents the estimated number of turkey AFOs required to apply for a permit under Scenario 2. As with other poultry operations, most of the Tier 2 turkey operations have inadequate land on which to apply the manure. Largely because of the lack of available land, approximately 97 percent of the Tier 2 facilities are defined as CAFOs under this scenario.

Table 9-18. Scenario 2: Turkey CAFOs Required to Apply for a Permit

Region	Total	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Central	90	30	60	0
Midwest	620	140	480	0
MidAtlantic	650	80	570	0
Pacific	150	50	100	0
South	200	60	140	0
Total	1,710	360	1,350	0

A summary of all AFOs required to apply for a permit under Scenario 2 is presented in Table 9-19.

Table 9-19. Scenario 2: Summary of CAFOs by Livestock Sector Required to Apply for a Permit*

Livestock	Total	Tier 1 (>1,000 AU)	Tier 2 (300-999 AU)	Tier 3 (<300 AU)
Beef	2,950	2,040	910	0
Dairy	5,445	1,420	4,020	5
Heifers	840	300	540	0
Veal	110	10	100	0
Swine	7,425	4,020	3,400	5
Layers	1,730	630	1,100	0
Broilers	11,720	3,880	7,840	0
Turkeys	1,710	360	1,350	0
Total	31,930	12,660	19,260	10

* Numbers rounded to nearest 10

9.2.4 Scenario 3: Three-Tier Structure with Check Box Certification Form for Middle Tier

Under Scenario 3, the certification scenario, the definition criteria are the same as those for Scenario 2 and the threshold is again maintained for large facilities (Tier 1). Under Scenario 3 all medium AFOs (Tier 2) are also automatically defined as CAFOs. However, operations in Tier 2 that can certify they meet the following conditions do not have to apply for a permit:

- Operation has sufficient storage capacity to contain all manure and wastewater from a 25-year, 24-hour storm event.
- Operation does not have animals in direct contact with WOUS.
- Operation has a feedlot or storage area not within 100 feet of WOUS.
- Operation has not been the subject of an enforcement action in the past 5 years.
- Operation has a nutrient management plan.
- If operation transports manure off-site for land application, there is a nutrient management plan at recipient's site.

Those operations in the Tier 2 size category that cannot certify to the conditions described above must apply for a permit. Tier 3 operations may also be designated as CAFOs on a case-by-case basis. The effect of this scenario is that all Tier 2 facilities (approximately 25,820) would have to either certify or apply for a permit. Additionally, all Tier 1 facilities would have to apply for a permit.

Who Must Certify or Apply for a Permit

The number of facilities required to certify or apply for a permit under Scenario 3 is the total of all Tier 1 and Tier 2 facilities. The number actually estimated to obtain a permit is the same as in Scenario 2, and the numbers are summarized in Table 9-19. A sample certification form is shown below.

Form for Certifying Out of the Concentrated Animal Feeding Operation Provisions of the National Pollutant Discharge Elimination System

This checklist is to assist you in determining whether your animal feeding operation (AFO) is, or is not, a concentrated animal feeding operation (CAFO) subject to certain regulatory provisions. For clarification, please see the attached fact sheet.

Section 1. Determine whether your facility is an AFO.

A facility that houses animals is an animal feeding operation if animals (other than aquatic animals) have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period. Animals are not considered to be stabled or confined when they are in areas such as pastures or rangeland that sustain crops or forage growth during the entire time that animals are present.

☐ Yes, my facility is an AFO. PROCEED TO SECTION 2.
☐ No, my facility is <u>not</u> an AFO. STOP. YOU DO NOT NEED TO SUBMIT THIS FORM.

Section 2. Determine the size range of your AFO.

If your facility is an AFO and the number of animals is in the size range for any animal type listed below, your facility might be a concentrated animal feeding operation.

200–700 mature dairy cattle (whether milked or dry)
300–1000 head of cattle other than mature dairy cattle
750–2,500 swine each weighing over 25 kilograms (55 pounds)
3,000–10,000 swine each weighing under 25 kilograms (55 pounds)
30,000–100,000 chickens
16,500–55,000 turkeys
150–500 horses
3,000–10,000 sheep or lambs
1,500–5,000 ducks

☐ <u>My AFO is within this size range</u>. PROCEED TO SECTION 3.

☐ <u>My AFO has fewer</u> than the lower threshold number of animals for any animal type so it is not a CAFO under this description. STOP.

☐ <u>My AFO has more</u> than the upper threshold number of animals for any animal type. STOP. PLEASE CONTACT YOUR PERMIT AUTHORITY FOR INFORMATION ON HOW TO APPLY FOR AN NPDES PERMIT.

Section 3. Minimum Requirements

Check all boxes that apply to your operation.

☐ My production area is not located within 100 feet of waters of the U.S.
☐ There is no direct contact of animals with waters of the U.S. in the production area.
☐ I am currently maintaining properly engineered manure and wastewater storage and containment structures designed to prevent discharge in either a 25-year, 24-hour storm (for beef and dairy facilities) or all circumstances (for all other facilities), in accordance with the effluent guidelines (40 CFR Part 412).
☐ There are no discharges from the production area and there have been no discharges in the past 5 years.
☐ I have not been notified by my state permit authority or EPA that my facility needs an NPDES permit.

If all of the boxes in this section are checked, PROCEED TO SECTION 4. *If any box in this section is not checked, you may not use this certification and you must apply for an NPDES permit.* STOP. PLEASE CONTACT YOUR PERMIT AUTHORITY FOR MORE INFORMATION.

Section 4. Land Application

A. *If all of the boxes in Section 3 are checked, you might be able to certify that you are not a CAFO on the basis of ensuring proper agricultural practices for land application of CAFO manure:*

☐ I either do not land apply manure or, if land applying manure, I have and am implementing a certified Permit Nutrient Plan (PNP). I maintain a copy of my PNP at my facility, including records of implementation and monitoring; and

B. Check One:

☐ My state has a program for excess manure in which I participate.

OR

☐ [Alternative 1: I do not transfer more than 12 tons of manure to any off-site recipients unless they have signed a certification form assuring me that they are (1) applying manure according to proper agricultural practices; (2) obtaining an NPDES permit for discharges; or (3) transferring manure to other non-land application uses; and]

☐ [For Alternative 2, this box is not needed] I maintain records of recipients receiving greater than 12 tons of manure annually, including the quantity and dates transferred, and I provide recipients an analysis of the content of the manure as well as information describing the recipients' responsibilities for appropriate manure management. If I transfer manure or wastewater to a manure hauler, I also obtain the name and location of the recipients of the manure, if known.

If a box is checked in both subsection A and subsection B above, you may certify that you are not a CAFO. PROCEED TO SECTION 5.*If a box is not checked in both subsection A and* *subsection B above, you may not use this certification form.* STOP. YOU MUST APPLY FOR AN NPDES PERMIT.

Section 5. Certification

I certify that I own or operate the animal feeding operation described herein and have legal authority to make management decisions about the operation. I certify that the information provided is true and correct to the best of my knowledge.

I understand that in the event of a discharge to waters of the U.S. from my AFO, I must report the discharge to the Permit Authority and apply for a permit. I will report the discharge by phone within 24 hours, submit a written report within 7 calendar days, and make arrangements to correct the conditions that caused the discharge.

In the event any of these conditions can no longer be met, I understand that my facility is a CAFO and I must immediately apply for a permit. I also understand that I am liable for any unpermitted discharges. This certification must be renewed every 5 years.

I certify under penalty of law that this document was either prepared by me or prepared under my direction or supervision. Based on my inquiry of the person or persons who gatheried the information, the information provided is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are penalties for submitting false information, including the possibility of fine and imprisonment for known violations.

Facility Name ___________________ Name of Certifier __________________________

Signature __________________________ Date _____________

Check one: ☐ owner ☐ operator

Name and address of other entity that exercises substantial operational control of this CAFO:____

Address of animal feeding operation:____
County:____ State:________________________
Latitude/Longitude:____
Phone:____ Email:____________________
Name of closest waters of the U.S.:__________________ Distance to Waters:__________
Description of closest waters: (e.g., intermittent stream, perennial stream, ground water aquifer):____

9.2.5 Scenario 4: Two-Tier Structure

Under Scenario 4 EPA established a two-tier structure based on facility size. Tier 1 operations must apply for a permit. Tier 2 operations may be designated CAFOs, in which case they, too, would have to apply for a permit. Small facilities—those in Tier 2—can be designated CAFOs if they are significant contributors of pollutants. EPA analyzed two thresholds for Scenario 4: 300 AU and 500 AU.

9.2.5.1 Scenario 4a: Two-Tier Structure at 500 AU

For Scenario 4a Tier 1 CAFOs are all operations with 500 or more AU. Tier 2 CAFOs for this scenario are those operations fewer than 500 AU. As an alternative EPA considered Scenario 4b, under which Tier 1 CAFOs are all operations with 300 or more AU.

The Unified AFO Strategy (hereafter called the Strategy) suggests that most facilities will have a voluntary CNMP and that approximately 5 percent of the facilities will be covered by a permit. The Strategy strongly promotes the use of CNMPs for AFOs as a means of protecting water quality. The regulatory role outlined in the Strategy is for EPA to permit those facilities that pose the greatest risk to water quality. EPA has made this determination based on the size of operation. EPA expects, at most, that states and EPA would designate 250 Tier 2 AFOs (50 per year) based on egregious water quality problems. EPA expects that USDA will focus on those facilities (to obtain a CNMP) that are defined as CAFOs under the current regulations but would no longer be defined as CAFOs and would not be designated CAFOs under the proposed regulations. Table 9-20 presents the number of facilities that would be required to apply for an NPDES permit under Scenario 4a.

Table 9-20. Scenario 4a: Summary of CAFOs by Livestock Sector Required to Apply for a Permit*

Livestock	Total CAFOs	Tier 1 (≥500 AUs)	Tier 2 (<500 AUs)
BEEF			
Central	600	600	0
Midwest	2,050	2,030	20
MidAtlantic	90	90	0
Pacific	90	90	0
South	30	30	0
Total	2,860	2,840	20

Livestock	Total CAFOs	Tier 1 (≥500 AUs)	Tier 2 (<500 AUs)
DAIRY			
Central	730	730	0
Midwest	630	560	70
MidAtlantic	570	530	40
Pacific	1,230	1,230	0
South	220	220	0
Total	3,380	3,270	110
HEIFERS			
Central	150	150	0
Midwest	120	120	0
MidAtlantic	120	120	0
Pacific	260	260	0
South	50	50	0
Total	700	700	0
VEAL			
Central	10	10	0
Midwest	10	10	0
MidAtlantic	10	10	0
Pacific	30	30	0
South	0	0	0
Total	60	60	0
SWINE			
Central	190	190	0
Midwest	5,450	5,370	80
MidAtlantic	1,630	1,610	20
Pacific	30	30	0
South	380	380	0
Total	7,680	7,580	100

Livestock	Total CAFOs	Tier 1 (≥500 AUs)	Tier 2 (<500 AUs)
LAYERS			
Central	140	140	0
Midwest	410	410	0
MidAtlantic	280	280	0
Pacific	200	200	0
South	410	400	10
Total	1,440	1,430	10
BROILERS			
Central	710	710	0
Midwest	310	310	0
MidAtlantic	2,310	2,300	10
Pacific	140	140	0
South	5,090	5,090	0
Total	8,560	8,550	10
TURKEYS			
Central	60	60	0
Midwest	400	390	0
MidAtlantic	390	390	0
Pacific	110	110	0
South	140	140	0
Total	1,100	1,090	0
Grand Total	25,770	25,520	250

* Numbers rounded to nearest 10.

9.2.5.2 Scenario 4b: Two-Tier Structure at 300 AU

Under Scenario 4b, EPA established a two-tier structure based on size. Tier 1 CAFOs for this scenario are all operations with 300 or more AU. Tier 2 CAFOs for this scenario are those operations fewer than 300 AU. Tier 1 operations must apply for a permit; Tier 2 operations may be designated CAFOs and then would have to apply for a permit. It is anticipated that approximately 10 Tier 2 AFOs would be designated based on egregious water quality problems. Table 9-21 presents the number of facilities that would be required to apply for an NPDES permit under Scenario 4b.

Table 9-21. Scenario 4b: Summary of CAFOs by Livestock Sector Required to Apply for a Permit

Livestock	Total CAFOs	Tier 1 (≥300 AUs)	Tier 2 (<300 AUs)
BEEF			
Central	680	680	0
Midwest	2,630	2,630	0
MidAtlantic	170	170	0
Pacific	110	110	0
South	50	50	0
Total	3,640	3,640	0
DAIRY			
Central	1,220	1,220	0
Midwest	1,255	1,250	5
MidAtlantic	1,180	1,180	0
Pacific	1,900	1,900	0
South	420	420	0
Total	5,975	5,970	5
HEIFERS			
Central	190	190	0
Midwest	170	170	0
MidAtlantic	170	170	0
Pacific	310	310	0
South	70	70	0
Total	910	910	0
VEAL			
Central	30	30	0
Midwest	30	30	0
MidAtlantic	30	30	0
Pacific	60	60	0
South	10	10	0
Total	160	160	0

Livestock	**Total CAFOs**	**Tier 1 (≥300 AUs)**	**Tier 2 (<300 AUs)**
SWINE			
Central	250	250	0
Midwest	9,365	9,360	5
MidAtlantic	2,050	2,050	0
Pacific	60	60	0
South	530	530	0
Total	12,255	12,250	5
LAYERS			
Central	170	170	0
Midwest	490	490	0
MidAtlantic	370	370	0
Pacific	230	230	0
South	500	500	0
Total	1,760	1,760	0
BROILERS			
Central	940	940	0
Midwest	420	420	0
MidAtlantic	3,460	3,460	0
Pacific	160	160	0
South	7,060	7,060	0
Total	12,040	12,040	0
TURKEYS			
Central	90	90	0
Midwest	630	630	0
MidAtlantic	670	670	0
Pacific	150	150	0
South	210	210	0
Total	1,090	1,750	0
Grand Total	38,490	38,480	10

* Numbers rounded to nearest 10

9.2.6 Summary of CAFOs Requiring Permits/Applications Under Regulatory Scenarios

Table 9-22 provides a summary of the total number of AFOs that will be required to apply for a permit (or certify they meet certain requirements, as described in Scenario 3), under all regulatory scenarios.

Table 9-22. Scenarios 1–4: AFOs by Livestock Sector Required to Apply for a Permit or Certify as to Permitting Requirements Under the Proposed Regulations

Livestock	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b
Beef	2,210	2,950	2,950	2,860	3,640
Dairy	3,120	5,445	5,445	3,380	5,975
Heifers	530	840	840	700	910
Veal	20	110	110	60	160
Swine	5,250	7,425	7,425	7,680	12,255
Layers	820	1,730	1,730	1,440	1,760
Broilers	4,180	11,720	11,720	8,560	12,040
Turkeys	390	1,710	1,710	1,100	1,750
Total	16,520	31,930	31,930	25,770	38,490

* Numbers rounded to nearest 10. Numbers may not add due to independent rounding.

9.3 State and Federal Administrative Costs for General and Individual Permits

States and the Federal government (EPA) incur administrative costs related to the development, issuance, and tracking of general or individual permits. In describing these administrative costs, this section first discusses findings regarding the Unfunded Mandates Reform Act of 1995 (UMRA). Subsequently, permitting cost estimates related to the issuance of general and individual permits for both states and the Federal government are presented. Finally, the section presents the total costs for both general and individual permits, for states and the Federal government, under the regulatory scenarios being considered.

9.3.1 Unfunded Mandates Reform Act

Title II of UMRA, Public Law 104-4, establishes requirements for federal agencies to assess the effects of their regulatory actions on state, local, and tribal governments and the private sector. Under section 202 of the UMRA, EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with Federal mandates that might result in costs to state, local, and tribal governments, in the aggregate, or to the private sector, of $100 million or more in any one year.

EPA has determined that the options being considered for the NPDES CAFO rule do not include a federal mandate that might result in estimated costs of $100 million or more to State, local, or tribal governments in the aggregate. State-incurred costs under the regulatory options being considered are discussed in the remaining portions of this section, along with Federal costs. Tribal governments might also incur compliance costs; however, these costs are expected to be modest and have not been estimated. EPA has determined that the options considered include no regulatory requirements that might significantly or uniquely affect local governments.

9.3.2 State and Federal Administrative Unit Costs for General Permits

A general permit will require states and EPA to issue public notices, answer any public comments received, and possibly conduct public hearings. States and EPA will also incur costs each time a facility operator applies for coverage under a general permit because of the expenses associated with a notice of intent. These per facility administrative costs include annual record keeping expenses associated with tracking notices of intent and performing initial facility inspections.

Table 9-23 provides estimates of administrative costs associated with a general permit. Unit general permit costs for public hearings, public notifications, and response to comments were provided by a number of state permitting branch employees (Allen, 1999; Kauz Loric, 1999). The most pertinent of these costs came from the state of Maryland, which has recently developed a general permit. Although the state of Washington also provided costs on general permit development, the state had incurred some exceptional expenses that were deemed unrepresentative. (The state had held 23 public meetings and had taken 4 years to answer all comments.)

Information regarding costs (for both general and individual permits) was typically provided in terms of labor hours. Hours were monetized using estimated average wage rates. For states, the annual average salary was estimated at $42,000, or $20.19 per hour assuming 2,080 work hours per year. This rate was multiplied by 1.4 to account for benefits to obtain a final loaded hourly wage rate of $28.27. Federal wage rates were estimated based on an annual rate of $47,891 (GS 12, Step 1), which was divided by 2,080 hours per year and then multiplied by 1.6 to account for benefits, resulting in a final loaded hourly labor rate of $36.84 (SAIC, 2000). State costs to issue one general permit and provide for public notification of applicants are estimated at approximately $35,820. Federal administrative costs are higher at $40,630.

Table 9-23 presents the administrative costs associated with a general permit. Permit development estimates were made based on the assumption that many states would adapt with relatively minor changes to the EPA model permit. Some states have experienced much higher costs, but that is believed to be the result of developing a permit without adapting EPA's model. The estimated permit development costs shown in the table appropriately account for states that might decide to develop a general permit independently as well as those states that will adapt EPA's model general permit. EPA obtained public notice/response to comment estimates from the Maryland and Washington state programs. Maryland mailed public notices to 10 papers (est. 10 hours), and responding to comments required 2 weeks of one FTE (80 hours); thus the Maryland total is 90 hours. Washington's costs for public notice were nominal, but responding to comments took four FTE working 25 percent for 4 years (2080 × 4). It is assumed that this

Table 9-23. Administrative Costs Associated With a General Permit

Item	Range (hours or $)		Representative Average	State Cost	Federal Cost
	Low	High			
General Permit Development and Administration Costs					
(1) Permit development	100	300	200	$5,650	$7,370
(2) Public notice/response to comments	90	8,000	120	$3,390	$4,420
(3) Public hearing(s)	120	360	240	$6,780	$8,840
(4) Quarterly public notification	$400	$8,000	$4,000	$20,000	$20,000
TOTAL				**$35,820**	**$40,630**
General Permit Costs Per Each Facility Covered					
Review/approve notice of intent	1	1	1	$30	$40
(5) Facility inspection	$1,000	$1,000	$1,000	$1,000	$1,000

cost was unusually high and that the Maryland experience is more representative. Public hearing estimates were based on an estimated time per meeting of 60 hours. EPA assumed states would have two to six meetings. Inspection costs were based on Region 6's and Texas's average costs per inspection of $1,000. EPA estimates 10 percent of facilities will be inspected. Hourly costs were monetized using a loaded rate of $28.27 per hour. This rate is based on $42,000 (1999 dollars) per year or $20.19/hour assuming 2,080 work hours multiplied by 1.4 to account for benefits. All costs were rounded to the nearest $10. Federal costs were based on $46,744/year (GS 12, Step 1, 1999), divided by 2,080 hours, then multiplied by 1.6 to account for benefits, resulting in a final loaded hourly labor rate of $36.84 (SAIC, 2000).

9.3.3 State and Federal Administrative Unit Costs for Individual Permits

Table 9-24 shows the administrative costs associated with individual permits for both states and the Federal government. Obtaining an individual permit requires a state or EPA to review the permit application, provide public notice, and possibly respond to public comments. In a percentage of cases (estimated in this analysis at 12 percent based on conversations with permitting authorities in Kansas, Indiana, Missouri, Ohio, and Wisconsin), a public hearing might be necessary. Additionally, an initial facility inspection might be necessary, estimated to cost the state or EPA approximately $1,000. Unit individual permit costs for permit review, public hearings, and inspections were provided by several state permitting branch contacts who issue individual permits (Clark, 1999; Foley, 1999; Nicholson, 1999; Teague, 1999). Additionally, public hearing costs were based on information obtained from general permit costs.

EPA used response-to-comments estimates from Kansas. Kansas estimates 2 to 3 FTEs dedicated to responding to comments, or from 4,160 to 6,240 hours divided by 50 to 100 permits per year. Washington provided hearing estimates, which indicated each hearing required approximately 100 to 150 hours of State employee time. Using best professional judgment, EPA assumes 1 to 2 public meetings or hearings per permit at 100 to150 hours per hearing. The percentage of applications requiring a hearing is based on data from Kansas (4 to 8 percent) and Indiana (15 to 20 percent). EPA based the average cost per inspection of $1,000 on data from Region 6 and Texas. EPA estimates 10 percent of facilities will be inspected.

Table 9-24. Administrative Costs Associated with an Individual Permit

Item	Range (hours)		Representative	State	Federal
	Low	**High**	**Average**	**Cost**	**Cost**
INDIVIDUAL PERMIT COST CATEGORIES FOR EACH FACILITY COVERED					
(1) Permit review/public notification/response to comments	60	80	70	$1,980	$2,580
(2) Public hearing	100	300	200		
(3) Percent of applications requiring hearing	4	20	12		
Ave. Public Hearing Cost/Permit				$680	$880
TOTAL				$2,660	$3,460
(4) Inspections	$1,000	$1,000	$1,000		

9.4 State and Federal Administration Costs by Regulatory Scenario

In this subsection, the estimated state and Federal permit administrative costs discussed in section 9.3 are applied to the number of livestock facilities that will be permitted or certified as described in section 9.2. The resulting costs are presented by the five regulatory scenarios.

In determining the total costs for each scenario, note that 70 percent of all permits issued were assumed to be general permits and the remaining 30 percent were assumed to be individual; EPA notes this is a somewhat heavier reliance on general permits than has historically been the case, but believes the trend toward general permits for the vast majority of CAFOs will continue. EPA estimates facility inspections are necessary for 10 percent of all permit applications. Finally, note that the 42 NPDES-authorized states were assumed to account for 96 percent of the total permits issued.[4] All costs are annualized using a 7 percent discount rate over a period of 5 years.

9.4.1 Scenario 1: State and Federal Administrative Costs for General and Individual Permits

Table 9-25 presents the breakout of state administrative costs for general and individual permits, and Table 9-26 shows Federal permit costs; both tables represent administrative costs for regulatory Scenario 1. Total administrative permitting costs over the 5-year permitting cycle are estimated at about $16.1 million for states and $1.1 million for the Federal government. Annualized costs are estimated at $3.9 million for the states and $0.3 million for the Federal government. The 16,520 total CAFOs permitted under Scenario 1 consist of 11,100 general (NOI) permits and 4,760 individual permits for a State total of 15,860, plus 460 general (NOI) permits and 200 individual permits for a Federal total of 660.

[4] The AFOs located in the eight states that do not have NPDES authorization for their CAFO programs account for less than 4 percent of the national total.

Table 9-25. State Administrative Costs Under Scenario 1

	Unit Cost	Number Req.	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$35,820	42	$1,504,440
General Permit Tracking Costs			
Notification of Intent	$30	11,100	$333,000
Inspections	$1,000	1,110	$1,110,000
Total General Permit Costs			$2,947,440
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$2,660	4,760	$12,661,600
Inspections	$1,000	476	$476,000
Total Individual Permit Costs			$13,137,600
GRAND TOTAL			**$16,085,040**
ANNUALIZED TOTAL			**$3,922,990**

Table 9-26. Federal Administrative Costs Under Scenario 1

	Unit Cost	Number Required	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$40,630	8	$325,040
General Permit Tracking Costs			
Notification of Intent	$40	460	$18,400
Inspections	$1,000	46	$46,000
Total General Permit Costs			$389,440
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$3,460	200	$692,000
Inspections	$1,000	20	$20,000
Total Individual Permit Costs			$712,000
GRAND TOTAL			**$1,101,440**
ANNUALIZED TOTAL			**$268,630**

9.4.2 Scenario 2: State and Federal Administrative Costs for General and Individual Permits

Scenario 2 requires that all Tier 1 facilities apply for an NPDES permit. AFOs in Tier 2 that meet specific criteria (insufficient waste storage capacity, direct contact with water, past violation, etc.) are defined as CAFOs and are required to apply for a permit. Both Tier 1 and Tier 2 facilities would be issued permits except in those cases (assumed to be infrequent) when an operation can demonstrate that it has "no potential to discharge." EPA estimates that a total of 31,930 facilities will be required to apply for a permit because of discharges or potential to discharge from the feeding operation itself or because of improper management of manure or wastewater.

Under Scenario 2, states may incur costs associated with permitting—both general and individual permits—of approximately $29.7 million, as shown in Table 9-27. Additionally, the Federal government is expected to spend approximately $1.7 million to permit CAFOs under Scenario 2, as shown in Table 9-28. Annualized costs to states are approximately $7.2 million and costs to the Federal government are $0.4 million. The 31,930 total CAFO permits under Scenario 2 consist of 21,460 general (NOI) permits and 9,190 individual permits for a State total of 30,650, plus 900 general (NOI) permits and 380 individual permits for a Federal total of 1,280.

Table 9-27. State Administrative Costs Under Scenario 2

	Unit Cost	Number Req.	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$35,820	42	$1,504,440
General Permit Tracking Costs			
Notification of Intent	$30	21,460	$643,800
Inspections	$1,000	2,146	$2,146,000
Total General Permit Costs			$4,294,240
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$2,660	9,190	$24,445,400
Inspections	$1,000	919	$919,000
Total Individual Permit Costs			$25,364,400
GRAND TOTAL			**$29,658,640**
ANNUALIZED TOTAL			**$7,233,470**

Table 9-28. Federal Administrative Costs Under Scenario 2

	Unit Cost	Number Req.	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$40,630	8	$325,040
General Permit Tracking Costs			
Notification of Intent	$40	900	$36,000
Inspections	$1,000	90	$90,000
Total General Permit Costs			$451,040
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$3,170	380	$1,204,600
Inspections	$1,000	38	$38,000
Total Individual Permit Costs			$1,242,600
GRAND TOTAL			**$1,693,640**
ANNUALIZED TOTAL			**$413,060**

9.4.3 Scenario 3: State and Federal Administrative Costs for General and Individual Permits

Under Scenario 3, the certification scenario, facilities in Tier 1 are CAFOs and, as described above, must obtain a permit unless they have demonstrated no potential to discharge. All Tier 2 AFOs are also initially defined as CAFOs and must either certify they do not meet specific conditions to be a CAFO or obtain a permit. Designated Tier 3 facilities must also obtain a permit. EPA estimates that a total of 38,490 facilities will be required to apply for a permit or certify that they do not meet the criteria specified in the scenario. For purposes of estimating administrative costs it is assumed that 31,930 facilities will actually obtain a permit.

Tables 9-29 and 9-30 present the estimated state and Federal administrative costs to permit CAFOs under Scenario 3. States will experience costs of approximately $29.8 million or $7.3 million annualized. The Federal government is estimated to incur approximately $1.7 million in costs or $0.4 million annualized to permit facilities under this scenario. The combined total number of CAFOs either certifying or obtaining permits is 38,490. The 31,930 total CAFO permits under Scenario 3 consist of 21,460 general (NOI) permits and 9,190 individual permits for a State total of 30,650, plus 900 general (NOI) permits and 380 individual permits for a Federal total of 1,280.

Table 9-29. State Administrative Costs Under Scenario 3

	Unit Cost	Number Req.	Total Cost
CERTIFICATION COSTS	$30	6,300	$189,000
GENERAL PERMIT COSTS			
General Permit Development Costs	$35,820	42	$1,504,440
General Permit Tracking Costs			
Notification of Intent	$30	21,460	$643,800
Inspections	$1,000	2,146	$2,146,000
Total General Permit Costs			$4,483,240
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$2,660	9,190	$24,445,400
Inspections	$1,000	919	$919,000
Total Individual Permit Costs			$25,364,400
GRAND TOTAL			**$29,847,640**
ANNUALIZED TOTAL			**$7,279,560**

Table 9-30. Federal Administrative Costs Under Scenario 3

	Unit Cost	Number Req.	Total Cost
CERTIFICATION COSTS	$40	260	$10,400
GENERAL PERMIT COSTS			
General Permit Development Costs	$40,630	8	$325,040
General Permit Tracking Costs			
Notification of Intent	$40	900	$36,000
Inspections	$1,000	90	$90,000
Total General Permit Costs			$461,440
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$3,170	380	$1,204,600
Inspections	$1,000	38	$38,000
Total Individual Permit Costs			**$1,242,600**
GRAND TOTAL			**$1,704,040**
ANNUALIZED TOTAL			**$415,600**

9.4.4 Scenario 4: State and Federal Administrative Costs for General and Individual Permits

Under Scenario 4a, facilities in Tier 1 are CAFOs and must obtain a permit as described above. Designated Tier 2 facilities, estimated at 250, must also obtain a permit. In total it is estimated that 25,770 facilities will be required to apply for a permit. Tables 9-31 and 9-32 present the estimated state and Federal administrative costs to permit CAFOs under regulatory Scenario 4a. The 25,770 total CAFOs permitted under Scenario 3 consist of 17,320 general (NOI) permits and 7,420 individual permits for a State total of 24,740, plus 720 general (NOI) permits and 310 individual permits for a Federal total of 1,030.

Under Scenario 4b, facilities in Tier 1 are CAFOs and must apply for a permit as described above. Designated Tier 2 CAFOs must also obtain a permit. EPA estimates that a total of 38,490 facilities will be required to apply for a permit. Tables 9-33 and 9-34 present the estimated state and Federal administrative costs to permit CAFOs under regulatory Scenario 4b. The 38,490 total CAFO permits under Scenario 4b consist of 25,870 general (NOI) permits and 11,080 individual permits for a State total of 36,950, plus 1,080 general (NOI) permits and 460 individual permits for a Federal Total of 1,540.

Table 9-31. State Administrative Costs Under Scenario 4a

	Unit Cost	Number Req.	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$35,820	42	$1,504,440
General Permit Tracking Costs			
Notification of Intent	$30	17,320	$519,600
Inspections	$1,000	1,732	$1,732,000
Total General Permit Costs			$3,756,040
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$2,660	7,420	$19,737,200
Inspections	$1,000	742	$742,000
Total Individual Permit Costs			$20,479,200
GRAND TOTAL			**$24,235,240**
ANNUALIZED TOTAL			**$5,910,750**

Table 9-32. Federal Administrative Costs under Scenario 4a

	Unit Cost	Number Req.	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$40,630	8	$325,040
General Permit Tracking Costs			
Notification of Intent	$40	720	$28,800
Inspections	$1,000	72	$72,000
Total General Permit Costs			$425,840
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$3,170	310	$982,700
Inspections	$1,000	31	$31,000
Total Individual Permit Costs			**$1,013,700**
GRAND TOTAL			**$1,439,540**
ANNUALIZED TOTAL			**$351,090**

Table 9-33. State Administrative Costs under Scenario 4b

	Unit Cost	Number Req.	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$35,820	42	$1,504,440
General Permit Tracking Costs			
Notification of Intent	$30	25,870	$776,100
Inspections	$1,000	2,587	$2,587,000
Total General Permit Costs			$4,867,540
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$2,660	11,080	$29,472,800
Inspections	$1,000	1,108	$1,108,000
Total Individual Permit Costs			$30,580,800
GRAND TOTAL			**$35,448,340**
ANNUALIZED TOTAL			**$8,645,520**

Table 9-34. Federal Administrative Costs Under Scenario 4b

	Unit Cost	Number Req.	Total Cost
GENERAL PERMIT COSTS			
General Permit Development Costs	$40,630	8	$325,040
General Permit Tracking Costs			
Notification of Intent	$40	1080	$43,200
Inspections	$1,000	108	$108,000
Total General Permit Costs			$476,240
INDIVIDUAL PERMIT COSTS			
Permit Review/Approval	$3,170	460	$1,458,200
Inspections	$1,000	46	$46,000
Total Individual Permit Costs			**$1,504,220**
GRAND TOTAL			**$1,980,440**
ANNUALIZED TOTAL			**$483,010**

9.4.5 Summary of State and Federal Administration Costs by Regulatory Scenario

Total annualized state and Federal administrative expenses for permitting CAFOs vary from approximately $4.2 million under Scenario 1 to $9.1 million under Scenario 4b (see Table 9-35). Under the most inclusive permitting scenario, State costs do not exceed $8.7 million per year annualized, which is well below the $100 million threshold for UMRA.

Table 9-35. Total Annualized State and Federal Administrative Costs by Regulatory Option

Regulatory Scenario	State	Federal	Total
Scenario 1	$3,922,990	$268,630	$4,191,620
Scenario 2	$7,233,470	$413,060	$7,646,530
Scenario 3	$7,279,560	$415,600	$7,695,160
Scenario 4a	$5,910,750	$351,090	$6,224,040
Scenario 4b	$8,645,520	$483,010	$9,128,530

9.5 Changes to NPDES Regulations

In addition to changing the threshold for determining which facilities are CAFOs, EPA is proposing a number of other changes that address how the permitting authority determines whether a facility is an AFO or a CAFO, which must apply for an NPDES permit. These changes also simplify, clarify, and strengthen the NPDES regulation.

9.5.1 Definition of AFO as It Relates to Pastures and Rangeland

EPA proposes to clarify the regulatory language that defines the term "Animal Feeding Operation," or "AFO," to remove ambiguity. (See proposed §122.23(a)(2).) The revised rule language would clarify that animals are not considered to be "stabled or confined" when they are in areas such as pastures or rangeland that sustain crops or forage during the entire time the animals are present. AFOs are enterprises where animals are kept and raised in confined situations. AFOs concentrate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, in fields, or on rangeland. The current regulation (40 CFR 122.23(b)(1)) defines an AFO as a "lot or facility where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period; *and where crops, vegetation[,] forage growth, or post-harvest residues are not sustained over any portion of the lot or facility in the normal growing season*" [emphasis added].

The existing definition states that animals must be kept on the lot or facility for a minimum of 45 days in a 12-month period. If an animal is at a facility for any portion of a day, it is considered to be at the facility for a full day. This definition does not mean that the same animals must remain on the lot for 45 consecutive days or more; it means only that some animals are fed or maintained on the lot or at the facility for 45 days out of any 12-month period. The 45 days do not have to be consecutive, and the 12-month period does not have to correspond to the calendar year. For example, June 1 to the following May 31 would constitute a 12-month period.

The definition has proven to be difficult to implement and has led to some confusion. Some CAFO operators have asserted that they are not AFOs under this definition where incidental growth occurs on small portions of the confinement area. In the case of certain wintering operations, animals confined during winter months quickly denude the feedlot of growth that grew during the summer months. The AFO definition includes those confinement areas that have growth over only a small portion of the facility or that have growth during only a portion of the time that the animals are present. The definition excludes pastures and rangeland that are largely covered with vegetation that can assimilate the nutrients in the manure. The intention is for AFOs to include areas where animals are confined in such a density that significant vegetation cannot be sustained over most of the confinement area.

As indicated in EPA's 1974 Development Document, the reference to vegetation in the definition is intended to distinguish feedlots (whether outdoor confinement areas or indoor covered areas with constructed floors) from pasture or grazing land. If a facility maintains animals in an area without vegetation, including dirt lots or constructed floors, the facility meets this part of the definition. EPA also considers dirt lots with nominal vegetative growth while animals are present to meet the second part of the AFO definition, even if substantial growth of vegetation occurs during months when animals are kept elsewhere. Thus, in the case of a wintering operation, EPA considers the facility an AFO potentially subject to NPDES regulations as a CAFO. It is not EPA's intention to include within the AFO definition pasture or rangeland that has a small, bare patch of land, in an otherwise vegetated area, that is caused by animals frequently congregating if the animals are not confined to the area.

The following examples are presented to further clarify EPA's intent. (1) When animals are restricted to vegetated areas as in the case of rotational grazing, they would not be considered to be confined in an AFO if they are rotated out of the area while the ground is still covered with vegetation. (2) If a small portion of a pasture is barren because, for example, animals congregate near the feed trough in that portion of the pasture, that area is not considered an AFO because animals are not confined to the barren area. (3) If an area has vegetation when animals are initially confined there, but the animals remove the vegetation during their confinement, that area would be considered an AFO. This situation might occur, for instance, at some wintering operations.

To address the ambiguities noted above, EPA is proposing regulatory language that defines the term "animal feeding operation" as follows: "*An animal feeding operation or AFO* is a facility where animals (other than aquatic animals) have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period. Animals are not considered to be stabled or confined when they are in areas such as pastures or rangeland that sustain crops or forage growth during the entire time that animals are present. Animal feeding operations include both the production area and land application area as defined below."

9.5.2 Definition of AFO as It Relates to Land Application Areas

EPA revised the definition of an AFO to include both the animal production areas of the operation and the land areas, if any, under the control of the owner or operator, on which manure and associated wastewaters are applied. (See proposed §122.23(a)(2).) The definition of a CAFO is based on the AFO definition and thus would include the land application areas as well. Accordingly, a permit for a CAFO would include requirements to control not only discharges from the production areas but also discharges from the land application areas. Under the existing regulations, discharges from a CAFO's land application areas that result from improper agricultural practices are already considered to be discharges from the CAFO and therefore are subject to the NPDES permitting program. However, EPA believes it would be helpful to clarify the regulations on this point.

By the term "production area" EPA means the animal confinement areas, the manure storage areas (e.g., lagoon, shed, pile), the feed storage areas (e.g., silo, silage bunker), and the waste containment areas (e.g., berms, diversions). The land application areas include any land to which a CAFO's manure and wastewater is applied (e.g., crop fields, fields, pasture) that is under the control of the CAFO owner or operator whether through ownership or a lease or contract. The land application areas do not include areas that are not under the CAFO owner's or operator's control. For example, where a nearby farm is owned and operated by someone other than the CAFO owner or operator, and the nearby farm applies manure from the CAFO to its own crop fields, those crop fields are not part of the CAFO.

The definition of an AFO under the existing regulations refers to a "lot or facility" that meets certain conditions, including that "[c]rops, vegetation[,] forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility" (40 CFR 122.23(b)(1)). In addition, the regulations define "discharge of a pollutant" as the addition of any pollutant to waters of the United States from any point source (40 CFR 122.2). EPA interprets the current regulations to include discharges of CAFO-generated manure and wastewaters from land application areas under the control of the CAFO as discharges from the CAFO itself. Otherwise, a CAFO could simply move its wastes outside the area of confinement and overapply or otherwise improperly apply those wastes, which would render the CWA prohibition on unpermitted discharges of pollutants from CAFOs meaningless. Moreover, the pipes and other manure-spreading equipment that convey CAFO manure and wastewaters to land application areas under the control of the CAFO are an integral part of the CAFO. Under the existing regulations, this equipment should be considered part of the CAFO, and discharges from this equipment that reach the waters of the United States should be considered discharges from the CAFO for this reason as well. In recent litigation brought by citizens against a dairy farm, a federal court reached a similar conclusion. See *CARE* v. *Sid Koopman Dairy, et al.*, 54 F. Supp. 2d 976 (E.D. Wash., 1999).

Land application areas are integral parts of many or most CAFO operations. Land application is typically the endpoint in the cycle of manure management at CAFOs. Significant discharges to the nation's waters in the past have been attributed to the land application of CAFO-generated manure and wastewater. EPA does not believe that Congress intended to exclude the discharges from a CAFO's land application areas from coverage as discharges from the CAFO point source. Moreover, defining CAFOs in this way is consistent with EPA's effluent limitations guidelines for other industries, which consider on-site waste treatment systems to be part of the production facilities in that the regulations restrict discharges from the total operation. Thus, it is reasonable for EPA to clarify the regulations by including land application areas in the definition of an AFO and CAFO.

EPA believes that amending the definition of an AFO (and, by extension, CAFO) to expressly include land application areas will help achieve clarity and will enable permitting authorities both to more effectively implement the proposed effluent guidelines and to more effectively enforce the CWA's prohibition on discharging without a permit. This revision clarifies that the term "CAFO" means the entire facility, including land application fields and other areas under the CAFO's control to which it land applies its manure and wastewater. By proposing to include land application areas in the definition of an AFO (and therefore, a CAFO), discharges from those areas would, by definition, be discharges from a point source, i.e., the CAFO. There would not need to be a separate showing of a discernible, confined, and discrete conveyance such as a ditch.

Although the proposal would clarify that land application areas are considered to be part of the AFO and CAFO, it would continue to count only those animals that are confined in the production area when determining whether a facility is a CAFO.

9.5.3 Elimination of the Term "Animal Units"

To remove confusion for the regulated community concerning the definition of the term "animal unit" or "AU," EPA is proposing to eliminate the use of the term in the revised regulation. Instead of referring to facilities as having greater or fewer than 500 animal units, for example, EPA will use the term "CAFOs" to refer to those facilities that are defined or designated as such and the term "AFOs" for all others. However, the term AU will be used in descriptive text to help the reader understand the differences between the existing regulation and the revisions. If this revision is adopted, the term AU will not be used in the final regulation.

EPA received comment on the concept of animal units during the AFO Strategy listening sessions and the small business outreach process, and in comments submitted for the draft *CAFO NPDES Permit Guidance and Example Permit*. EPA's decision to move away from the concept of animal units is supported by the inconsistent use of this concept across a number of federal programs, which has resulted in confusion in the regulated community. A common thread across all of the federal programs is the need to normalize numbers of animals across animal types. Animal units have been established based on a number of different values that include live weight, forage requirements, and nutrient excretion. Among others, USDA and EPA have different "animal unit" values for the livestock sectors. Animal unit values most often used by USDA are live-weight based and account for all sizes and breeds of animals likely to be at a given operation. This is particularly confusing because USDA's animal unit descriptions result in different values in each sector and at each operation.

The United States Department of the Interior (Bureau of Land Management and National Park Service) also references the concept of animal unit in a number of programs. These programs are responsible for the collection of grazing fees for federal lands. The animal unit values used in these programs are based upon forage requirements. For federal lands an animal unit represents one mature cow, bull, steer, heifer, horse, or mule, or five sheep, or five goats, all over 6 months of age. An animal unit month is based on the amount of forage needed to sustain one animal unit for one month. Grazing fees for federal lands are charged by animal unit months.

In summary, using the total number of head that defines an operation as a CAFO will minimize confusion with animal unit definitions established by other programs.

9.5.4 Elimination of Multipliers for Mixed Animal Types

EPA proposes to eliminate the existing mixed animal provision, which currently requires an operator to add the number of animal units from all animal sectors at the facility when determining whether it is a CAFO. Poultry, dairy calves, and swine under 55 pounds are currently excluded from this mixed animal type calculation. Although the mixed calculation would be eliminated, once the number of animals from any one livestock sector causes an operation to be defined as a CAFO, manure and animals from all confined animal types at the facility would be covered by the permit. In the event waste streams from multiple livestock species are commingled, the permit must apply the more stringent limitations as permit conditions.

In the existing regulation, a facility is a CAFO when the cumulative number of animal units exceeds 1,000. Animal unit means a unit of measurement for any animal feeding operation calculated by adding the following numbers: the number of slaughter and feeder cattle multiplied by 1.0, plus the number of mature dairy cattle multiplied by 1.4, plus the number of swine weighing more than 25 kilograms (approximately 55 pounds) multiplied by 0.4, plus the number of sheep multiplied by 0.1, plus the number of horses multiplied by 2.0. As mentioned, poultry operations are excluded from this mixed unit calculation because the current regulation simply stipulates the number of birds that define the operation as a CAFO and assigns no multiplier.

Because simplicity is one objective of these proposed regulatory revisions, the Agency believes that either (1) all animal types covered by the effluent guidelines and NPDES regulation, including poultry and immature animals, should be included in the formula for mixed facilities, or (2) EPA should eliminate the animal multipliers from the revised rule. Note the revised rule also changes those animal types and sizes that would have to be factored into a revised mixed animal calculation, which could make the regulation more complicated.

EPA believes that the effect of this change would be sufficiently protective of the environment while maintaining a consistently enforceable regulation. EPA estimates 25 percent of AFOs with fewer than 1,000 AU have multiple animal types present simultaneously at one location, and only a small fraction of these AFOs would be CAFOs larger than either 300 AU or 500 AU when all animal types are counted. Census data suggest that few large AFOs house more than one animal type due to the increasingly specialized nature of livestock and poultry production. Most facilities with mixed animal types tend to be much smaller farms, tend to be less specialized, and typically engage in both animal and crop production. These farms have sufficient cropland and fertilizer requirements to land apply most, if not all, manure nutrients generated by the farm. Therefore, EPA believes that a rule requiring mixed animal types to be part of the threshold calculation to determine whether a facility is a CAFO would result in relatively few additional operations meeting the definition of a CAFO. Nevertheless, should such an AFO be found to be a significant contributor of pollution to waters of the United States, it could still be designated a CAFO by the permit authority.

EPA, therefore, proposes to eliminate the mixed animal calculation in determining which AFOs are CAFOs. Once an operation is a CAFO for any reason, manure from all confined animal types at the facility is subject to the permit requirements.

9.5.5 Elimination of 25/24 Storm Permit Exemption

The existing NPDES definition of a CAFO provides that "no animal feeding operation is a concentrated animal feeding operation… as defined above… if such animal feeding operation discharges only as the result of a 25-year, 24-hour storm event " (40 CFR 122.23, Appendix B). This provision applies to AFOs with 300 AU or more that are defined as CAFOs under the existing regulation. Facilities of any size that are CAFOs by virtue of designation are not eligible for this exemption because, by the terms of designation, the exemption does not apply to them. Moreover, they have been determined by the permit authority to be a significant contributor of pollution to waters of the United States. EPA proposes to eliminate the 25-year, 24-hour storm event exemption from the CAFO definition (40 CFR 122.23, Appendix B) and to require any operation that meets the definition of a CAFO either to apply for a permit or to establish that it has no potential to discharge.

The 25-year, 24-hour standard is an engineering standard used for construction of storm water detention structures. The term "25-year, 24-hour storm event" means the maximum 24-hour precipitation event with a probable recurrence of once in 25 years, as defined by the National Weather Service (NWS) in Technical Paper Number 40 (TP40), "Rainfall Frequency Atlas of the United States," May 1961, and subsequent amendments, or by equivalent regional or state rainfall probability information developed therefrom. As discussed in Chapter 8, the 25-year, 24-hour storm event is used as a design standard in the effluent limitation guideline.

The circularity of the 25-year, 24-hour storm event exemption in the existing CAFO definition has created confusion and has led to difficulties in implementing the NPDES regulation. The effluent guidelines regulation, which is applicable to permitted CAFOs, requires that CAFOs be designed and constructed to contain such an event. However, the NPDES regulations allow facilities that discharge only as a result of such an event to avoid obtaining a permit. This exemption has resulted in very few operations actually obtaining NPDES permits, which has hampered implementation of the NPDES program. Although an estimated 12,000 AFOs are likely to meet the current definition of a CAFO, only about 2,500 such facilities have obtained an NPDES permit. Many of these unpermitted facilities may incorrectly believe they qualify for the 25-year, 24-hour storm permitting exemption; these unpermitted facilities operate outside the current NPDES program. Consequently, state and EPA NPDES permit authorities lack the basic information needed to determine whether the exemption has been applied correctly and whether the CAFO operation is in compliance with NPDES program requirements.

EPA proposes to eliminate the 25-year, 24-hour storm exemption from the CAFO definition to (1) ensure that all CAFOs with a potential to discharge are appropriately permitted; (2) ensure through permitting that facilities are, in fact, properly designed, constructed, and maintained to contain a 25-year, 24-hour storm event, or to meet a zero discharge requirement, as the case may be; (3) improve the ability of EPA and state permit authorities to monitor compliance; (4) ensure that facilities do not discharge pollutants from their production areas or from excessive land application of manure and wastewater; (5) make the NPDES permitting provision consistent with the proposal to eliminate the 25-year, 24-hour storm design standard from the effluent guidelines for swine, veal, and poultry; and (6) achieve EPA's goals of simplifying the regulation, providing clarity to the regulated community, and improving the consistency of implementation.

EPA considered limiting this change to the very largest CAFOs (e.g., operations with 1,000 or more animal units) and retaining the exemption for smaller facilities. However, EPA is concerned that this approach would allow significant discharges resulting from nonagricultural land application of manure and wastewater to remain beyond the scope of the NPDES permitting program, thereby resulting in ongoing discharge of CAFO-generated pollutants into waters of the United States. EPA is also concerned about reports of small facilities in aggregate contributing large quantities of pollutants to waters of the United States. Moreover, EPA believes that retaining the exemption for certain operations adds unnecessary complexity to the CAFO definition.

9.5.6 No Potential to Discharge/ Duty to Apply

EPA is proposing to adopt regulations that would expressly require all CAFO owners or operators to apply for an NPDES permit. That is, owners or operators of all facilities defined or designated as CAFOs would be required to apply for an NPDES permit. The existing regulations contain a general duty to apply for a permit, which EPA believes applies to virtually all CAFOs. The majority of CAFO owners or operators, however, have not applied for an NPDES permit. The proposed revisions would clarify that all CAFO owners or operators must apply for an NPDES permit; however, if the owner or operator believes the CAFO does not have a potential to discharge pollutants to waters of the United States from either its production area or its land application area(s), he or she could make a no potential discharge demonstration to the permit authority in lieu of submitting a full permit application. If the permit authority agrees that the CAFO does not have a potential to discharge, the permit authority would not need to issue a permit. However, if the unpermitted CAFO does indeed discharge, it would be violating the CWA prohibition against discharging without a permit and would be subject to civil and criminal penalties. Thus, an unpermitted CAFO does not receive the benefit of the 25-year, 24-hour storm standard established by the effluent guidelines for beef and dairy, nor does it have the benefit of the upset and bypass affirmative defenses.

EPA believes that virtually all facilities defined as CAFOs already have a duty to apply for a permit under the current NPDES regulations because of their past or current discharges or potential for future discharge. Large CAFOs pose a risk of discharge in a number of different ways. For example, a discharge of pollutants to surface waters can occur through a spill from the waste handling facilities, from a breach or overflow of those facilities, or through runoff from the feedlot area. A discharge can also occur through runoff of pollutants from application of manure and associated wastewaters to cropland, or through seepage from the production area to ground water where there is a direct hydrologic connection between ground water and surface water. Given the large volume of manure these facilities generate and the variety of ways they may discharge, and based on EPA's and the states' own experience in the field, EPA believes that all or virtually all large CAFOs have had a discharge in the past, have a current discharge, or have the potential to discharge in the future. A CAFO that meets any one of these three criteria would be a facility that “discharges or proposes to discharge” pollutants and would, therefore, need to apply for a permit under the current regulations.

Where a CAFO has not discharged pollutants in the past, does not now discharge pollutants, and does not expect to discharge pollutants in the future, EPA believes that the owner or operator of that facility should demonstrate during the NPDES permit application process that it is, in fact, a “no discharge” facility. EPA anticipates that very few large CAFOs will be able to successfully demonstrate that they do not discharge pollutants and do not have a reasonable potential to discharge in the future. Furthermore, very few large CAFOs will wish to forego the protections of an NPDES permit. For instance, only those beef and dairy CAFOs with an NPDES permit will be authorized to discharge in a 25-year, 24-hour storm.

The nature of these operations is that any discharges from manure storage structures to waters of the United States are usually only intermittent, due to either accidental releases from equipment failures or storm events or, in some cases, deliberate releases such as pumping out lagoons or pits. The intermittent nature of these discharges, combined with the large numbers of animal feeding operations nationwide, makes it very difficult for EPA and state regulatory agencies to know where discharges have occurred (or, in many cases, where AFOs are even located), given the limited resources for conducting inspections. In this sense, CAFOs are distinct from typical industrial point sources subject to the NPDES program, such as manufacturing plants, where a facility’s existence and location and the fact that it is discharging wastewaters at all are usually not in question. Accordingly, it is much easier for CAFOs to avoid the permitting system by not reporting their discharges, and there is evidence that such avoidances have taken place.

EPA believes that virtually all large CAFOs have had a past discharge or have a current discharge or have the potential to discharge in the future, and that meeting any one of these criteria would trigger a duty to apply for a permit. EPA proposes to revise the regulations by finding that, as a rebuttable presumption, all CAFOs do have a potential to discharge and, therefore, are required to apply for and to obtain an NPDES permit unless they can demonstrate that they will not discharge. EPA has not previously sought to categorically adopt a duty to apply for an NPDES permit for all facilities within a particular industrial sector. EPA proposes to do so for CAFOs for reasons that involve the unique characteristics of CAFOs and the zero discharge regulatory approach that applies to them.

9.5.7 Applicability to All Poultry

The existing NPDES CAFO definition is written such that the regulations apply only to laying hen or broiler operations that have continuous overflow watering or liquid manure handling systems (i.e.,”wet” systems) (40 CFR 22.23, Appendix B). EPA has interpreted this language to include poultry operations in which dry litter is removed from pens and stacked in areas exposed to rainfall or in piles adjacent to a watercourse. These operations may be considered to have established a crude liquid manure system (see 1995 NPDES Permitting Guidance for CAFOs). The existing CAFO regulations also specify different thresholds for determining which AFOs are CAFOs depending on which of these two types of systems the facility uses (e.g., 100,000 laying hens or broilers if the facility has continuous overflow watering; 30,000 laying hens or boilers if the facility has a liquid manure system). When the NPDES CAFO regulations were promulgated, EPA selected these thresholds because the Agency believed that most commercial operations used wet systems (38 FR 18001, 1973). Note that turkeys were regulated at 55,000 birds (1,000 AU) irrespective of manure handling system.

In the 25 years since the CAFO regulations were promulgated, the poultry industry has changed many of its production practices. Many changes to the layer production process have been instituted to keep manure as dry as possible, such as high-rise houses or houses with belts under the cages. The broiler industry uses litter-based systems almost exclusively. Consequently, the existing regulations do not apply to most broiler and laying hen operations despite the fact that chicken production poses risks to surface water and ground water quality from improper storage of dry manure and improper land application. It is EPA's understanding that continuous overflow watering has been largely discontinued, and has been replaced with more efficient watering methods (on-demand watering), and that liquid manure handling systems represent few layer operations overall, although in the South approximately half of the layer operations might still have wet manure systems (see Chapter 4).

Despite the CAFO regulations, nutrients from large poultry operations continue to contaminate surface water and ground water because of rainfall coming into contact with outdoor manure stacks, accidental spills, faulty watering lines, open lagoons for egg wash water, and so forth. Poultry production concentrated in areas such as the Southeast, the Delmarva Peninsula in the Mid Atlantic, and key midwestern states has been shown to cause serious water quality impairments (see Environmental Impact Assessment document). In addition, land application remains the primary management method for significant quantities of poultry litter (including manure generated from facilities using "dry" systems). Many poultry operations are located on smaller parcels of land in comparison to other livestock sectors, oftentimes owning no significant cropland or pasture, placing increased importance on the proper management of the potentially large amounts of manure they generate. EPA also believes that all major livestock operations should be treated equitably under the revised regulation.

The existing regulation already applies to laying hen and broiler operations with 100,000 birds when a continuous flow watering system is used, and to operations with 30,000 birds when a liquid manure handling system is used. In revising the threshold for poultry operations, EPA evaluated several additional methods for equating poultry to the existing definition of an animal unit. EPA considered laying hens, pullets, broilers, and roasters separately to reflect the differences in size, age, production, feeding practices, housing, waste management, manure generation, and nutrient content of the manure. Manure generation and pollutant parameters considered include nitrogen, phosphorus, BOD_5, volatile solids, and COD. Analysis of these parameters consistently results in a threshold of 70,000 to 140,000 birds as being equivalent to 1,000 animal units. EPA also considered a live-weight basis for defining poultry. The live-weight definition of animal unit used by USDA defines 455,000 broilers and pullets and 250,000 layers as being representative of 1,000 animal units. EPA data indicate that using a live-weight basis at 1,000 AU would exclude virtually all broiler operations from the regulation.

Consultations with industry indicated EPA should evaluate the different sizes (ages) and purposes (eggs versus meat) of chickens separately. However, when evaluating broilers, roasters, and other meat-type chickens, EPA concluded that a given number of birds capacity represented the same net annual production of litter and nutrients. For example, a farm producing primarily broilers would raise birds for 6 to 8 weeks with a final weight of 3 to 5 pounds, and a farm producing roasters would raise birds for 9 to 11 weeks with a final weight of 6 to 8 pounds, whereas a farm producing game hens might keep birds for only 4 to 6 weeks with a final weight of less than 2 pounds. The housing, production practices, waste management, and manure nutrients and process wastes generated in each case, however, are essentially the same. Layers are typically fed less than broilers of equivalent size and are generally maintained as smaller chickens. However, a laying hen is likely to be kept for a year of egg production. The layer is then sold or molted for several weeks, followed by a second period of egg production. Pullets are housed until a laying age of approximately 18 to 22 weeks. In all cases manure nutrients and litter generated result in a threshold of 80,000 to 130,000 birds as being the equivalent of 1,000 animal units. (See Chapters 4 and 6 for more information.)

The proposed NPDES (and effluent guidelines) requirements for poultry eliminate the distinction between how manure is handled and the type of watering system used. EPA is proposing this change because it believes there is a need to control poultry operations regardless of the manure handling or watering system. EPA believes that improper storage, as well as land application rates that exceed agricultural use, has contributed to water quality problems, especially in areas with large concentrations of poultry production. Inclusion of poultry operations in the proposed NPDES regulation is intended to be consistent with the proposed effluent guidelines regulation. EPA is proposing that 100,000 laying hens or broilers be considered the equivalent of 1,000 animal units.

Consequently, EPA proposes to establish 50,000 birds as the threshold under the two-tier alternative structure (Scenario 4) that defines which operations are CAFOs at 500 animal units. Facilities subject to designation are those with fewer than 50,000 birds. This threshold would address approximately 10 percent of all chicken AFOs nationally and more than 70 percent of all manure generated by chickens. On a sector-specific basis, this threshold would address approximately 28 percent of all broiler operations (including all meat-type chickens) while addressing more than 70 percent of manure generated by broiler operations. For layers (including pullets) the threshold would address less than 5 percent of layer operations while addressing nearly 80 percent of manure generated by layer operations. EPA believes this threshold is consistent with the threshold established for the other livestock sectors.

Under the proposed alternative three-tier structures (Scenarios 1, 2, and 3), any operation with more than 100,000 chickens is automatically defined as a CAFO. This upper tier reflects 4 percent of all chicken operations. Additionally, those poultry operations with 30,000 to 100,000 chickens are defined as CAFOs if they meet certain unacceptable conditions (see section 9.2). This middle tier would address an additional 10 percent of poultry facilities. By sector this middle tier would potentially cover an additional 45 percent of broiler manure and 22 percent of layer manure. In aggregate this scenario would address 14 percent of chicken operations and 86 percent of manure.

The revision would remove the limitation on the type of manure handling or watering system employed at laying hen and broiler operations and would, therefore, address all poultry operations equally. This approach would be consistent with EPA's objective of better addressing the issue of water quality impacts associated with both storage of manure at the production area and land application of manure while simultaneously simplifying the regulation.

EPA acknowledges that this poultry threshold pulls in a substantial number of broiler operations in select regions. However, a higher threshold would include very few poultry facilities in other select regions. Geographic regions with high density of poultry production have experienced water quality problems related to an overabundance of nutrients, to which the poultry industry has contributed. The chicken and turkey sectors also have higher percentages of operations with insufficient or no land under the control of the AFO on which to apply manure. Thus EPA believes this threshold is appropriate to adequately control the potential for discharges from poultry CAFOs.

9.5.8 Applicability to Immature Animals

Only swine over 55 pounds and mature dairy cows are specifically included in the current definition (although manure and wastewater generated by immature animals confined at the same operation with mature animals are subject to the existing requirements). Immature animals were not a concern in the past because they were generally part of operations that included mature animals and, therefore, their manure was included in the permit requirements of the CAFO. In recent years, however, these livestock industries have become increasingly specialized with the emergence of increasing numbers of large stand-alone facilities such as nurseries and contract heifer operations. Further, manure from immature animals tends to have higher concentrations of pathogens and hormones and thus poses greater risks to the environment and human health.

Since the 1970s the animal feeding industry has become more specialized, especially at larger operations. Dairies often move immature heifers to a separate location until they reach maturity. These off-site operations may confine the heifers in a manner that is very similar to a beef feedlot, or the heifers may be placed on pasture. The existing CAFO definition does not address operations that confine only immature heifers. EPA acknowledges that dairies may keep heifers and calves and a few bulls on site. EPA data indicate some of these animals are in confinement, some are pastured, and some are moved back and forth between confinement, open lots, and pasture. However, the actual milking herd tends to be a more constant number of animals that are confined at least during milking. The current CAFO definition thus considers only the mature milking cows. This has raised some concerns that many dairies with significant numbers of immature animals could be excluded from the regulatory definition even though they might generate as much manure as a dairy with a milking herd large enough to make the dairy a CAFO.

EPA considered options for dairies that would take into account all animals maintained in confinement, including calves, bulls, and heifers, when determining whether a dairy is a CAFO. EPA examined two approaches for this option—one that would count all animals equally and another based on the proportion of heifers, calves, and bulls likely to be present at the dairy. The milking herd is usually a constant at a dairy, but the proportion of immature animals can vary substantially among dairies and even at a given dairy over time. Some operations maintain their immature animals on-site but keep them on pasture most of the time. Some operations keep immature animals on-site and maintain them in confinement all or most of the time. Some operations may also have one or two bulls on-site, which can also be kept either in confinement or on pasture, while many keep none on-site. Some operations do not keep their immature animals on-site at all; instead, they place them off-site, usually in a stand-alone heifer operation. The variety of practices at dairies makes it very difficult to estimate how many operations have immature animals on-site in confinement. EPA believes that basing the applicability on the numbers of immature animals and bulls would make implementing the regulation more difficult for the permit authority and the CAFO operator.

When the CAFO regulations were issued, it was typical to house swine from birth to slaughter together at the same operation, known as a farrow-to-finish operation. Although more than half of swine production continues to occur at farrow-to-finish operations, today it is common for swine to be raised in phased production systems. Though EPA could not identify any large stand-alone nursery facilities in 1997, other data indicate the emergence of several large nursery operations. EPA proposes to count either swine over 55 pounds or swine under 55 pounds to determine the size of the AFO and the applicability of the NPDES and effluent limitations guidelines (ELG) regulations.

The proposed thresholds for swine were established on the basis of the average phosphorus excreted from immature swine in comparison to the average phosphorus excreted from swine over 55 pounds. A similar threshold would be obtained when evaluating live-weight manure generation, nitrogen, COD, and volatile solids (VS). See Chapter 6 for more information on manure constituents. The thresholds for heifers are based on the thresholds for beef cattle. EPA's data on contract heifer operations indicate the heifers are often maintained on feedlots in a manner identical to the manner in which beef cattle are raised; additionally, some beef feedlots have been known to temporarily maintain heifers on-site.

Thus, EPA proposes to include immature swine and heifer operations under the CAFO definition. In the proposed three-tier structure, the 300 AU and 1,000 AU equivalents, respectively, for each animal type would be 3,000 head and 10,000 head for immature swine and 300 head and 1,000 head for heifers. In the proposed two-tier structure, EPA would establish the 500 AU threshold equivalent for defining which operations are CAFOs as operations with 5,000 or more swine weighing 55 pounds or less; those with fewer than 5,000 swine under 55 pounds are AFOs that may be designated CAFOs. Immature dairy cows, or heifers, would be counted equivalent to beef cattle; that is, the 500 AU threshold equivalent for defining CAFOs would be operations with 500 or more heifers, and those with fewer than 500 heifers could be designated CAFOs.

9.5.9 NPDES Thresholds for Animal Types Not Covered by the ELG

The animal types covered by the NPDES program are defined in the current regulation (40 CFR Part 122, Appendix B). The beef, dairy, swine, poultry, and veal sectors are being addressed by both revisions to the ELG and NPDES regulations. However, EPA is not revising the ELG for any animal sector other than beef (including veal), dairy, swine, and poultry. Therefore, any CAFO in the horse, sheep, lamb and duck sectors with fewer than 1,000 AU will not be subject to the ELG, but will have NPDES permits developed on a best professional judgment basis. EPA is proposing to lower the threshold for defining which AFOs are CAFOs for these sectors if the two-tier structure is adopted. This action is being taken to be consistent with the NPDES proposed revisions for beef, dairy, swine, and poultry. Under the three-tier structures, the existing thresholds would remain as they are under the existing regulation. A facility confining any other animal type that is not explicitly mentioned in the NPDES and ELG regulations is still subject to NPDES permitting requirements if it meets the definition of an AFO and if the permit authority designates it a CAFO on the basis that it is a significant contributor of pollution to waters of the United States.

The economic analysis for the NPDES rule does not cover animal types other than beef, dairy, swine, and poultry. EPA chose to analyze those animal types that produce the greatest amount of manure and wastewater in the aggregate while in confinement. EPA believes that most horse, sheep, and lamb operations are not confined and, therefore, will not be subject to permitting. Thus the Agency expects the impacts in these sectors to be minimal.

9.5.10 Duty to Maintain Permit Coverage Until Closure

EPA proposes to require operators of permitted CAFOs that cease operations to retain NPDES permits until the facilities are properly closed, i.e., no longer have the potential to discharge. Similarly, if a facility ceases to be an active CAFO (e.g., it decreases the number of animals to below the threshold that defined it as a CAFO, or ceases to operate), the CAFO must remain permitted until all wastes at the facility that were generated while the facility was a CAFO no longer have the potential to reach waters of the United States. If a permit is about to expire and the manure storage facility has not yet been properly closed, the facility would be required to apply for a permit renewal because the facility has the potential to discharge to waters of the United States until it is properly closed. Proper facility closure includes removal of wastes from lagoons and stockpiles, proper land application of manure and wastewater, and proper disposal of other wastes in accordance with NPDES permit requirements.

The existing regulations do not explicitly address whether a permit should be allowed to expire when an owner or operator ceases operations. However, the public has expressed concerns about facilities that go out of business, leaving lagoons, stockpiles, and other contaminants unattended and unmanaged. Moreover, there are a number of documented instances of spills and breaches at CAFOs that have ceased operations, leaving behind environmental problems that became a public burden to resolve (NCDENR, 1999).

EPA considered five options for NPDES permit requirements to ensure that CAFO operators provide assurances for proper closure of their facilities (especially manure management systems such as lagoons) in the event of financial failure or other business curtailment. EPA examined the costs to the industry and the complexity of administering such a program for all options.

Closure Option 1 would require a closure plan. The CAFO operator would be required to have a written closure plan detailing how the facility plans to dispose of animal waste from manure management facilities. The plan would be submitted with the permit application and be approved with the permit application. The plan would identify the steps necessary to perform final closure of the facility, including at least the following:

- A description of how each major component of the manure management facility(e.g., lagoons, settlement basins, storage sheds) will be closed.
- An estimate of the maximum inventory of animal waste ever on-site, accompanied with a description of how the waste will be removed, transported, land applied or otherwise disposed.
- A closure schedule for each component of the facility, along with a description of other activities necessary during closure (e.g., control runoff/run-on, ground water monitoring if necessary).

EPA also investigated several options that would provide financial assurances in the event the CAFO went out of business, such as contribution to a sinking fund, commercial insurance, surety bond, and other common commercial mechanisms. Under Closure Option 2, permittees would have to contribute to a sinking fund to cover closure costs of facilities that abandon their manure management systems. The contribution could be on a per-head basis and could be levied on the permitting cycle (every 5 years) or annually. The sinking fund would be available to clean up any abandoned facility (including those which are not permitted). Data on lagoon closures in North Carolina (NCDENR, 1999) indicate that the average cost of lagoon closure for which data are available is approximately $42,000. Assuming a levy of $0.10 per animal, the sinking fund would cover the cost of approximately 50 abandonments nationally per year, not accounting for any administrative costs associated with operating the funding program.

Closure Option 3 would require permittees to provide financial assurance by one of several generally accepted mechanisms, including the following: (1) commercial insurance, (2) financial test, (3) guarantee, (4) certificate of deposit or designated savings account, (5) letter of credit, or (6) surety bond. The actual cost to the permittee would depend on which financial assurance option was available and implemented. The financial test would likely be the least expensive for some operations, entailing documentation that the net worth of the CAFO operator is sufficient to make it unlikely that the facility will be abandoned for financial reasons. The guarantee would also be inexpensive, consisting of a legal guarantee from a parent corporation or other party (integrator) that has sufficient levels of net worth. The surety bond would likely be the most expensive, typically requiring an annual premium of 0.5 to 3.0 percent of the value of the bond; this mechanism would likely be a last resort for facilities that could not meet the requirement of the other mechanisms.

Option 4 is a combination of Options 2 and 3. Permittees would have to provide financial assurance by using one of several generally accepted mechanisms or by participating in a sinking fund. CAFO operators could meet closure requirements through the most economical means available for their operations.

Option 5 simply requires CAFOs to maintain NPDES permit coverage until proper closure. Under this option, facilities would be required to maintain their NPDES permits, even upon curtailment of the operation, for as long as the facility has the potential to discharge. The costs for this option would be those costs associated with maintaining a permit.

EPA selected Option 5: to require NPDES permits to include a condition that imposes a duty to reapply for a permit unless an owner or operator has closed the facility such that there is no potential for discharges. The NPDES program offers legal and financial sanctions that are sufficient, in EPA's view, to ensure that operators comply with this requirement. EPA believes that this option would accomplish its objectives and would be generally easy and effective to implement. However, there are concerns that it would not be effective for abandoned facilities because, unlike some of the other options, no financial assurance mechanism would be in place.

9.5.11 Assessment of Direct Hydrological Connection to Surface Water as Permit Condition

Because of its relevance to today's proposal, EPA is restating that the Agency interprets the Clean Water Act to apply to discharges of pollutants from a point source via ground water that has a direct hydrologic connection to surface water. Specifically, the Agency is proposing that all CAFOs, including those that discharge or that have the potential to discharge CAFO wastes to navigable waters via ground water with a direct hydrologic connection, must apply for an NPDES permit. In addition, the proposed effluent guidelines will require some CAFOs to achieve zero discharge from their production areas, including via ground water that has a direct hydrologic connection to surface water. Further, for CAFOs not subject to such an effluent guideline, permit writers would in some circumstances be required to establish special conditions to address such discharges. In all cases, a permittee would have the opportunity to provide a hydrologist's report to rebut the presumption that there is likely to be a discharge from the production area to surface waters via ground water with a direct hydrologic connection.

For subcategories that would be subject to an effluent guideline that includes requirements for zero discharge from the production area to surface water via ground water, the proposed regulations would presume that there is a direct hydrologic connection to surface water. The permittee would be required to either achieve zero discharge from the production area via ground water and perform the required ground water monitoring, or provide a hydrologist's statement that there is no direct connection of ground water to surface water at the facility.

Other subcategories are subject to an effluent guideline that does not include ground water requirements. In these cases the permit writer first determines whether the facility is in an area with topographical characteristics that indicate the presence of ground water that is likely to have a direct hydrologic connection to surface water. If the permit writer determines that pollutants may be discharged at a level that might cause or contribute to an excursion above any State water quality standard, the permit writer would be required to include special conditions to address potential discharges via ground water. EPA proposes that the permittee must either comply with those conditions or provide a hydrologist's statement that the facility does not have a direct hydrologic connection to surface water.

If an ELG does not apply to the particular CAFO subcategory, the permit writer would be required to decide on a case-by-case basis whether effluent limitations (technology-based and water quality-based, as necessary) should be established to address potential discharges to surface water via hydrologically connected ground water. Again, the permittee could avoid or satisfy such requirements by providing a hydrologist's statement that there is no direct hydrologic connection.

9.6 Land Application of Manure

EPA proposes to improve control of discharges that occur from land-applied manure and wastewater. Analysis conducted by USDA indicates that, in some regions, the amount of nutrients present in land-applied manure has the potential to exceed the nutrient needs of the crops grown in those regions. Actual soil sample information compiled by researchers at various land grant universities provides an indication of areas where there is widespread phosphorus saturation. Other research by USDA documents the runoff potential of land-applied manure under normal and peak precipitation. Furthermore, research from a variety of sources indicates that there is a high correlation between areas with impaired lakes, streams, and rivers due to nutrient enrichment and areas where there is dense livestock and poultry production.

For CAFOs that land apply their manure, EPA is proposing that owners or operators implement specific agricultural practices, including land application of manure and wastewater at a specified rate, development and implementation of a Permit Nutrient Plan, a prohibition on the application of CAFO manure or wastewater within 100 feet of surface water, and, as determined to be necessary by the permit authority, restrictions on application of manure to frozen, snow-covered, or saturated ground. The Agency is proposing to require these specific agricultural practices under its CWA authority both to define the scope of the agricultural storm water discharge exemption and to establish the best available technology for specific industrial sectors. Given the history of improper disposal of CAFO waste and Congress's identification of CAFOs as point sources, the Agency believes it should clearly define the agricultural practices that must be implemented at CAFOs.

The Agency is proposing to allow AFO owners or operators who land apply manure obtained from CAFOs and more traditional row crop farmers who land apply manure obtained from CAFOs to qualify for the agricultural storm water exemption as long as they are applying manure and wastewater at proper rates established by the state. Under the proposal, EPA is co-proposing whether to require CAFOs that transfer manure to off-site recipients obtain a letter of certification from the recipient land applier that the recipient intends to determine the nutrient needs of its crops based on realistic crop yields for its area, sample its soil at least once every 3 years to determine existing nutrient content, and not apply the manure in quantities that exceed the land application rates calculated using the Phosphorus Index, Phosphorus Threshold, or Soil Test Phosphorus method as specified in the revised ELG. For purposes of the CAFO's permit, recipient land appliers need not implement all of the proper agricultural practices identified above that CAFOs would be required to implement at their own land application areas. EPA believes that this proposal enables the Agency to implement Congress's intent to both exclude truly agricultural discharges due to storm water and regulate the disposition of the vast quantities of manure and wastewater generated by CAFOs.

9.6.2 Other Special Permit Conditions

Permit writers establish effluent limits for land application areas in the form of rates and practices that constitute proper agricultural practices to the extent necessary to fulfill the requirements of the effluent guidelines or based on best professional judgment as well as to the extent necessary to ensure that a CAFO's practices are agricultural in that they minimize the operation's impact on water quality. Standard conditions in an NPDES permit list preestablished conditions that apply to all NPDES permits. The special conditions in an NPDES permit are used primarily to supplement effluent limitations and ensure compliance with the CWA.

In addition to closure, ground water, and off-site certification, EPA is proposing to require permit authorities to develop special conditions that specify:

- How the permittee is to calculate the allowable manure application rate.
- Timing restrictions, if necessary, on land application of manure and wastewater, including restrictions on application to frozen, snow-covered, or saturated ground.

The ELG specifies three methods for determining the basis of manure application rates: (1) the Phosphorus Index, (2) the Soil Phosphorus Threshold Level, and (3) the Soil Test Phosphorus Level. EPA adopted these three methods from the USDA Natural Resource Conservation Service's nutrient management standard (Standard 590, USDA NRCS, 2000). State Departments of Agriculture are developing state nutrient standards that incorporate one of these three methods. EPA is proposing to require that each authorized state permit authority adopt one of these three methods as part of the state NPDES program, in consultation with the State Conservationist.

EPA considered establishing a national prohibition on applying CAFO-generated manure to frozen, snow-covered or saturated ground in the ELG (Technology Option 7). Disposal of manure or wastewater to frozen, snow-covered, or saturated ground is generally not a beneficial use for agricultural purposes. Although such conditions can occur anywhere in the United States, pollutant runoff associated with such practices is a site-specific consideration and is dependent on a number of variables, including climate and topographic variability, distance to surface water, and slope of the land. Such variability makes it difficult to develop a national technology-based standard that is consistently reasonable and does not impose unnecessary cost on CAFO operators.

Although EPA believes that many permit writers will find a prohibition on applying CAFO-generated manure to frozen, snow-covered, or saturated ground to be reasonably necessary to achieve the effluent limitations and to carry out the purposes and intent of the CWA, EPA is aware that there are areas where these practices might be allowed provided they are restricted. Application on frozen ground, for example, might be appropriate in some areas provided there are restrictions on the slope of the ground and proximity to surface water. Many states have already developed such restrictions. The permit writer could further develop the restrictions based on a consideration of local crop needs, climate, soil types, slope, and other factors.

Although the proposed regulations would not establish a national technology-based limitation or BMP, EPA is proposing at section 122.23(j)(2) that permit writers consider the need for these limits. Permit authorities would be expected to develop restrictions on timing and method of application that reflect regional considerations, which restrict applications that are not an appropriate agricultural practice and have the potential to result in pollutant discharges to waters of the United States. It is likely that the operators would need to consider means of ensuring adequate storage to hold manure and wastewater for the period during which manure may not be applied. EPA estimates that storage periods might range from 45 to 270 days, depending on the region and the proximity to surface water, and to ground water with a direct hydrologic connection to surface water. Permit authorities are expected to work with state agricultural departments, USDA's Natural Resource Conservation Service, the EPA regional office, and other local interests to determine the appropriate standard, and include the standard consistently in all NPDES permits for CAFOs.

EPA's estimate that storage periods would range from 45 days to 270 days is derived using published freeze/frost data from the National Oceanic and Atmospheric Administration, National Center for Disease Control. For the purpose of estimating storage requirements to prevent application to frozen ground, EPA assumed CAFOs could apply manure only between the last spring frost and the first fall frost, called the "freeze free period." With a 90 percent probability, EPA could also use a 28 degree temperature threshold to determine the storage time required, rounded to the nearest 45-day increment. This calculation results in 45 days of storage in the South, 225 days in parts of the Midwest and the Mid-Atlantic, and as high as 270 days storage in the Central region.

EPA believes the costs for this provision are minimal because the ELG already restricts manure application to a rate that can be assimilated by the crops and soil. Where winter spreading results in runoff of the manure nutrients, the CAFO could not apply additional nutrients to compensate. In other words, the PNP creates an incentive to apply nutrients only in a manner where they are available to crops.

9.6.3 Non-CAFO Land Application Activities

In some instances, CAFO owners or operators transport their manure and/or wastewater off-site. If off-site recipients land apply the CAFO-generated manure, they may be subject to regulation under the Clean Water Act. In addition, AFOs may land apply their own manure and wastewater, and they, too, may be subject to regulation under the Clean Water Act. A land applier could be subject to regulation if (1) its field has a point source, as defined under the CWA, through which (2) a discharge occurs that is not eligible for the agricultural storm water exemption, and (3) the land applier is designated on a case-by-case basis as a regulated point source of storm water (40 CFR 122.26(a)(1)(v)). EPA notes that under the three-tier structure, an AFO with between 300 AU and 1,000 AU that has submitted a certification that it does not meet any of the conditions for being a CAFO and, therefore, does not receive an NPDES permit, would be immediately subject to enforcement and regulation under the Clean Water Act if it has a discharge that is not subject to the agricultural storm water discharge exemption; EPA and the state do not need to designate such a facility either a CAFO or a regulated storm water point source.

EPA emphasizes again that this regulatory approach is relevant only to discharges composed entirely of storm water. If it is not due to precipitation, a discharge of manure or wastewater through a point source, such as a ditch, into the waters of the United States need not be designated subject to enforcement and regulation under the Clean Water Act.

As noted above, case-by-case designation of point sources at land application areas that are not under the control of a CAFO owner or operator may already occur under existing regulations. Either the permitting authority or EPA may designate a discharge that he or she determines contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. EPA is soliciting comment on whether to clarify the term "significant contributor of pollutants" for the purposes of designating a discharge of manure and/or wastewater. If a land applier is applying manure and/or wastewater such that he or she is not eligible for the agricultural storm water discharge exemption and if the receiving waterbody (into which there are storm water discharges associated with manure and/or wastewater) is not meeting water quality standards for a pollutant in the waste (such as phosphorus, nitrogen, dissolved oxygen, or fecal coliforms), EPA could propose that, by regulation, such a discharge constitutes a "significant contributor of pollutants." For example, if a land applier is applying manure and/or wastewater at a rate above the rate that qualifies the recipient for the agricultural storm water discharge exemption, and if, due to precipitation, waste runs off the land application area through a ditch into a navigable water that is impaired due to nutrients, the permit authority may designate that point source as a regulated storm water point source. The designee would then need to apply for an NPDES permit or risk being subject to enforcement actions for unpermitted discharges.

9.7 NPDES Reporting and Recordkeeping Requirements

The section of the NPDES permit on monitoring and reporting requirements identifies the specific conditions related to the types of monitoring to be performed, the frequencies for collecting samples or data, and how to record, maintain, and transmit the data and information to the permit authority. This information allows the NPDES permit authority to determine compliance with the permit requirements.

EPA is proposing revisions to the effluent guidelines that would require the operator to conduct periodic visual inspection and to maintain all manure storage and handling equipment and structures, as well as all runoff management devices. The NPDES permit would also require the permittee to (1) test and calibrate all manure application equipment annually to ensure that manure is land applied in accordance with the proper application rates established in the NPDES permit; (2) sample manure for nutrient content at least once annually, and up to twice annually if manure is applied more than once or removed to be sent off-site more than once per year; and (3) sample soils for phosphorus once every 3 years. The proposed effluent guidelines would also require the operator to review the PNP annually and amend it if practices change either at the production area or at the land application area and submit notification to the permit authority. Examples of changes in practice necessitating a PNP amendment include a substantial increase in animal numbers (e.g., more than 20 percent) that would significantly increase the volume of manure and nutrients produced on the CAFO; a change in the cropping program that would significantly alter land application of animal manure and wastewater; elimination or addition of fields receiving animal waste application; or changes in animal waste collection, storage facilities, treatment, or land application method.

CAFO operators would be required to submit their PNPs, as well as any information necessary to determine compliance with their PNPs and other permit requirements, to the permit authority upon request. The CAFO operator would also be required to make a copy of the PNP cover sheet and executive summary available to the public in any of several ways. Operators of new facilities seeking coverage under a general permit and applicants for individual permits would be required to submit a copy of their draft PNP cover sheet and executive summary to the permit authority at the time of NOI submittal or application.

EPA is also proposing to require operators to submit a written notification to the permit authority, signed by the certified planner, that the PNP has been developed or amended and is being implemented, accompanied by a fact sheet summarizing certain elements of the PNP. This written notice of PNP availability would play an important role in verifying that the permittee is complying with one of the requirements of the NPDES permit.

9.7.1 PNP Notification

EPA is proposing to require that applicants for individual permits and operators of new facilities submitting notices of intent for coverage under a general permit submit a copy of the draft PNP cover sheet and executive summary to the permit authority at the time of application or NOI submittal (§§122.21(i)(1)(iv) and 122.28(b)(2)(ii)). Operators of existing facilities seeking coverage under a general permit must submit a notice of final PNP development within 90 days of seeking coverage but are not required to provide a copy of the PNP to the permit authority unless requested. The reporting requirements, including the notice of PNP development and notice of PNP amendment, are discussed in more detail in preamble section VII.E.3.

Initial installation of manure control technologies is significantly less costly than retrofitting existing facilities, and early development of a PNP will help to ensure that, when a new facility is being designed, the operator is considering optimal control technologies. In addition, in situations where individual permits are warranted, the public interest demands early review of the summary of the PNP, rather than waiting for its availability after the permit has been in effect for some time.

EPA is proposing that the permit authority be required, upon request from the public, to obtain a copy of the PNP cover sheet and executive summary and make it available to the public if it is not available by other means. The CAFO operator would be required to provide a copy to the permit authority unless the operator has made it available through other means. For example, the CAFO operator may choose to (1) maintain a copy of the PNP cover sheet and executive summary at the facility and make it available to the permit authority as a publicly viewable document upon request; (2) maintain a copy of the PNP cover sheet and executive summary at the facility and make it available directly to the requestor; (3) place a copy of the PNP cover sheet and executive summary at a publicly accessible site, such as a public library; or (4) submit a copy to the permit authority. It is important to ensure that the public has access to information needed to determine whether a CAFO is complying with its permit, including the land application provisions.

9.7.2 Certification from Non-CAFO Recipients of CAFO-Generated Manure

Inappropriate land application of CAFO-generated manure poses a significant risk to water quality. Further, EPA estimates that the majority of CAFO-generated manure is in excess of CAFO's crop needs and will very likely be transferred off-site. The ultimate success of the CAFO program depends on whether recipients handle manure appropriately and in a manner that prevents discharge to waters.

EPA considered a range of approaches including no consideration of off-site manure transfer, basic recordkeeping, and reporting requirements; requiring certification from manure recipients that they will apply the manure using proper agricultural practices; and requiring certification from the manure recipient that a nutrient management plan has been written and implemented by the recipient. To estimate the number of recipients needed to accept manure transferred off-site, EPA used the following baseline assumptions:

- Hauling of excess manure is paid for by the CAFO.
- Crop farmers already maintain records and have a nutrient management plan, though the plan is not necessarily a certified CNMP.
- Recipients will apply manure at nitrogen rate; i.e., assume that the crop farmer will accept manure only if spreading is on a nitrogen basis.
- To calculate the amount of excess manure generated at CAFOs, excess manure nitrogen was obtained from a USDA analysis of 1997 census data (Kellogg et al., 2000).
- To calculate the number of farms needed to properly apply excess manure, the average crop farm size was assumed to be 487 acres (per 1997 Census of Agriculture summary statistics).
- Fifty four percent of crop farmers already sample soils every 3 years (CTIC, 2000).

Costs include soil sampling and incremental recordkeeping costs identical to those costs developed for CAFOs in Chapter 11. They include $10 labor and $10 analytical costs for every

10 acres of cropland. For upper-bound costs an additional cost of $5 per acre was included if a full PNP or CNMP is written by the recipient as a result of this requirement. Setbacks for manure spreading are not included. Training and certification for manure spreaders costs $117, as identified in Chapter 11. Calibration of manure spreading equipment is paid for by the CAFO.

The following table presents the range of costs for various approaches to managing manure transferred off-site.

Table 35. Recipients and Costs for Off-Site Locations Receiving Manure from CAFOs

	NPDES Scenario (Definition of CAFO)		
	> 1,000 AU	>#500 AU	>#300 AU
Number of off-site manure recipients	13,489	17,923	21,155
Cost per recipient for records	$994	$994	$994
Total costs to all recipients for records	$7.2 million	$9.6 million	$11.3 million
Upper-bound costs for nutrient plan (assuming PNP or CNMP development)	$33.1 million	$44.0 million	$51.9 million

EPA is not proposing to regulate off-site recipients through CAFO permit requirements; however, EPA is proposing two alternatives for ensuring that CAFO-generated manure that is transferred to off-site recipients is managed to prevent water quality impairment. In the first alternative, EPA is proposing certain certification and recordkeeping requirements to help ensure responsible handling of manure. In the second alternative, EPA is proposing recordkeeping requirements only.

In the first alternative, EPA is proposing to require CAFO operators to obtain a certification from recipients (other than manure haulers that do not land apply the waste) of more than 12 tons per year of CAFO-generated manure and wastewater certifying the recipients will do one of the following: (1) land apply according to proper agricultural practices (which the proposal would define to mean that the recipient determines the nutrient needs of its crops based on realistic crop yields for its area, sample its soil at least once every 3 years to determine existing nutrient content, and does not apply the manure in quantities that exceed the land application rates calculated using one of the methods specified in the proposed rule); (2) obtain an NPDES permit for discharges resulting from nonagricultural land application; or (3) utilize the manure for purposes other than land application. (See proposed §122.23(j)(4)).

EPA is proposing both requirements: (1) that CAFOs obtain a certification and (2) that recipients of CAFO-generated manure so certify, pursuant to section 308 of the CWA. Under section 308, EPA has the authority to require the owner or operator of a point source to establish and maintain records and provide any information the Agency reasonably requires. The Agency has documented historic problems associated with overapplication of CAFO waste by both CAFO operators and recipients of CAFO waste. The proposal would establish effluent limitations designed to prevent discharges due to overapplication. To determine whether CAFOs are meeting the effluent limitations that would be established under the proposals, EPA believes it is necessary for the Agency to have access to information concerning where a CAFO's excess manure is sent. Furthermore, to determine whether the recipients of CAFO manure should be permitted (which might be required if they do not land apply the CAFO manure in accordance with proper agricultural practices and they discharge from a point source), EPA has determined that it will be necessary for such recipients to provide information about their land application methods. Recipients who certify that they are applying manure in accordance with proper agricultural practices are responding to a request under section 308 of the CWA. Therefore, a recipient who falsely certifies is subject to all applicable civil and criminal penalties under section 309 of the CWA.

In some cases, CAFOs give or sell manure to many different recipients, including those taking small quantities, and this requirement could result in an unreasonable burden. EPA is primarily concerned with recipients who receive and dispose of large quantities, presuming that recipients of small quantities pose less risk of inappropriate disposal or overapplication. To relieve the paperwork burden, EPA is proposing that CAFOs not be required to obtain certifications from recipients that receive less than 12 tons of manure per year from the CAFO. The CAFO would, however, be required to keep records of transfers to such recipients, as describe below.

The Agency believes that it would be reasonable to exempt from the PNP certification requirements recipients who receive small amounts of manure from CAFOs. EPA considered exempting amounts such as a single truckload per day or a single truckload per year. EPA decided that an appropriate exemption would be based on an amount that would typically be used for personal, rather than commercial, use. The exemption in the proposed regulation is based on the amount of manure that would be appropriately applied to 5 acres of land because 5 acres is at the low end of the amount of land that can be profitably farmed. See, for example, "The New Organic Grower," Eliott Coleman (1995)).

To determine the maximum amount of manure that could be appropriately applied to five acres of land, an average nutrient requirement per acre of cropland and pastureland was computed. Based on typical crops and national average yields, 160 pounds of nitrogen (N) and 14.8 pounds of phosphorus (P) are required annually per acre. See *Manure Nutrient Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients*, (USDA, 2000). The nutrient content of manure was based on a USDA-NRCS (1998) report, Nutrients Available from *Livestock Manure Relative to Crop Growth Requirements*.

The nitrogen content of manure at the time of land application ranges from 1.82 pounds per ton for heifers and dairy calves to 18.46 pounds per ton for hens and pullets. Using the low-end rate of 1.82 pounds of nitrogen per ton, 87.4 tons of manure would be needed for a typical acre, or 439 tons of manure for 5 acres, to achieve the 160 pounds per acre rate. Using the high-end rate of 18.46 pounds of nitrogen per ton, 8.66 tons of manure would be needed for a typical acre, or 43.3 tons of manure for 5 acres, to achieve the 160 pounds per acre rate. Thus, the quantity of manure needed to meet the nitrogen requirements of a 5 acre plot would range from 43.3 tons to 439 tons, depending on the animal type.

The phosphorus content of manure at the time of land application ranges from 1.10 pounds per ton for heifers and dairy calves to 11.23 pounds per ton for turkeys for breeding. Using the high-end 11.23 pound per ton rate for phosphorus, only about 1.3 tons would be needed for an average acre, or 6.5 tons for 5 acres, to meet the 14.8 pounds of phosphorus required annually for a typical acre of crops. Using the low-end 1.1 pound per ton rate for phosphorus, about 13.2 tons would be needed for an average acre, or 66 tons for 5 acres. Using the phosphorus content for broilers of 6.61 pounds per ton is more typical of the content of manure and would result in 2.23 tons per acre being needed for an average acre, or 11.2 tons for 5 acres.

Clearly, exempting the high-end amount of manure based on nitrogen content could lead to excess application of phosphorus. Regulating based on the most restrictive P requirement could lead to manure not being available for personal use. The exemption is only an exemption from the requirement that the CAFO obtain a certification. The recipient would remain subject to any requirements of state or federal law to prevent discharge of pollution to waters of the United States.

EPA is proposing to set the threshold at 12 tons per recipient per year. This is rounding the amount based on typical P content. It also allows 1 ton pickup load per month, which is consistent with one of the alternative approaches EPA considered. Recipients that receive more than 12 tons would have to certify that the waste will be properly managed.

For CAFO owners or operators who transfer CAFO-generated manure and wastewater to manure haulers who do not land apply the waste, EPA is proposing that the CAFO owner or operator must (1) obtain the name and address of the recipients, if known; (2) provide the manure hauler with an analysis of the nutrient content of the manure, to be provided to the recipients; and (3) provide the manure hauler with a brochure to be given to the recipients describing the recipients' responsibility to properly manage the land application of the manure to prevent discharge of pollutants to waters of the United States.

In the second alternative proposal for ensuring proper management of manure that is transferred off-site, EPA is not proposing to require CAFO owners or operators to obtain the certification described above. Rather, CAFO owners or operators would be required to maintain records of transfer.

Concern has been expressed that many potential recipients of CAFO manure will choose to forego CAFO manure and buy commercial fertilizers instead to avoid signing such a certification and being brought under EPA regulation. The result could be that CAFO owners and operators might be unable to find a market for proper disposal, thereby turning the manure into a waste rather than a valuable commodity.

This alternative is potentially protective of the environment because non-CAFO land appliers would be liable for being designated as a point source in the event that there is a discharge from improper land application. EPA's proposed requirements for what constitutes proper agricultural practices would ensure that CAFO-generated manure is properly managed.

9.8 References

Allen, P. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia. May 19.

Bickert, W. 1999. Record of communication CAFO permitting rule. Telephone conversation with R. Johnson, DPRA, Alexandria, Virginia. May 18.

Bracht, G. 1999. Regarding the CAFO Questions. E-mail message to DPRA, Arlington, Virghinia. November 15.

Bredencamp, T. 1999. Facility Comments - Draft Final SVR - Nebraska Site Visits. E-mail message to DPRA, Arlington, Virginia. August 16.

Byron, T. 1999. Regarding the CAFO Questions. E-mail message to DPRA, Arlington, Virginia. November 12.

Carey, J.B. 1999. Swine and Poultry Survey. E-mail message to DPRA, Arlington, Virginia. April 16.

Clark, J. 1999. KDHE response. E-mail message to DPRA, Arlington, Virginia, April 13.

Coleman, E. 1995. The organic grower: a master's manual of tools and techniques for the home and market gardener. United States.

CTIC. 2000. Nutrient management research. Prepared for the Conservation Technology Information Center by Marketing Directions.

Ernst, R. 1999. Regarding Estimates on the Percentage of Swine Facilities. E-mail message to DPRA, Arlington, Virginia. November 11.

Foley, G. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia. April 14.

Funk, T. 1999. FYI. E-mail message to DPRA, Arlington, Virginia. November 23.

Gale, J.A. 1999. Utah - response. E-mail message to DPRA, Arlington, Virginia. May 5.

Greenless, W. 1999. Completed Survey—Iowa. E-mail message from J. Blair, DPRA, Alexandria, Virginia. April 27.

Groves, R. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia. May 14.

Gunter, T. 1999. Regarding the Requested Numbers of CAFO Operations with 300 to 1000 Animal Units. E-mail message to DPRA, Arlington, Virginia. December 7.

Harrelson. 1999. KS Beef. E-mail message from C. Simons, DPRA, Alexandria, Virginia. August 16.

Holmes, B. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia. May 14.

Jacobson, L.D. 1999. Survey Response - MN. E-mail message to DPRA, Arlington, Virginia. April 14.

Johnson, D. 1999. Regarding responses and questions for the dairy industry. E-mail message to DPRA, Arlington, Virginia. May 17.

Kauz Loric, P. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia. May 11.

Kellogg, R.L., C.H. Lander, D. Moffitt, and N. Gollehon. 2000. *Manure nutrients relative to the capacity of cropland and pastureland to assimilate nutrients: Spatial and temporal trends for the United States*. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC.

Lory, J. 1999. Feeding Operations. E-mail message to DPRA, Arlington, Virginia. April 16.

Malone, G. 1999. Record of Communication. Memorandum to DPRA, Arlington, Virginia. November 19.

NCDENR. 1999 Lagoon closure information. North Carolina Department of Environmental and Natural Resources, Division of Soil and Water Conservation. Raleigh, North Carolina.

Nicholson, B. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia. April 16.

Orth, R. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia. May 17.

Patterson, P. 1999. Record of Communication. E-mail message to DPRA, Arlington, Virinia. March 25.

Ramsey, D. 1999. CAFOs. E-mail message to DPRA, Arlington, Virginia. March 2.

SAIC. 1999. Aggregated ARMS financial data received by USDA, ERS, and spreadsheet versions of files converted by M. Beljak. May 7.

SAIC. 2000. Memorandum: Federal wage rate discrepancy between CAFO documents. S. Ragland and T. Carpenter, Science Applications International Corporation. May 30.

Steinhart, T. 1999. Answers to recent questions - Iowa. E-mail message to DPRA. Arlington, Virginia. April 15.

Teague, F. 1999. CAFO Permitting Rule. E-mail message to DPRA, Arlington, Virginia, May 17.

Thomas, J. 1999. Completed Survey - MS. E-mail message to DPRA, Arlington, Virginia. April 15.

Tyson, T.W. 1999. Survey response - Alabama. E-mail message to DPRA, Arlington, Virginia. April 22.

USDA NRCS. 1998. *Nutrients available from livestock manure relative to crop growth requirements*. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington DC.

USDA NRCS. 1998. *National Handbook of Conservation Practices*. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington DC.

USDA NRCS. 2000. National handbook of conservation practices. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington DC.

USEPA. 1995. *Guidance manual on NPDES regulations for concentrated animal feeding operations*. EPA 833-B-95-001. U.S. Environmental Protection Agency, Washington, DC.

USEPA. 1999. *State Compendium: Programs and regulatory activities related to animal feeding operations*. U.S. Environmental Protection Agency, Washington, DC.

Wilson, R. 1999. Questions Regarding Beef Feeding Industry. E-mail message to DPRA, Arlington, Virginia.

York, K. 1999. CAFO Permitting. E-mail message to DPRA, Arlington, Virginia. March 3.

CHAPTER 10

TECHNOLOGY OPTIONS CONSIDERED

10.1 Changes to Effluent Guidelines Applicability

The existing effluent guidelines regulations for feedlots apply to operations with 1,000 AU and greater. EPA is proposing to establish effluent guidelines requirements for the beef, dairy, swine, chicken and turkey subcategories that would apply to any operations in these subcategories that are defined as a CAFO under either the two-tier or three-tier structure.

EPA also proposes to establish a new subcategory that applies to the production of veal cattle. Veal production is currently included in the beef subcategory. However, veal production practices and wastewater and manure handling are very different from the practices used at beef feedlots; therefore, EPA proposes to establish a separate subcategory for veal.

Under the three-tier structure the proposed effluent guidelines requirements for the beef, dairy, swine, veal and poultry subcategories will apply to all operations defined as CAFOs by today's proposal having at least as many animals as listed below.

200 mature dairy cattle (whether milked or dry);
300 veal cattle;
300 cattle other than mature dairy cattle or veal;
750 swine weighing over 55 pounds;
3,000 swine weighing 55 pounds or less;
16,500 turkeys; or
30,000 chickens.

Under the two-tier structure, the proposed requirements for the beef, dairy, swine, veal and poultry subcategories will apply to all operations defined as CAFOs by today's proposal having at least as many animals as listed below.

350 mature dairy cattle (whether milked or dry);
500 veal cattle;
500 cattle other than mature dairy cattle or veal;
1,250 swine weighing over 55 pounds;
5,000 swine weighing 55 pounds or less;
27,500 turkeys; or
50,000 chickens.

EPA is proposing to apply the effluent guidelines requirements for the beef, dairy, veal, swine, chicken and turkey subcategories, to all operations in these subcategories that are defined as CAFOs under either of these permitting scenarios. Operations below the 500 AU threshold or the 300 AU threshold in the three-tier structure that are designated as CAFOs are not subject to the proposed effluent guidelines.

EPA has evaluated the technology options described in this section and evaluated the economic achievability for these technologies for all operations with at least as many animals listed above for both the two-tier and three-tier NPDES structures. The technology requirements for operations defined as CAFOs under the two-tier structure are the same requirements for operations defined as CAFOs under the three-tier structure.

10.2 Changes to Effluent Limitations and Standards

EPA is proposing to revise BAT and new source performance standards for the beef, dairy, veal, swine and poultry subcategories. EPA is proposing to establish technology-based limitations on land application of manure to lands owned or operated by the CAFO, maintain the zero discharge standard and establish management practices at the production area.

10.2.1. Current Requirements

The existing regulations, which apply to operations with 1,000 AU or greater, require zero discharge of wastewater pollutants from the production area. Discharge is allowed when rainfall events, either chronic or catastrophic cause an overflow of process wastewater from a facility designed, constructed and operated to contain all process generated wastewaters plus runoff from a specific storm event. The magnitude of the storm event depends varies on the requirement, for the existing BPT requirements EPA established the design criteria on the 10-year, 24-hour event and based the existing BAT and New Source requirements on a 25-year, 24-hour storm event. In other words, wastewater and wastewater pollutants are allowed to be discharged as the result of a chronic or catastrophic rainfall event so long as the operation has designed, constructed and operated a manure storage and/or runoff collection system to contain all process generated wastewater, including the runoff from a specific rainfall event. The effluent guidelines do not set discharge limitations on the pollutants in the overflow.

10.2.2. Best Practicable Control Technology Limitations Currently Available (BPT)

EPA is proposing to establish BPT limitations for the beef, dairy, swine, veal chicken and turkey subcategories. There are BPT limitations in the existing regulations which apply to CAFOs with 1,000 AU or more in the beef, dairy swine and turkey subcategories. BPT requires that these operations achieve zero discharge of process wastewater from the production area except in the event of a 10-year, 24-hour storm event. EPA is proposing to revise this BPT requirement and to expand the applicability of BPT to all operations defined as CAFOs in these subcategories including CAFOs with fewer than 1,000 AU.

The Clean Water Act requires that BPT limitations reflect the consideration of the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such applications. EPA considered two options as the basis for BPT limitations.

Option 1. This option would require zero discharge from a facility designed, maintained and operated to hold the waste and wastewater, including storm water, from runoff plus the 25-year 24-hour storm event. Both this option and Option 2 would add record keeping requirements and practices that ensure this zero discharge standard is met. As described in Section V there are numerous reports of operations discharging pollutants from the production area during dry weather. The reason for these discharges varies from intentional discharge to poor maintenance of the manure storage area or confinement area. As described in Chapter 11 and in the cost methodology appendices, EPA's cost models reflect the different precipitation and climatic factors that affect an operations ability to meet this requirement.

Option 1 would require weekly inspection to ensure that any storm water diversions at the animal confinement and manure storage areas are free from debris, and daily inspections of the automated systems providing water to the animals to ensure they are not leaking or spilling. The manure storage or treatment facility would have to be inspected weekly to ensure structural integrity. For liquid impoundments, the berms would need to be inspected for leaking, seepage, erosion and other signs of structural weakness. The proposal requires that records of these inspections would be maintained on-site, as well as records documenting any problems noted and corrective actions taken. EPA believes these inspections are necessary to ensure proper maintenance of the production area and prevent discharges apart from those associated with a storm event from a catastrophic or chronic storm.

Liquid impoundments (e.g., lagoons, ponds and tanks) that are open and capture precipitation would be required to have depth markers installed. The depth marker indicates the maximum volume that should be maintained under normal operating conditions allowing for the volume necessary to contain the 25-year, 24-hour storm event. The depth of the impoundment would have to be noted during each week's inspection and when the depth of manure and wastewater in the impoundment exceeds this maximum depth, the operation would be required to notify the Permit Authority and inform him or her of the action that will be taken to address this exceedance. Closed or covered liquid impoundments must also have depth markers installed, with the depth of the impoundment noted during each week's inspection. In all cases, this liquid may be land applied only if done in accordance with the permit nutrient plan (PNP) described below. Without such a depth marker, a CAFO operator may fill the lagoons such that even a storm less than a 25-year, 24-hour storm causes the lagoon to overflow, contrary to the discharge limit proposed by the BPT requirements.

Option 1 would require operations to handle dead animals in ways that prevent contributing pollutants to waters of the U.S. EPA proposes to prohibit any disposal of dead animals in any liquid impoundments or lagoons. The majority of operations have mortality handling practices that prevent contamination of surface water. These practices include transferring mortality to a rendering facility, burial in properly sited lined pits, and composting.

Option 1 also would establish requirements to ensure the proper land application of manure and other process wastes and wastewaters. Under Option 1 land application of manure and wastewater to land owned or operated by the CAFO would have to be performed in accordance with a PNP that establishes application rates for manure and wastewater based on the nitrogen requirements for the crop. Pollutants in runoff are directly related to quantity of chemicals or fertilizer applied. EPA believes that application of manure and wastewater in excess of the crop's nitrogen requirements would increase the pollutant runoff from fields.

In addition, Option 1 includes a requirement that manure be sampled at least once per year and analyzed for its nutrient content including nitrogen, phosphorus and potassium. EPA believes that annual sampling of manure is the minimum frequency to provide the necessary nutrient content on which to establish the appropriate rate. If the CAFO applies its manure more frequently than once per year, it may choose to sample the manure more frequently. Sampling the manure as close to the time of application as practical provides the CAFO with a better measure of the nitrogen content of the manure. Generally, nitrogen content decreases through volatilization during manure storage when the manure is exposed to air.

The manure application rate established in the PNP would have to be based on the following factors: (1) the nitrogen requirement of the crop to be grown based on the agricultural extension or land grant university recommendation for the operation's soil type and crop; and (2) realistic crop yields that reflect the yields obtained for the given field in prior years or, if not available, from yields obtained for same crop at nearby farms or county records. Once the nitrogen requirement for the crop is established the manure application rate would be determined by subtracting any other sources of nitrogen available to the crop from the crop's nitrogen requirement. These other sources of nitrogen can include residual nitrogen in the soil from previous applications of organic nitrogen, nitrogen credits from previous crops of legumes, and crop residues, or applications of commercial fertilizer, irrigation water and biosolids. Application rates would be based on the nitrogen content in the manure and should also account for application methods, such as incorporation, and other site specific practices.

The CAFO would have to maintain the PNP on-site, along with records of the application of manure and wastewater including: (1) the amount of manure applied to each field; (2) the nutrient content of manure; (3) the amount and type of commercial fertilizer and other nutrient sources applied; and (4) crop yields obtained. Records must also indicate when manure was applied, application method and weather conditions at the time of application.

While Option 1 would require manure to be sampled annually, it would not require soil sampling and analysis for the nitrogen content in the soil. Nitrogen is present in the soil in different forms and depending on the form the nitrogen will have different potential to move from the field.

Nitrogen is present in an organic form from the decay of proteins and urea found in livestock manure and biosolids, or from other organic compounds that result from decaying plant material. These organic compounds are broken down by soil bacteria to inorganic forms of nitrogen such as nitrate and ammonia. Inorganic nitrogen or urea may be applied to crop or pasture land as commercial fertilizer. Inorganic nitrogen is the form taken up by the plant. It is also more soluble and readily volatile, and can leave the field through runoff or emissions. Nitrogen can also be added to the soil primarily through cultivation of legumes which will “fix” nitrogen in the soil. At all times nitrogen is cycling through the soil, water, and air, and does not become adsorbed or built up in the soil in the way that phosphorus does, as discussed under Option 2. Thus, EPA is not proposing to require soil sampling for nitrogen. EPA would, however, require that, in developing the appropriate application rate for nitrogen, any soil residue of nitrogen resulting from previous contributions by organic fertilizers, crop residue or legume crops should be taken into account when determining the appropriate nitrogen application rate. State Agricultural Departments and Land Grant Universities have developed methods for accounting for residual nitrogen contributed from legume crops, crop residue and organic fertilizers.

Option 1 would also prohibit application of manure and wastewater within 100 feet of surface waters, tile drain inlets, sinkholes and agricultural drainage wells. EPA strongly encourages CAFOs to construct vegetated buffers, however, Option 1 only prohibits applying manure within 100 feet of surface water and would not require CAFOs to take crop land out of production to construct vegetated buffers. CAFOs may continue to use land within 100 feet of surface water to grow crops.

Under Option 1, EPA included costs for facilities to construct minimal storage, typically three to six months, to comply with the manure application rates developed in the PNP. Data indicate that when the manure has been stored and aged prior to land application, pathogen “concentrations” in surface waters adjacent to land that received manure does not vary significantly from pathogen “concentrations” adjacent to land that did not receive manure. In addition to pathogen reductions achieved through storage, EPA believes the 100 foot setback and proper manure application, will minimize the potential runoff of pathogens, hormones and metals and reduce the nutrient and sediment runoff.

EPA chose not to propose requiring operations to take land out of production and construct a vegetated buffer because a buffer may not be the most cost-effective application to control erosion in all cases. There are a variety of field practices that should be considered for the control of erosion. EPA encourages CAFOs to obtain and implement a conservation management plan to minimize soil losses, and also to reduce losses of pollutant bound to the soils. Erosion and sediment controls are discussed in Chapter 8.

Today’s proposal requires a greater setback distance than the distance that would be needed for a cost effective buffer under most circumstances. Since EPA is not requiring the construction of a vegetated buffer, the additional setback distance will compensate for the loss of pollutant reductions in the surface runoff leaving the field that would have been achieved with a vegetated buffer without requiring CAFOs to remove this land from production.

Farmers entering stream buffers in the Conservation Reserve Program's (CRP) Continuous Sign-Up receive bonus payments, as an added incentive to enroll, include a 20 percent rental bonus, a $100 per acre payment up-front (at the time they sign up), and another bonus at the time they plant a cover. These bonus payments more than cover costs associated with enrolling stream buffers, (i.e., rents forgone for the duration of their 10 or 15 year CRP contracts, and costs such as seed, fuel, machinery and labor for planting a cover crop). The bonuses provide a considerable incentive to enroll stream buffers because the farmers receive payments from USDA well in excess of what they could earn by renting the land for crop production. Farmers can enter buffers into the CRP program at any time.

EPA may also consider providing CAFOs the option of prohibiting manure application within 100 feet or constructing a 35 foot vegetated buffer. As discussed in more detail in Chapter 11 and the cost methodology appendices, the cost associated with taking land out of production and planting with a vegetated buffer is included in the cost for Option 1 and all subsequent options, even though it is not a requirement. Chapter 8 describes the application of a buffer and its advantages and disadvantages.

Option 1 is estimated to cost $432.1 million annually for all operations defined as CAFOs under the two-tier structure and $462.8 million annually for all operations defined as CAFOs under the three-tier structure. These estimates account for practices and technologies already in place at operations and thus represent the incremental costs that would be incurred by operations to comply with the requirements of Option 1. Option 1 is estimated to reduce nutrient loads reaching the edge of the field amounting to 624 million pounds under the three-tier structure. Option 1 is also estimated to achieve a 37 million pound reduction of the metals reaching the edge of the field and reduce fecal coliform by 135 billion colony forming units (cfu) and fecal streptococcus by 218 billion cfu under the three-tier structure. Under the two-tier structure the reductions are estimated to be 553 million pounds of nutrients, 31 million pounds of metals and 116 billion cfu, and 206 billion cfu of fecal coliforms and streptococcus, respectively.

Option 2. Option 2 retains all the same requirements for the feedlot and manure storage areas described under Option 1 with one exception: Option 2 would impose a BMP that requires manure application rates be phosphorus based where necessary, depending on the specific soil conditions at the CAFO.

Manure is phosphorus rich, so application of manure based on a nitrogen rate may result in application of phosphorus in excess of crop uptake requirements. Traditionally, this has not been a cause for concern, because the excess phosphorus does not usually cause harm to the plant and can be adsorbed by the soil where it was thought to be strongly bound and thus environmentally benign. However, the capacity for soil to adsorb phosphorus will vary according to soil type, and recent observations have shown that soils can and do become saturated with phosphorus. When saturation occurs, continued application of phosphorus in excess of what can be used by the crop and adsorbed by the soil results in the phosphorus leaving the field with storm water via leaching or runoff. Phosphorus bound to soil may also be lost from the field through erosion.

Repeated manure application at a nitrogen rate has now resulted in high to excessive soil phosphorus concentrations in some geographic locations across the country. Option 2 would require manure application be based on the crop removal rate for phosphorus in locations where soil concentrations or soil concentrations in combination with other factors indicate that there is an increased likelihood that phosphorus will leave the field and contribute pollutants to nearby surface water and groundwater. Further, when soil concentrations alone or in combination with other factors exceed a given threshold for phosphorus, the proposed rule would prohibit manure application. EPA included this restriction because the addition of more phosphorus under these conditions is unnecessary for ensuring optimum crop production.

Nutrient management under Option 2 includes all the steps described under Option 1, plus the requirement that all CAFOs collect and analyze soil samples at least once every 3 years from all fields that receive manure. EPA would require soil sampling at 3 year intervals because this reflects a minimal but common interval used in crop rotations. This frequency is also commonly adopted in nutrient management plans prepared voluntarily or under state programs. When soil conditions allow for manure application on a nitrogen basis, then the PNP and record keeping requirements are identical to Option 1. Permit nutrient plans would have to be reviewed and updated each year to reflect any changes in crops, animal production, or soil measurements and would be rewritten and certified at a minimum of once every five years or concurrent with each permit renewal.

The CAFO's PNP would have to reflect conditions that require manure application on a phosphorus crop removal rate. The manure application rate based on phosphorus requirements takes into account the amount of phosphorus that will be removed from the field when the crop is harvested. This defines the amount of phosphorus and the amount of manure that may be applied to the field. The PNP must also account for the nitrogen requirements of the crop. Application of manure on a phosphorus basis will require the addition of commercial fertilizer to meet the crop requirements for nitrogen. Under Option 2, EPA believes there is an economic incentive to maximize proper handling of manure by conserving nitrogen and minimizing the expense associated with commercial fertilizer. EPA expects manure handling and management practices will change in an effort to conserve the nitrogen content of the manure, and encourages such practices since they are likely to have the additional benefit of reducing the nitrogen losses to the atmosphere.

EPA believes management practices that promote nitrogen losses during storage will result in higher applications of phosphorus because in order to meet the crops requirements for nitrogen a larger amount of manure must be applied. Nitrogen volatilization exacerbates the imbalance in the ratio of nitrogen to phosphorus in the manure as compared to the crop's requirement. Thus application of manure to meet the nitrogen requirements of the crop will result in over application of phosphorus and the ability of the crops and soil to assimilate phosphorus will reach a point at which the facility must revise the PNP to reflect phosphorus based application rates.

Under both Option 1 (N) and Option 2 (P), the application of nitrogen from all sources may not exceed the crop nutrient requirements. Since a limited amount of nutrients can be applied to the field in a given year, EPA expects facilities will select the site-specific practices necessary to optimize use of those nutrients. Facilities that apply manure at inappropriate times run the risk of losing the value of nutrients applied and will not be permitted to reapply nutrients to compensate for this loss. Consequently crop yields may suffer, and in subsequent years, the allowable application rates will be lower. For these reasons, facilities with no storage are assumed to need a minimal storage capacity to allow improved use of nutrients. Costs were estimated for operations which do not currently have adequate storage, see Chapter 11 and the cost methodology appendices for a discussion of how these costs were determined and how many operations were costed for this requirement.

Option 2 provides three methods for determining the manure application rate for a CAFO. These three methods are:

- Phosphorus Index
- Soil Phosphorus Threshold Level
- Soil Test Phosphorus Level

These three methods are adapted from NRCS' nutrient management standard (Standard 590), which is being used by States' Departments of Agriculture to develop State nutrient standards that incorporate one or a combination of these three methods. EPA is proposing to require that each authorized state Permit Authority adopt one or a combination of these three methods in consultation with the State Conservationist. CAFOs would then be required to develop their PNP based on the State's method for establishing the application rate. In those states where EPA is the permitting authority, the EPA Director would adopt one of these three methods in consultation with that State's Conservationist.

Phosphorus Index – This index assesses the risk that phosphorus will be transported off the field to surface water and establishes a relative value of low, medium, high or very high, as specified in §412.33. Alternatively, it may establish a numeric ranking. At the present time there are several versions of the P-Index under development. Many states are working on a P-Index for their state in response to the NRCS 590 Standard, and NRCS itself developed a P-Index template in 1994 and is in the process of updating that template at the present time. There are efforts underway in the scientific community to standardize a phosphorus index and assign a numeric ranking.

At a minimum the phosphorus index must consider the following factors:

- soil erosion
- irrigation erosion
- runoff class
- soil P test
- P fertilizer application rate
- P fertilizer application method
- organic P source application rate
- organic P source application method

Other factors could also be included, such as:

- subsurface drainage
- leaching potential
- distance from edge of field to surface water
- priority of receiving water

Each of these factors is listed in a matrix with a score assigned to each factor. For example, the distance from edge of field to surface water assigns a score to different ranges of distance. The greater the measured distance, the lower the score. Other factors may not be as straightforward. For example, the surface runoff class relates field slope and soil permeability in a matrix, and determines a score for this element based on the combination of these factors. The same kind of approach could also be used for the subsurface drainage class, relating soil drainage class with the depth to the seasonal high water table. The values for all variables that go into determining a P-Index can either be directly measured, such as distance to surface water, or can be determined by data available from the state, such as soil drainage class that is based on soil types found in the state and assigned to all soil types. Finally, each factor is assigned a weight depending on its relative importance in the transport of phosphorus.

When a P-Index is used to determine the potential for phosphorus transport in a field and the overall score is high, the operations would apply manure on a phosphorus basis (e.g., apply to meet the crop removal rate for phosphorus). When a P-Index determines that the transport risk is very high, application of manure would be prohibited. If the P-Index results in a rating of low or medium, then manure may be applied to meet the nitrogen requirements of the crop as described under Option 1. However, the CAFO must continue to collect soil samples at least every three years. If the phosphorus concentration in the soil is sharply increasing, the CAFO may want to consider managing its manure differently. This may include changing the feed formulations to reduce the amount of phosphorus being fed to the animals, precision feeding to account for nutrient needs of different breeds and ages of animals. It may also include changing manure storage practices to reduce nitrogen losses. These practices are discussed in detail in Chapter 8. The CAFO may also consider limiting the application of manure. For example, the CAFO may apply manure to one field to meet the nitrogen requirements for that crop but not return to that field until the crops have assimilated the phosphorus that was applied from the manure application.

<u>Phosphorus Threshold</u> – This threshold which would be developed for different soil types is a measure of phosphorus in the soil that reflects the level of phosphorus at which phosphorus movement in the field is acceptable. Scientists are currently using a soluble phosphorus concentration of 1 part per million (ppm) as a measure of acceptable phosphorus movement. When the soil concentration of phosphorus reaches this threshold the concentration of phosphorus in the runoff would be expected to be 1 ppm. The 1 ppm value has been used as an indicator of acceptable phosphorus concentration because it is a concentration that has been applied to POTWs in their NPDES permits. An alternative phosphorus discharge value could be the water quality concentration for phosphorus in a given receiving stream.

States which adopt this method in their state nutrient management standard would need to establish a phosphorus threshold for all types of soils found in their state.

Use of the phosphorus threshold in developing an application rate allows for soils with a phosphorus concentration less than three quarters the phosphorus threshold to apply manure on a nitrogen basis. When soils have a phosphorus concentration between 3/4 and twice the phosphorus threshold then manure must be applied to meet the crop removal requirements for phosphorus. For soils which have phosphorus concentrations greater than twice the phosphorus threshold, no manure may be applied.

<u>Soil Test Phosphorus</u> – The soil test phosphorus is an agronomic soil test that measures for phosphorus. This method is intended to identify the point at which the phosphorus concentration in the soil is high enough to ensure optimum crop production. Once that concentration range (often reported as a “high” value from soil testing laboratories) is reached, phosphorus is applied at the crop removal rate. If the soil test phosphorus level reaches a very high concentration, then no manure may be applied. Most soils need to be nearly saturated with phosphorus to achieve

optimum crop yields. The soil phosphorus concentration should take into account the crop response and phosphorus application should be restricted when crop yield begins to level off.

The soil test phosphorus method establishes requirements based on low, medium, high and very high soil condition, and applies the same restrictions to these measures as are used in the P-Index. States that adopt this method must establish the soil concentration ranges for each of these risk factors for each soil type and crop in their state.

EPA anticipates that in most states, the permit authority will incorporate the State's nutrient standard (590 Standard) into CAFO permits. For example, if the permit authority, in consultation with the State Conservationist, adopts a Phosphorus Index, then CAFO permits would include the entire P-Index as the permit condition dictating how the application rate must be developed. If a permit authority selects the Phosphorus Threshold, then the CAFO permits must contain soil concentration limitations that reflect phosphorus-based application, as well as the level at which manure application is prohibited.

Finally, under Option 2 EPA is proposing to require CAFOs that transfer manure off-site to provide the recipient of the manure with information as to the nutrient content of the manure and provide the recipient with information on the correct use of the manure.

EPA estimates Option 2 would cost $548.8 million annually for all operations defined as CAFOs under the two-tier structure and $582.8 million annually under the three-tier structure. EPA estimates that Option 2 will achieve reductions at the edge of field of 760 million pounds of nutrients (nitrogen and phosphorus)under the two-tier structure and 860 million pounds under the three-tier structure. The two-tier structure would also achieve a reduction at the edge of the field of 95 million pounds of metals under the two-tier structure and 103 million pounds of metals under the three-tier structure. Option 2 would also achieve reductions in the numbers of pathogen colonies which reach the edge of the field, under the two-tier structure the reduction is estimated to be 125 billion cfu of fecal coliform and 244 billion cfu of fecal streptococcus, the three-tier structure would achieve additional reductions of 21 billion cfu fecal coliforms and 26 billion cfu of fecal streptococcus.

As discussed in Chapter 8, compliance costs for manure transfer assessed to the CAFO include hauling costs and record keeping. If the recipient is land applying the manure, the recipient is most likely a crop farmer, and the recipient is assumed to already have a nutrient management plan that considers typical yields and crop requirements. The recipient is also assumed to apply manure and wastes on a nitrogen basis, so the application costs are offset by the costs for commercial fertilizer purchase and application.   EPA assumes the recipient may need to sample soils for phosphorus, and costs for sampling identically to the CAFO, i.e. every three years. EPA has not accounted for costs that would result from limiting the amount or way recipients are currently using manure.

EPA is considering requiring training for persons that will apply manure. There are some states which have these requirements. Proper application is critical to controlling pollutant discharges from crop fields. Some states have established mandatory training for persons that apply manure. EPA will consult with USDA on the possibility of establishing a national training program for manure applicators.

10.2.3 Proposed Basis for BPT Limitations.

EPA is not proposing to establish BPT requirements for the beef, dairy, swine, veal and poultry subcategories on the basis of Option 1, because it does not represent the best practicable control technology. In areas that have high to very high phosphorus build up in the soils, Option 1 would not require that manure application be restricted or eliminated. Thus, the potential for phosphorus to be discharged from land owned or controlled by the CAFOs would not be controlled by Option 1. Consequently Option 1 would not adequately control discharges of phosphorus from these areas. Option 2 would reduce the discharge of phosphorus in field runoff by restricting the amount of phosphorus that may be applied to the amount that is appropriate for agricultural purposes or prohibiting the application of manure when phosphorus concentrations in the soil are very high and additional phosphorus is not needed to meet crop requirements.

EPA's cost estimates assume that a percentage of operations will have to apply manure to crop land on a phosphorus basis dependent on the region and information available in the USDA's ARS publication entitled "*Agricultural Phosphorus and Eutrophication*" (ARS-149). This is discussed in more detail in Chapter 11.

EPA is proposing to establish BPT limitations for the beef, dairy, swine, veal and poultry subcategories on the basis of Option 2. EPA's decision to base BPT limitations on Option 2 treatment reflects consideration of the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application. Option 2 is expected to cost $549 million under the two-tier structure and achieve a reduction of pollutants reaching surface waters over baseline (current) practices 624 million pounds of nutrient and metals for a total cost to pound ratio of $0.88. The three-tier structure is estimated to cost $583 and achieve a reduction of 703 million pounds of pollutants for a total cost to pounds removed ratio of $0.82.

The Option 2 technology is one that is readily applicable to all CAFOs. The production area requirements represent the level of control achieved by the majority of CAFOs in the beef, dairy, swine, poultry and veal subcategories. USDA and the American Society of Agricultural Engineers cite the 25-year, 24-hour storm as the standard to which storage structures should comply. This has been the standard for many years, and most existing lagoons and other open liquid containment structures are built to this standard. As described above, the land application requirements associated with Option 2 are believed to represent proper agricultural practice and to ensure that CAFO manure is applied to meet the requirements of the crops grown and not exceed the ability of the soil and crop to absorb nutrients.

EPA believes any of the three methods for determining when manure should be applied on a phosphorus basis would represent BPT. Each method has distinct advantages which, depending on the circumstances, could make one method preferred over another. There has been considerable work done in this area within the past few years and this work is continuing. EPA believes that this proposed BPT approach provides adequate flexibility to allow states to develop an approach that works best for the soils and crops being grown within their state.

CAFOs must also develop and implement a PNP that establishes the appropriate manure application rate. EPA believes the land application rates established in accordance with one of the three methods described in today's proposed regulation, along with the prohibition of manure application within 100 feet of surface water, will ensure manure and wastewater are applied in a manner consistent with proper agricultural use. For a detailed discussion of how a PNP is expected to be developed refer to the Draft Guidance Manual for PNPs.

EPA believes that state sampling and analytical protocols are effective; however, soil phosphorus levels can vary depending on how the soil samples are collected. For example, a CAFO that surface-applies manure will deposit phosphorus in the surface layer of the soil and should collect soil samples from the top layer of soil. If this CAFO collects soil samples to a depth of several inches the analysis may understate the phosphorus build-up near the soil surface. Thus, EPA may evaluate the need to establish specific soil sampling protocols.

10.2.4 Best Control Technology for Conventional Pollutants (BCT)

In evaluating possible BCT standards, EPA first considered whether there are any candidate technologies (i.e., technology options); that are technologically feasible and achieve greater conventional pollutant reductions than the proposed BPT technologies. (Conventional pollutants are defined in the Clean Water Act as including: Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), pH, oil and grease and fecal coliform.) EPA considered the same BAT technology options described below and their effectiveness at reducing conventional pollutants. EPA's analysis of pollutant reductions has focused primarily on the control of nutrients, nitrogen and phosphorus. However, the Agency has also analyzed what the technology options can achieve with respect to sediments (or TSS), metals, and pathogens. Although livestock waste also contains BOD, EPA did not analyze the loadings or loadings reductions associated with the technology options for BOD. Thus, the only conventional pollutant considered in the BCT analysis is TSS. EPA identified no technology option that achieves greater TSS removals than the proposed BPT technologies see Chapter 12. EPA does not believe that these technology options would substantially reduce BOD loads. There are therefore no candidate technologies for more stringent BCT limits. If EPA had identified technologies that achieve greater TSS reductions than the proposed BPT, EPA would have performed the two part BCT cost test. (See 51 FR 24974 for a description of the methodology EPA employs when setting BCT standards.)

EPA is proposing to establish BCT limits for conventional pollutants equivalent to the proposed BPT limits.

10.2.5. Best Available Technology Economically Achievable (BAT)

EPA is considering six technology options to control discharges from CAFOs in the beef, veal and poultry subcategories, and seven technology options for the dairy and hog subcategories. All of the technology options include restrictions on land application of manure, best management practices (BMPs), inspections and record keeping for the animal confinement areas, and wastewater storage or treatment structures. The following table summarizes the requirements for each of the seven technology options. Note that a given technology option may include a combination of technologies

Table 10-1. Requirements Considered in the Technology Options

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Zero Discharge w/ overflow when a 25-24 Design Standard is met	X	X	X	X	Cattle & Dairy		
Depth markers for lagoons	X	X	X	X	Cattle & Dairy	X	X
Annual Manure Testing	X	X	X	X	X	X	X
N-based PNP	X						
100' LA setback	X	X	X	X	X	X	X
P-based PNP (where necessary)		X	X	X	X	X	X
Soil Test - every 3yrs.		X	X	X	X	X	X
Zero discharge without any allowance for overflow					Swine & Poultry		
Hydrologic Link Assessment & Zero Discharge to Groundwater beneath Production Area			X	X			
Ambient Surface Water Sampling (N, P, TSS)				X			
Anaerobic Digestion w/power generation					Swine	Swine & Dairy	
Frozen/snow covered/saturated application prohibitions							X

X = All Subcategories

Option 1. This option is equivalent to Option 1 described under BPT. Option 1 would require zero discharge from the production area and that liquid storage be designed, constructed and maintained to handle all process wastewater and storm water runoff from the 25-year, 24-hour storm event. In addition, Option 1 requires management practices to ensure that the production area (which includes manure and wastewater storage) is being adequately maintained.

Option 1 also would establish a requirement to develop a PNP which establishes the proper land application rate for manure and wastewater to meet the nitrogen requirements for the crops being grown by the CAFO and require a 100 foot setback from surface water, sinkholes, tile drain inlets and agricultural drainage wells.

Option 2. This option is equivalent to Option 2 described under BPT (See section 10.2.2 of this Chapter). Option 2 includes all of the requirements established under Option 1. However, Option 2 would further restrict the amount of manure that can be applied to crop land owned or controlled by the CAFO. The CAFO would be required to apply manure and wastewater at the appropriate rate taking into account the nutrient requirements of the crop and soil conditions. Specifically, Option 2 would require that manure be applied at crop removal rate for phosphorus if soil conditions warrant and, if soils have a very high level phosphorus build-up, no manure or wastewater could be applied to the crop land owned or controlled by the CAFO.

Option 3. Option 3 includes all the requirements for Option 2 and would require that all operations perform an assessment to determine whether the ground water beneath the feedlot and manure storage area has a direct hydrological connection to surface water. EPA has authority to control discharges to surface water through ground water that has a direct hydrological connection to surface water. A hydrological connection refers to the interflow and exchange between surface impoundments and surface water through an underground corridor or ground water. EPA is relying on the permitting authority to establish the region-specific determination of what constitutes a direct hydrological link. Option 3 would require all CAFOs to determine whether they have a direct hydrological connection between the ground water beneath the production area and surface waters. If a link is established, the facility would have to monitor ground water up gradient and down gradient of the production area to ensure that they are achieving zero discharge to ground water.

The literature indicates earthen basins and clay liners leak, and EPA believes clay is not sufficient to prevent discharges to groundwater. Clay liners are routinely constructed from materials obtained locally. These clays vary in their conductivity, and are subject to cracking due to drying of the sidewalls. Therefore clays do not consistently pose an impermeable barrier. Similarly, concrete basins may crack and leak over time, particularly in climates with frequent freeze thaw cycles. EPA has assumed that CAFOs would comply with the zero discharge requirement by installing liners of synthetic material beneath lagoons and ponds, and impervious pads below storage of dry manure stockpiles. EPA's costs for liners reflect both a synthetic liner to provide an impervious layer, and compacted clay to protect the liner and prolong its useful life.

The clay serves to prevent tearing of the liner by heavy equipment, and also serves to prolong the life of the synthetic material.

USDA's Natural Resources Inventory (NRI) database for land cover/use which is in close proximity to animal agricultural facilities (i.e., barns, feedlots, corrals, pens, etc.) were assumed to be potential sites for animal waste storage structures. Thus NRI subcategories of "Other Farmland," Farmstead and Ranch Headquarters," and "Other Land in Farms" as well as two other categories for "Agricultural Production, Facilities" and "Waste, Agricultural Waste" categories were compiled as potential sites for manure storage structures. Next the NRI soil/hydrologic data were overlaid onto these potential sites. Soil conditions which were indicative of a potential hydrologic connection were identified. These conditions included sandy soil textures, shallow depth to groundwater and karst or karst-like conditions. A percentage of acres which met the cover/use descriptions and had the characteristics indicative of a potential for a hydrologic connection was determined for each of the five regions and for the nation as a whole. This percentage was determined to be 23 percent nationally and this was used to estimate the number of CAFOs that could incur the costs associated with lining lagoons and monitoring groundwater. The remaining CAFOs were assumed to incur the cost of obtaining a hydrologic assessment.

CAFOs with a direct hydrologic link would be required to sample the groundwater from the monitoring wells (located up gradient and down gradient of the production area) at a minimum frequency of twice per year. These samples are necessary to ensure that pollutants are not being discharged through groundwater to surface water from the production area. The samples shall be monitored for nitrate, ammonia, total coliform, fecal coliform, Total Dissolved Solids (TDS) and total chloride. Differences in concentration of these pollutants between the monitoring well(s) located up gradient and down gradient of the production area are assumed to represent a discharge of pollutants and must be prevented. As noted below, coliforms are not necessarily good indicators of livestock discharges. Also, it is difficult to determine "concentrations" of coliforms as they are not necessarily evenly distributed in the way chemical contaminants generally are. EPA requests comment on technical concerns associated with including total and fecal coliforms in the groundwater monitoring and protection requirements and on ways to address such concerns.

Option 3 is estimated to cost $746.7 million annually for operations defined as CAFOs under the two-tier structure. This is an incremental annual cost of $198.1 million over Option 2 costs. For operations defined as CAFOs under the three-tier structure, Option 3 is estimated to cost $854.1 million annually, which is an incremental annual cost above Option 2 of $271.3 million. Option 3 is estimated to achieve an incremental reduction of pollutants of 5 million pounds of nitrogen annually. This reflects the pounds lost from nitrogen leaching to groundwater which is directly connected to surface water.

Option 4. Option 4 includes all the requirements for Option 3 and would require sampling of surface waters adjacent to feedlots and/or land under control of the feedlot to which manure is applied. This option would require CAFOs to sample surface water both upstream and downstream from the feedlot and land application areas following a one half inch rain fall (not to exceed 12 sample events per year). The samples would be analyzed for concentrations of nitrogen, phosphorus and total suspended solids (TSS). EPA selected these pollutants because it believes these pollutants provide an adequate indication of whether a discharge is occurring from the operation. All sampling results would be reported to the permit authority. Any difference in concentration between the upstream and downstream samples would be noted. This monitoring requirement could provide some indication of discharges from the land application or feedlot areas.

EPA also considered requiring that pathogens and BOD_5 be analyzed in samples collected. EPA decided that this would not be practical, because sampling under Option 4 is linked to storm events which limits the ability to plan in advance for analysis of the samples and making arrangements for shipping samples to laboratories. Fecal coliform and BOD samples all have very short holding times before they need to be analyzed. Most CAFOs are located in rural areas with limited access to overnight shipping services and are probably not near laboratories that can analyze for these pollutants. Further, fecal coliform and similar analytes that are typically used as indicators in municipal wastewater are not necessarily good indicators of livestock discharges. If CAFOs were required to monitor for pathogens which could indicate discharges of manure or CAFO wastewater, it would be better to require monitoring for fecal enterococci, or even specific pathogens such as salmonella, Giardia, and Cryptosporidium. However, the cost for analyzing these parameters is very high and the holding times for these parameters are also very short.

Furthermore, EPA determined pathogen analyses are also inappropriate because the pathogens in manure are found in areas without animal agriculture. For example *Enterobacter, Klebsiella, Bacillus cereus, Clostridium,* and *Listeria* are all naturally occurring soil and plant microorganisms and are found in soils that have never received manure. Pathogens may also be deposited onto land from wildlife. Thus, EPA concluded that requiring analysis for these pollutants was impractical at best and potentially very expensive.

EPA estimated the annual cost of Option 4 to be $903.9 million under the two-tier structure which is $154.2 million incremental to Option 3 . Under the three-tier structure the estimated annual cost of Option 4 is $1.088 billion which is an incremental annual cost of $234.1 million. The monitoring requirements associated with Option 4 do not directly reduce the pollutants discharged from CAFOs thus no incremental pollutants reductions were estimated. There could be some pollutant reductions associated with increased vigilance associated with the monitoring, however it is not possible to quantify this reduction.

Option 5. Option 5 includes the requirements established by Option 2 and would establish a zero discharge requirement from the production area that does not allow for an overflow under any circumstances. By keeping precipitation from contacting with the animals, raw materials, waste handling and storage areas, CAFOs could operate the confinement areas and meet zero discharge regardless of rainfall events. Option 5 includes the same land application requirements as Option 2, which would restrict the rate of manure and wastewater application to a crop removal rate for phosphorus where necessary depending on the specific soil conditions at the CAFO. Additionally, as in Option 2, application of manure and wastewater would be prohibited within 100 feet of surface water.

EPA considered Option 5 for the poultry, veal and hog subcategories, where it is common to keep the animals in total confinement, feed is generally maintained in enclosed hoppers and the manure and wastewater storage can be handled so as to prevent it from contacting storm water. EPA considered a number of ways a facility might meet the requirements of no discharge and no overflow. In estimating the costs associated with Option 5, EPA compared the total costs and selected the least expensive technology for a given farm size, geographic region, and manure management system. Costs also depend on whether the facility's PNP indicates land application must be based on nitrogen or phosphorus, and how many acres the facility controls. The technologies described below were used singularly or in combination to meet the requirements of Option 5.

Many facilities can achieve Option 5 by covering open manure and storage areas, and by constructing or modifying berms and diversions to control the flow of precipitation. EPA costed broiler and turkey operations for storage sheds sufficient to contain six months of storage. Some poultry facilities, particularly turkey facilities, compost used litter in the storage sheds, allowing recycle and reuse of the litter. EPA costed swine, veal, and poultry facilities which use lagoons or liquid impoundments for impoundment covers.

EPA believes that operations which have excess manure nutrients and use flush systems to move manure out of the confinement buildings will have an incentive to construct a second lagoon cell. A second storage or treatment cell should accomplish more decomposition of the waste and will allow flush water to be recycled out of the second cell or lagoon, thus reducing the addition of fresh water to the system. Reducing the total volume of stored waste reduces the risk of a catastrophic failure of the storage structure. In the absence of large volumes of water, facilities with an excess of manure nutrients will be able to transfer the excess manure off-site more economically due to a lower volume of waste needing to be hauled. Water reduction also results in a more concentrated product which would have a higher value as a fertilizer.

Covered systems substantially reduce air emissions, and help maintain the nutrient value of the manure. Covered systems also may benefit facilities by reducing odors emanating from open storage. This option also creates a strong incentive for facilities to utilize covered lagoon digesters or multistage covered systems for treatment. The use of covers will allow smaller and more stable liquid impoundments to be constructed. Finally, the use of covered impoundments encourages treatment and minimal holding times, resulting in pathogen die-off and reduction of BOD and volatile solids.

Other technologies can be effectively used at some facilities, such as conversion of flush systems to scrape systems, or by retrofit of slatted floor housing to V-shaped under house pits that facilitate solid liquid separation. Solids can be stored or composted in covered sheds, while the urine can be stored in small liquid impoundments. Solid-liquid separation is discussed in Chapter 8.

In the event the facility has insufficient land to handle all nutrients generated, EPA evaluated additional nutrient management strategies. First, the manure could pass through solid separation, resulting in a smaller volume of more concentrated nutrients that is more effectively transported offsite. Second, land application could be based on the uppermost portion of a covered lagoon containing a more dilute concentration of nutrients. Data indicates much of the phosphorus accumulates in the bottom sludge, which is periodically removed and could be transported offsite for proper land application. Though many facilities report sludge removal of a properly operating lagoon may occur as infrequently as every 20 years, EPA assumed facilities would pump out the phosphorus and metals enriched sludge every three years. This is consistent with the ANSI/ASAE standards for anaerobic treatment lagoons (EP403.3 JUL99) that indicates periodic sludge removal and liquid draw down is necessary to maintain the treatment volume of the lagoon. Third, swine and poultry farms can implement a variety of feeding strategies, as discussed under Option 2 (see Section VII.C.3). Feed management including phytase, multistage diets, split sex feeding, and precision feeding have been shown to reduce phosphorus content in the manure by up to 50%. This results in less excess nutrients to be transported offsite, and allows for more manure to be land applied at the CAFO.

EPA is aware of a small number of swine facilities that are potentially CAFOs and use either open lots or some type of building with outside access to confine the animals. EPA data indicate these types of operations are generally smaller operations that would need to implement different technologies than those described above. CAFOs that provide outdoor access for the animals need to capture contaminated storm water that falls on these open areas. Open hog lots would find it difficult to comply with a requirement that does not allow for overflows in the event of a large storm. EPA costed these facilities to replace the open lots with hoop houses to confine the animals and storage sheds to contain the manure. Hoop structures are naturally ventilated structures with short wooden or concrete sidewalls and a canvas, synthetic, or reflective roof supported by tubes or trusses. The floor of the house is covered with straw or similar bedding materials. The manure and bedding is periodically removed and stored. The drier nature of the manure lends to treatment such as composting as well as demonstrating reduced hauling costs as compared to liquid manure handling systems.

EPA considered a variation to Option 5 that would require CAFOs to use dry or drier manure handling practices. This variation assumed conversion to a completely dry manure handling system for hogs and laying hens using liquid manure handling systems. In addition to the advantages of reduced water use described above, a completely dry system is more likely to minimize leaching to ground water and, where directly connected hydrologically to surface water, will also reduce loads to surface waters. For the beef and dairy subcategories EPA assumes that the liquid stream would be treated to remove the solids and the solids would be composted. It is not practical to assume existing beef and dairy operations can avoid the generation of liquid waste because operations in both subcategories tend to have animals in open areas exposed to precipitation resulting in a contaminated storm water that must be captured. Also dairies generate a liquid waste stream from the washing of the milking parlor.

Option 5 is estimated to cost $1,515.9 million annually under the two-tier structure and $1,632.9 annually under the three-tier structure. The amount of manure and application methods under Option 5 are no different than required under Options 2. Therefore, the quantify of pollutants which reach the edge-of-field under Option 5 is not expected to be any less than under Option 5. Options 5 will reduce pollutants discharged from the production area during chronic or catastrophic storms that exceed the design standard, however, EPA has not quantified this amount.

Option 6. Option 6 includes the requirements of Option 2 and requires that large hog and dairy operations (hog operations and dairies with 2,000 AU) would install and implement anaerobic digestion to treat their manure and use the captured methane gas for energy or heat generation. With proper management, such a system can be used to generate additional on-farm revenue. The enclosed system will reduce air emissions, especially odor and hydrogen sulfide, and potentially reduces nitrogen losses from ammonia volatilization. The treated effluent will also have less odor and should be more transportable relative to undigested manure, making offsite transfer of manure more economical. Anaerobic digestion under thermophilic or heated conditions would achieve additional pathogen reductions. Digester technology is described in Chapter 8, see 8.2.3.1.

Option 6 is estimated to cost $621.6 million annually under the two-tier structure and $736.9 million annually under the three-tier structure. As described under Option 5, Option 6 does not affect the amount of manure or the chemical characteristics of the manure applied to the land, thus the pollutant loads expected to reach the edge of the field are the same as under Option 2. There could be some reduction from fewer discharges at the production area, but the requirement to use a anaerobic digester does not eliminate the need for storage which is not assumed to be covered under Option 6, thus the requirement would allow for an overflow.

Option 7. Option 7 includes the requirements of Option 2 and would prohibit manure application to frozen, snow covered or saturated ground. This prohibition requires that CAFOs have adequate storage to hold manure for the period of time during which the ground is frozen or saturated. The necessary period of storage ranges from 45 to 270 days depending on the region. In practice, this may result in some facilities needing storage to hold manure and wastes for 12 months. EPA assumed storage would be needed to contain manure and precipitation generated for the entire period between the first frost in the fall until the last frost in the spring rounded to the nearest 45 day interval. In northern states this period can be as long as 270 days. It is likely that there could be opportunities to apply manure during this period, depending on how the restrictions on application are defined, thus EPA's cost estimates for this option should represent a worst-case cost.

EPA estimates the cost for Option 7 to be $671.3 million annually under the two-tier structure, and $781.9 million annually under the three-tier structure. EPA did not estimate pollutant reductions from this technology option because the Agency has limited information on how frequently manure is being applied by existing CAFOs, and the runoff associated with application on frozen, snow-covered or saturated ground is dependent on regional factors such as rainfall patterns and site-specific factors such as topography.

10.2.6 Proposed Basis for BAT

10.2.6.1 BAT Requirements for the Beef and Dairy Subcategories

EPA is proposing to establish BAT requirements for both the beef and dairy subcategories based on the same technology option. The beef subcategory includes stand-alone heifer operations and applies to all confined cattle operations except for operations that confine mature dairy cattle or veal. Under the two-tier structure, the BAT requirements would apply to any beef operation with 500 head of cattle or more. Under the three-tier structure, the BAT requirements for beef would apply to any operation with more than 1,000 head of cattle and any operation with 300 to 1,000 head which meets the conditions that define the operation as a CAFO.

EPA proposes to establish BAT requirements for dairy operations which meet the following definitions: under the two-tier structure, all dairy with 350 head of mature dairy cows or more would be subject to the proposed BAT requirements. Under the three-tier approach any dairy with more than 700 head of mature dairy cows or 250 to 700 head of mature dairy cows which meets the conditions that define the operation as a CAFO (see Chapter 9) would be subject to today's proposed BAT requirements.

EPA proposes to establish BAT requirements for the beef and dairy subcategories based on Option 3. BAT would require all beef and dairy CAFOs to monitor the ground water beneath the production area by drilling wells up gradient and down gradient to measure for a plume of pollutants discharged to ground water at the production area. A beef or dairy CAFO can avoid this ground water monitoring by demonstrating, to the permit writer's satisfaction, that it does not have a direct hydrological connection between the ground water beneath the production area and surface waters.

EPA proposes to require CAFOs in the beef and dairy subcategories to monitor their ground water unless they determine that the production area is not located above ground water which has a direct hydrological connection to surface water. CAFOs would have to monitor for ammonia, nitrate, fecal coliform, total coliform, total chlorides and TDS. EPA selected these pollutants because they may be indicators of livestock waste and are pollutants of concern to ground water sources. If the down gradient concentrations are higher than the up gradient concentration this indicates a discharge which must be controlled. For operations have a direct hydrologic connection, EPA based the BAT zero discharge requirement on the installation of liners in liquid storage structures such as lagoons and storm water retention ponds and concrete pads for the storage of dry manure stockpiles. If the CAFO is determined to have a direct hydrologic connection between the groundwater beneath the production area and surface water, the CAFO would need to line lagoons to prevent leaching and construct concrete pads on which to store manure stockpiles. EPA's cost estimates assumed operations would construct new liquid storage structures with both a synthetic and clay liner.

Beef and dairy CAFOs must also develop and implement a PNP that is based on application of manure and wastewater to crop land either at a crop removal rate for phosphorus where soil conditions require it, or otherwise on the nitrogen requirements of the crop. EPA believes the land application rates established in accordance with one of the three methods described in today's proposed regulation, along with the prohibition of manure application within 100 feet of that surface water will ensure manure and wastewater are applied in a manner consistent with proper agricultural use. See the draft guidance entitled "Managing Manure Nutrients at Concentrated Animal Feeding Operations" for a detailed discussion of how a PNP is developed.

EPA believes that technology option 3 is economically achievable and represents the best available technology for the beef and dairy subcategories, and is therefore proposing this option as BAT for these subcategories. The incremental annual cost of Option 3 relative to Option 2 for these subcategories is $170 million pre-tax under the two-tier structure, and $1205 million pre-tax under the three tier structure. EPA estimated annual ground water protection benefits from the proposed requirements of $70-80 million. EPA estimates Option 3 for the beef and dairy subcategories will reduce loadings to surface waters from hydrologically connected ground water by 3 million pounds of nitrogen. To determine economic achievability, EPA analyzed how many facilities would experience financial stress severe enough to make them vulnerable to closure under each regulatory option. As explained in more detail in the Economic Analysis, the number of facilities experiencing stress may indicate that an option might not be economically achievable, subject to additional considerations. Under Option 2, no facilities in either the beef or dairy sectors were found to experience stress, while under Option 3, the analysis projects 10 beef and 329 dairy CAFOs would experience stress under the two-tier structure, and 40 beef and 610 dairy CAFOs would experience stress under the three-tier structure. Of these, EPA has determined that 40 beef operations are considered small businesses based on size standards established by the Small Business Administration. This analysis assumes that 76% of affected operations would be able to demonstrate that their ground water does not have a hydrological connection to surface water and would therefore not be subject to the proposed requirements. EPA projects the cost of making this demonstration to the average CAFO would be $3,000.

EPA is not proposing to establish BAT requirements for the beef and dairy subcategories on the basis of Option 4 due to the additional cost associated with ambient stream monitoring and because the addition of in-stream monitoring does not by itself achieve any better controls on the discharges from CAFOs as compared to the other options. In-stream monitoring could be an indicator of discharges occurring from the CAFO; however, it is equally likely that in stream monitoring will measure discharges that may be occurring from adjacent non-CAFO agricultural sources. Through the use of commercial fertilizers these non-CAFO sources would likely be contributing the same pollutants being analyzed under Option 4. EPA has not identified a better indicator parameter which would isolate constituents from CAFO manure and wastewater from other possible sources contributing pollutants to a stream. Livestock specific pathogen analysis could be an indicator if adjacent operations do not also have livestock or are not using manure or biosolids as fertilizer sources. However, as described earlier, EPA has concerns about the ability of CAFOs to collect and analyze samples for these pollutants because of the holding time constraints associated with the analytical methods for these parameters. Accordingly, EPA does not believe that specifying these additional in-stream monitoring BMP requirements would be appropriate; and would not be useful in ensuring compliance with the Clean Water Act. Moreover, in-stream monitoring would be a very costly requirement for CAFOs to comply with.

EPA is not proposing to establish BAT requirements for the beef and dairy subcategories on the basis of Option 5. Option 5 would require zero discharge with no overflow from the production area. Most beef feedlots are open lots which have large areas from which storm water must be collected; thus, it is not possible to assume that the operation can design a storm water impoundment that will never experience an overflow even under the most extreme storm. Stand alone heifer operations (other than those that are pasture-based) are configured and operated in a manner very similar to beef feedlots. Unlike the hog, veal and poultry subcategories, EPA is not aware of many large beef operations that keep all cattle confined under roof at all times.

Dairies also frequently keep animals in open areas for some period of time, whether it is simply the pathway from the barn to the milk house or an open exercise lot. Storm water from these open areas must be collected in addition to any storm water that contacts food or silage. As is the case for beef feedlots, the runoff volume from the exposed areas is a function of the size of the area where the cattle are maintained, and the amount of precipitation. Since the CAFO operator cannot control the amount of precipitation, there always remains the possibility that an extreme storm event can produce enough rainfall that the resulting runoff would exceed the capacity of the lagoon.

EPA did consider a new source option for new dairies that would enforce total confinement of all cattle at the dairy. The new source option as analyzed, poses a barrier to entry for new sources, therefore, EPA assumes that this option if applied to existing sources would be economically unachievable. EPA plans to continue evaluating this option and will consider other technology approaches that could be applied. EPA has also evaluated a variation of Option 5 that would apply to existing beef and dairy operations and would require the use of technologies which achieve a less wet manure. These technologies include solid-liquid separation and composting the solids. EPA is not proposing to establish BAT on the use of these technologies, but does believe these technologies may result in cost savings at some operations. Additionally, composting will achieve pathogen reductions. As described in Chapter 7, EPA is continuing to examine pathogen controls and may promulgate requirements on the discharge of pathogens. If EPA set limitations on pathogens, composting technology would likely become a basis for achieving BAT limits.

For any operation that has inadequate crop land on which to apply its manure and wastewater, solid-liquid separation and composting could benefit the CAFO, as these technologies will make the manure more transportable. Drier manure is easier to transport; and therefore, EPA believes solid liquid separation and composting will be used in some situations to reduce the transportation cost of excess manure that has been treated to concentrate and compost the solids. In addition, composting is a value-added process that improves the physical characteristics (e.g., reduces odor and creates a more homogenous product) of the manure. It can also make the manure a more marketable product. As a result, a CAFO with excess manure may find it easier to give away, or even sell, its excess manure. EPA encourages all CAFOs to consider technologies that will reduce the volume of manure requiring storage and make the manure easier to transport.

Option 6, which requires anaerobic digestion treatment with methane capture, was not considered for the beef subcategory, but was considered for the dairy subcategory for treatment of liquid manure. Anaerobic digestion can only be applied to liquid waste. As described previously in Chapter 4, beef feedlots maintain a dry manure, yet they capture storm water runoff from the dry lot and manure stockpile. The storm water runoff is generally too dilute to apply digestion technology.

Most dairies, however, handle manure as a liquid or slurry which is suited to treatment through anaerobic digestion. EPA concluded that application of anaerobic digesters at dairies will not necessarily lead to significant reductions in the pollutants discharged to surface waters from CAFOs. An anaerobic digester does not eliminate the need for liquid impoundments to store dairy parlor water and barn flush water and to capture storm water runoff from the open areas at the dairy. Neither do digesters reduce the nutrients nitrogen or phosphorus. Thus, basing BAT on digester technology would not change the performance standard that a production area at a CAFO would achieve and would not reduce or eliminate the need for proper land application of manure. Digesters were considered because they achieve some degree of waste stabilization and more importantly they capture air emissions generated during manure storage. The emission of ammonia from manure storage structures is a potentially significant contributor of nitrogen to surface waters. Covered anaerobic digesters will prevent these emissions while the waste is in the digester, but the digester does not convert the ammonia into another form of nitrogen, such as nitrate, which is not as volatile. Thus as soon as the manure is exposed to air the ammonia will be lost. Operations may consider additional management strategies for land application such as incorporation in order to maintain the nitrogen value as fertilizer and to reduce emissions.

As mentioned above, the application of ambient temperature or mesophilic anaerobic digesters would not change the performance standard that a CAFO would achieve. Thermophilic digestion or pasteurization processes which apply heat to the waste will reduce pathogens. As described in Chapter 7 EPA is still evaluating effective controls for pathogens and thermophilic process is one of the controls EPA will continue to evaluate. At present thermophilic anaerobic digestion is only used for centralized treatment of animal waste in Europe. Thermophilic aerobic treatment is practiced on municipal waste. This technology has also been evaluated for transferability to CAFOs. These technologies, their advantages and limitations are discussed in Chapter 8.

EPA is not proposing to base BAT requirements on Option 7 for the beef and dairy subcategories. Option 7 would prohibit manure application on saturated, snow covered or frozen ground. Pollutant runoff associated with application of manure or wastewater to saturated, snow covered or frozen ground is a site specific consideration, and depends on a number of site specific variables, including distance to surface water and slope of the land. EPA believes that establishing a national standard that prohibits manure or wastewater application is inappropriate because of the site specific nature of these requirements and the regional variability across the nation.

Requirements for the beef and dairy subcategories would still allow for an overflow in the event of a chronic or catastrophic storm that exceeds the 25-year, 24-hour storm. EPA believes this standard reflects the best available technology. Under the proposed revisions to Part 122, permits will require that any discharge from the feedlot or confinement area be reported to the permitting authority within 24 hours of the discharge event. The CAFO operator must also report the amount of rainfall and the approximate duration of the storm event.

10.2.6.2 BAT Requirements for the Swine, Veal and Poultry Subcategories

EPA is proposing to establish BAT requirements for the swine, veal and poultry subcategories based on Option 5. Option 5 requires zero discharge of manure and process wastewater and provides no overflow allowance for manure and wastewater storage. Land application requirements for these operations would be the same as the requirements under Option 2.

EPA is proposing Option 5 because swine, veal and poultry operations can house the animals under roof and feed is also not exposed to the weather. Thus, there is no opportunity for storm water contamination. Broiler and turkey operations generate a dry manure which can be kept covered either under a shed or with tarps. Laying hens with dry manure handling usually store manure below the birds' cages and inside the confinement building. Veal and poultry operations confine the animals under roof, thus there are no open animal confinement areas to generate contaminated storm water. Those operations with liquid manure storage can comply with the restrictions proposed under this option by diverting uncontaminated storm water away from the structure, and covering the lagoons or impoundments.

The technology basis for the poultry BAT requirements at the production area are litter sheds for broiler and turkey CAFOs, and under house storage for laying hens with dry manure handling systems. For laying hen CAFOs with liquid manure handling systems, EPA's technology basis is solid separation and covered storage for the solids and covered lagoons.

Laying hen farms may also have egg wash water from in-line or off-line processing areas. Only 10% of laying hen operations with fewer than 100,000 birds have on farm egg processing, while

35% of laying hen operations with more than 100,000 birds have on farm egg processing. The wash water is often passed through a settling system to remove calcium, then stored in above ground tanks, below ground tanks, or lagoons. Today's proposal is based on covered storage of the egg wash water from on-farm processing, to prevent contact with precipitation. The ultimate disposal of egg wash water is through land application which must be done in accordance with the land application rates established in the PNP. EPA believes the low nutrient value of egg wash water is unlikely to cause additional incremental costs to laying hen facilities to comply with the proposed land application requirements.

EPA assumes large swine operations (e.g., operations with more than 1,250 hogs weighing 55 pounds or greater) operate using total confinement practices. EPA based BAT Option 5 on the same approach described above of covering liquid manure storage. CAFOs can operate covered lagoons as anaerobic digesters which is an effective technology for achieving zero discharge and will provide the added benefits of waste stabilization, odor reduction and control of air emissions from manure storage structures. Anaerobic digesters also can be operated to generate electricity which can be used by the CAFO to offset operating costs.

Although Option 5 is the most expensive option for the hog subcategory, EPA believes this option reflects best available technology economically achievable because it prevents discharges resulting from liquid manure overflows that occur in open lagoons and ponds. Similarly, the technology basis of covered treatment lagoons and drier manure storage is believed to reduce the likelihood of those catastrophic lagoon failures associated with heavy rainfalls. Option 5 also achieves the greatest level of pollutant reductions from runoff reaching the edge of the field. Non-water quality environmental impacts include reduced emissions and odor, with a concurrent increase in nitrogen value of the manure, however as mentioned previously, the ammonia concentration is not reduced and once the manure is exposed to air the ammonia will volatilize. Water conservation and recycling practices associated with Option 5 will promote increased nutrient value of the manure, reduced hauling costs via reduced water content, and less fresh water use.

One technology basis evaluated for Option 5, solid-liquid separation and storage of the solids, has the advantage of creating a solid fraction which is more transportable, thus hog CAFOs that have excess manure can use this technology to reduce the transportation costs.

EPA is aware of three open lot hog operations that have more than 1,250 hogs and there may be a small number of others, but the predominant practice is to house the animals in roofed buildings with total confinement. For open lot hog CAFOs, EPA is proposing to base BAT on the application of hoop structures as described above. Under EPA's proposed three-tier structure, operations defined as CAFOs in the middle tier that are smaller than 1,250 hogs have a greater potential for being an open lot type of operation. These operations would also be subject to the proposed zero discharge requirement, which is based on the application of hoop houses and covered manure storage.

Veal operations use liquid manure management and store manure in lagoons. EPA has based BAT on covered manure and feed storage. The animals are housed in buildings with no outside access. Thus, by covering feed and waste storage the need to capture contaminated storm water is avoided.

In evaluating the economic achievability of Option 5 for the swine, veal and poultry subcategories, EPA evaluated the costs and impacts of this option relative to Option 2. For these subcategories, the incremental annual cost of Option 5 over Option 2 would be $110 million pre-tax under the two-tier structure, and $140 million pre-tax under the three-tier structure. Almost all of these incremental costs are projected to be in the swine sector. EPA projects that there would be no additional costs under the two-tier structure, and only very small additional costs under the three-tier structure for the veal and poultry subcategories to move from Option 2 to Option 5. Under Option 2, EPA estimates 300 swine operations and 150 broiler operations would experience stress under the two-tier structure, and 300 swine operations and 330 broiler operations would experience stress under the three-tier structure. Under Option 5 an additional 1,120 swine operations would experience stress under both the two-tier and three-tier structures. All affected hog operations have more than 1000 AU. None of these affected hog operations are small businesses based on the Small Business Administration's size standards. There would be no additional broiler operations experiencing stress under Option 5, and no veal, layer, or turkey operations are projected to experience stress under either Option 2 or Option 5. EPA did not analyze the pollutant reductions of Option 5 relative to Option 2. Under Option 2 operations are required to be designed, constructed and operated to contain all process generated waste waters, plus the runoff from a 25-year, 24-hour rainfall event for the location of the point source. Thus, the benefit of Option 5 over Option 2 would be the value of eliminating discharges during chronic or catastrophic rainfall events of a magnitude of the 25-year, 24-hour rainfall event or greater. Further benefit would be realized as a result of increased flexibility on the timing of manure application to land. By preventing the rainfall and run-off from mixing with wastewater, CAFOs would not need to operate such that land application during storm events was necessary.

EPA is not proposing Option 2 for these sectors. As mentioned previously, all of these sectors maintain their animals under roof eliminating the need to capture contaminated storm water from the animal confinement area. In addition, most poultry operations generate a dry manure, which when properly stored, under some type of cover, eliminates any possibility of an overflow in the event of a large storm. Therefore EPA believes that Option 5 technology which prevents the introduction of storm water into manure storage is achievable and represents Best Available Technology, without redesigning the capacity of existing manure storage units.

EPA is not proposing to base BAT for the swine, poultry and veal subcategories on Option 3, because EPA believes Option 5 is more protective of the environment. If operators move towards dry manure handling technologies and practices to comply with Option 5, there should be less opportunity for ground water contamination and surface water contamination through a direct hydrological connection. EPA strongly encourages any newly constructed lagoons or anaerobic digesters to be done in such a manner as to minimize pollutant losses to ground water.

A treatment lagoon should be lined with clay or synthetic liner or both and solid storage should be on a concrete pad or a glass-lined steel tank as EPA has included in its estimates of BAT costs. Additionally, Option 5 provides the additional non-water quality benefit of achieving reductions in air emissions from liquid storage systems. EPA estimates that the cost of complying with both Option 3 and 5 at existing facilities would be economically unachievable.

EPA believes the proposed technology basis for broilers, turkeys and laying hens with dry manure management will avoid discharges to ground water since the manure is dry and stored in such a way as to prevent storm water from reaching it. Without some liquid to provide a transport mechanism, pollutants cannot move through the soil profile and reach the ground water and surface water through a direct hydrological connection.

EPA is not proposing to base BAT on Option 4 for the same reasons described above for the beef and dairy subcategories.

EPA is not proposing to base BAT on Option 6, because EPA believes that the zero discharge aspect of the selected option will encourage operations to consider and install anaerobic digestion in situations where it will be cost effective.

As with beef and dairy, EPA is not proposing to base BAT for swine, veal and poultry on Option 7, but believes that permit authorities should establish restrictions as necessary in permits issued to CAFOs. Swine, veal and poultry operations should take the timing of manure application into account when developing the PNP. Any areas that could result in pollutant discharge from application of manure to frozen, snow covered or saturated ground should be identified in the plan and manure or wastewater should not be applied to those areas when there is a risk of discharge.

Mixed Animal CAFOs. As described in the preamble of the proposed regulation, EPA is proposing to drop from the definition of CAFO the mixed animal calculations. Nonetheless, there are operations that will be CAFO by virtue of having a livestock enterprise which meets the definition of CAFO. If an operation is defined as a CAFO for one or more livestock enterprises, then all livestock which is maintained in confinement will be covered under the NPDES permit requirements. EPA assumes that each distinct livestock sector would be subject to the appropriate requirements for that sector, however, if the waste or wastewater from two sectors are commingled then the more stringent requirements would apply to the commingled waste stream.

PNP Requirements

There are a number of elements that are addressed by both USDA's "Guidance for Comprehensive Nutrient Management Plans (CNMPs)" and EPA's PNP which would be required by the effluent guidelines and NPDES proposed rules and is detailed in the guidance document "Managing Manure Nutrients at Concentrated Animal Feeding Operations." EPA's proposed PNP would establish requirements for CAFOs that are consistent with the technical guidance published by USDA experts, but go beyond that guidance by identifying specific management practices that must be implemented. What follows is a brief description of what must be included in a PNP.

General Information. The PNP must have a Cover Sheet which contains the name and location of the operation, the name and title of the owner or operator and the name and title of the person who prepared the plan. The date (month, day, year) the plan was developed and amended must be clearly indicated on the Cover Sheet. The Executive Summary would briefly describe the operation in terms of herd or flock size, total animal waste produced annually, crop identity for the full 5 year period including a description of the expected crop rotation and, realistic yield goal. The Executive Summary must include indication of the field conditions for each field unit resulting from the phosphorus method used (e.g., phosphorus index), animal waste application rates, the total number of acres that will receive manure, nutrient content of manure and amount of manure that will be shipped off-site. It should also identify the manure collection, handling, storage, and treatment practices, for example animals kept on bedding which is stored in a shed after removal from confinement house, or animals on slatted floors over a shallow pull plug pit that is drained to an outdoor in-ground slurry storage inpoundment. Finally, the Executive Summary would have to identify the watershed(s) in which the fields receiving manure are located or the nearest surface water body. While the General Information section of a PNP would give a general overview of the CAFO and its nutrient management plan, subsequent sections would provide further detail.

Animal Waste Production. This subsection details types and quantities of animal waste produced along with manure nutrient sampling techniques and results. Information would be included on the maximum number of livestock ever confined and the maximum livestock capacity of the CAFO, in addition to the annual livestock production. This section would provide an estimate of the amount of animal waste collected each year. Each different animal waste source should be sampled annually and tested by an accredited laboratory for nitrogen, phosphorous, potassium, and pH.

Animal Waste Handling, Collection, Storage, and Treatment. This subsection details best management practices to protect surface and groundwater from contamination during the handling, collection, storage, and treatment of animal waste. A review would have to be conducted of potential water contamination sources from existing animal waste handling, collection, storage, and treatment practices. The capacity needed for storage would be calculated.

Contaminated feedlot runoff would have to be contained and adequately managed. Runoff diversion structures and animal waste storage structures would have to be visually inspected for: seepage, erosion, vegetation, animal access, reduced freeboard, and functioning rain gauges and irrigation equipment, on a weekly basis. Deficiencies based on visual inspections would have to be identified and corrected within a reasonable time frame. Depth markers would have to be permanently installed in all open lagoons, ponds, and tanks. Lagoons, ponds, and tanks at beef and dairy CAFOs would have to be maintained to retain capacity for the 25-year, 24-hour storm event. Dead animals, required to be kept out of lagoons, would have to be properly handled and disposed of in a timely manner. Finally, an emergency response plan for animal waste spills and releases would have to be developed.

Land Application Sites. This subsection details field identification and soil sampling. County(ies) and watershed code(s) where feedlot and land receiving animal waste applications are located would be identified. Total acres of operation under the control of the CAFO (owned and rented) and total acres where animal waste will be applied would be included. A detailed farm map or aerial photo, to be included, would have to indicate: location and boundaries of the operation, individual field boundaries, field identification and acreage, soil types and slopes, and the location of nearby surface waters and other environmentally sensitive areas (e.g., wetlands, sinkholes, agricultural drainage wells, and aboveground tile drain intakes) where animal waste application is restricted.

Separate soil sampling, using an approved method, would have to be conducted every 3 years on each field receiving animal waste. The samples shall be analyzed at an accredited laboratory for total phosphorous. Finally, the phosphorous site rating for each field would have to be recorded according to the selected assessment tool.

Land Application. This subsection details crop production and animal waste application to crop production areas. Details of crop production would have to include: identification of all planned crops, expected crop yields and the basis for yield estimates, crop planting and harvesting dates, crop residue management practices, and nutrient requirements of the crops to be grown. Calculations used to develop the application rate, including nitrogen credits from legume crops, available nutrients from past animal waste applications, and nutrient credits from other fertilizer and/or biosolids applications would have to be included.

Animal waste application rates cannot exceed nitrogen requirements of the crops. However, animal waste application rates would be limited to the agronomic requirements for phosphorous if the soil phosphorous tests are rated “high”, the soil phosphorous tests are equal to 3/4, but not greater than twice the soil phosphorous threshold value, or the Phosphorous Index rating is “high.” Finally, animal waste could not be applied to land if the soil phosphorous tests are rated “very high”, the soil phosphorous tests are greater than twice the soil phosphorous threshold value, or the Phosphorous Index rating is “very high.” In some cases, operators may choose to further restrict application rates to account for other limiting factors such as salinity or pH.

Animal wastes cannot be applied to wetlands or surface waters, within 100 feet of a sinkhole, or within 100 feet of water sources such as rivers, streams, lakes, ponds, and intakes to agricultural drainage systems (e.g., aboveground tile drain intakes, agricultural drainage wells, pipe outlet terraces). EPA requests comment on how serious would be the limitations imposed by these requirements. Manure spreader and irrigation equipment would have to be calibrated at a minimum once each year, but preferably before each application period. Finally, the date of animal waste application and calibration application equipment, and rainfall amounts 24-hours before and after application would be recorded.

Other Uses/Off-Site Transfer. The final required subsection for a PNP details any alternative uses and off-site transport of animal wastes. If used, a complete description of alternative uses of animal waste would have to be included. If animal wastes are transported off-site the following would have to be recorded: date (day, month, year), quantity, and name and location of the recipient of the animal waste.

Voluntary Measures. Many voluntary best management practices can be included within various subsections of a PNP. These voluntary best management plans are referenced in EPA's guidance document for PNP "Managing Manure Nutrients at Concentrated Animal Feeding Operations."

Annual Review and Revision. While a PNP is required to be renewed every 5 years (coinciding with NPDES permitting), an annual review of the PNP would have to occur and the PNP would be revised or amended as necessary.

The most likely factor which would necessitate an amendment or revision to a PNP is a change in the number of animals at the CAFO. A substantial increase in animal numbers (for example an increase of greater than 20%) would significantly increase the volume of manure and total nitrogen and phosphorous produced on the CAFO. Because of this, the CAFO will need to re-evaluate animal waste storage facilities to ensure adequate capacity, and may need to re-examine the land application sites and rates.

A second reason which would require an amendment or revision to a PNP is a change in the cropping program which would significantly alter land application of animal waste. Changes in crop rotation or crop acreage could significantly alter land application rates for fields receiving animal waste. Also the elimination or addition of fields receiving animal waste application would require a change in the PNP.

Changes in animal waste collection, storage facilities, treatment, or land application method would require an amendment or revision to a PNP. For example, the addition of a solid-liquid separator would change the nutrient content of the various animal waste fractions and the method of land application thereby necessitating a revision in a PNP. Changing from surface application to soil injection would alter ammonia volatilization subsequently altering animal waste nutrient composition requiring a revision of land application rates.

When CAFOs Must Have PNPs. EPA proposes to allow two groups of CAFOs up to 90 days to obtain a PNP:

1. existing CAFOs which are being covered by a NPDES permit for the first time; or
2. existing CAFOs that are already covered under an existing permit which is reissued within 3 years from the date of promulgation of these regulations.

EPA proposes that all other existing CAFOs must have a PNP at the time permits are issued or renewed.

10.2.7 New Source Performance Standards

For purposes of applying the new source performance standards (NSPS) being proposed today, a source would be a new source if it commences construction after the effective date of the forthcoming final rule. Each source that meets this definition would be required to achieve any newly promulgated NSPS upon commencing operation of the CAFO.

EPA proposes to consider an operation as a new source if any of the following three criteria apply. The definition of new source being proposed for Part 412 states three criteria that determine whether a source is a "new source."

First, a facility would be a new source if it is constructed at a site at which no other source is located. These new sources have the advantage of not having to retrofit the operation to comply with BAT requirements, and thus can design to comply with more stringent and protective requirements.

The second criterion for defining a new source would be where new construction at the facility "replaces the housing, waste handling system, production process, or production equipment that causes the discharge or potential to discharge pollutants at an existing source." Confinement housing and barns are periodically replaced, allowing the opportunity to install improved systems that provide increased environmental protection. The modern confinement housing used at many swine, dairy, veal, and poultry farms allows for waste handling and storage in a fashion that generates little or no process water. Such systems negate the need for traditional flush systems and storage lagoons, reduce the risks of uncontrollable spills, and decrease the costs of transporting manure.

Third, a source would be a new source if construction is begun after the date this rule is promulgated and its production area and processes are substantially independent of an existing source at the same site. Facilities may construct additional production areas that are located on one contiguous property, without sharing waste management systems or commingling waste streams. Separate production areas may also be constructed to help control biosecurity. New production areas may also be constructed for entirely different animal types, in which case the more stringent NSPS requirements for that subcategory would apply to the separate and newly constructed production area. In determining whether production and processes are substantially independent, the permit authority is directed to consider such factors as the extent to which the new production areas are integrated with the existing production areas, and the extent to which the new operation is engaging in the same general type of activity as the existing source.

EPA also considered whether a certain level of facility expansion, measured as an increase in animal production, should cause an operation to be subject to new source performance standards.

If so, upon facility expansion, the CAFO would need to go beyond compliance with BAT requirements to meet the more stringent standards represented by NSPS. In today's proposal, that increment of additional control, for the swine, poultry and veal subcategories, would amount to the need to monitor ground water and install liners in lagoons and impoundments to prevent discharges to ground water that has a direct hydrological connection to surface water; unless the CAFO could demonstrate that no such direct hydrological link existed. In the beef and dairy subcategories, the NSPS proposed today are the same as the BAT standards.

EPA considered the same seven options for new source performance standards (NSPS) as it considered for BAT. EPA also considered an additional option for new dairies, which if selected, would prohibit dairies from discharging any manure or process wastewater from animal confinement and manure storage areas (i.e., eliminating the allowance for discharging overflows associated with a storm event). New sources have the advantage of not having to retrofit the operation to comply with the requirements and thus can design the operation to comply with more stringent requirements. In selecting new source performance standards, EPA evaluates whether the requirements under consideration would impose a barrier to entry to new operations.

EPA is proposing to select Option 3 as the basis for NSPS for the beef and dairy subcategories. Option 3 includes all the requirements proposed for existing sources including complying with zero discharge from the production area except in the event of a 25-year, 24-hour storm and the requirement to develop a PNP which establishes the rate at which manure and wastewater can be applied to crop or pasture land owned or controlled by the CAFO. The application of manure and wastewater would be restricted to a phosphorus based rate where necessary depending on the specific soil conditions at the CAFO. Additionally, other best management practice requirements would apply, including the prohibition of manure and wastewater application within 100 feet of surface water. The proposed new source standard for the beef and dairy subcategories includes a requirement for assessing whether the ground water beneath the production area has a direct hydrological connection to surface water. If a direct hydrological connection exists, the operation must conduct additional monitoring of ground water up gradient and down gradient from the production area, and implement any necessary controls based on the monitoring results to ensure that zero discharge to surface water via the ground water route is achieved for manure stockpiles and liquid impoundments or lagoons. For the purpose of estimating compliance costs, EPA has assumed that operations located in areas with a direct hydrological connection will install synthetic material or compacted clay liners beneath any liquid manure storage and construct impervious pads for any dry manure storage areas. The operator would be required to collect and analyze ground water samples twice per year for total dissolved solids, chlorides, nitrate, ammonia, total coliforms and fecal coliform. EPA is believes that Option 3 is economically achievable for existing sources. Since new sources are able to install impermeable liners at the time the lagoon or impoundment is being constructed, rather than retrofitting impoundments at existing source, costs associated with this requirement should be less for new sources in comparison to existing sources. EPA has concluded that Option 3 requirements will not pose a barrier to entry for new sources.

EPA is proposing to establish NSPS for all swine and poultry operations based on Option 5 and Option 3 combined. In addition the BAT requirements described in Section VIII.C.6, the proposed new source standards would require no discharge via any ground water that has a direct hydrological link to surface water. As described above, Option 3 requires all CAFOs to monitor the ground water and impose appropriate controls to ensure compliance with the zero discharge standard, unless the CAFO has demonstrated that there is no direct hydrological link between the ground water and any surface waters. The proposed new source standard also restricts land application of manure and wastewater to a phosphorus based rate where necessary depending on the specific soil conditions at the CAFO. Additionally, the same land application best management practice requirements as required under BAT would apply, including the prohibition from applying manure and wastewater within 100 feet of surface water.

EPA encourages new swine and poultry facilities to be constructed to use dry manure handling. Dry manure handling is currently the standard practice at broiler and turkey operations. As described previously, some existing laying hen operations and most hog operations use liquid manure handling systems. The proposed new source performance standard would not require the use of dry manure handling technologies, but EPA believes this is the most efficient technology to comply with its requirements.

EPA has analyzed costs of installing dry manure handling at new laying hen and swine operations. Both sectors have operations which demonstrate dry manure handling can be used as an effective manure management system. The dry manure handling systems considered for both sectors require that the housing for the animals be constructed in a certain fashion, thus making this practice less practical for existing sources. Both sectors have developed a high rise housing system, which houses the animals on the second floor of the building allowing the manure to drop to the first floor or pit. In the laying hen sector this is currently a common practice and with aggressive ventilation, the manure can be maintained as a dry product. Hog manure has a lower solids content, thus the manure must be mixed with a bedding material (e.g., wood chips, rice or peanut hulls and other types of bedding) which will absorb the liquid. To further aid in drying the hog manure, air is forced up through pipes installed in the concrete floor of the pit. With some management on the part of the CAFO operator, involving mixing and turning the hog manure in the pit periodically, the manure can be composted while it is being stored. The advantages of the high rise system for hogs and laying hens include a more transportable manure, which, in the case of the hog high rise system, has also achieved a fairly thorough decomposition. The air quality inside the high rise house is greatly improved, and the potential for leaching pollutants into the groundwater is greatly reduced. The design standard of these high rise houses include concrete floors and also assume that the manure would be retained in the building until it will be land applied, thus there is no opportunity for storm water to reach the manure storage and virtually no opportunity for pollutants to leach to groundwater beneath the confinement house. EPA believes that the cost savings associated with ease of manure transportation, as well as improved animal health and performance associated with the dry manure handling system for hogs will off-set the increased cost of operation and maintenance associated with the high rise hog system. Thus, EPA concludes the proposed new source performance standards based on the high-rise house, does not pose a barrier to entry for either the laying hen and hog sectors. Although the high rise house is the basis of the new source standards for the swine and laying hen sectors, operations are not prevented from constructing a liquid manure handling system. If new sources in these sectors choose to construct a liquid manure handling system, they would be required to line the lagoons if the operation is located in an area that has a direct hydrologic connection, but the cost associated with lining a lagoon at the time it is being constructed is much less than the cost to retrofit lagoon liners. New operations that chose to use a liquid manure handling system would still be expected to cover these structures to avoid capturing precipitation which causes an overflow. Covered liquid storage would be smaller than an open storage, because there wouldn't be capacity included in the design to accommodate storm water.

EPA proposes to establish new source requirements for the veal subcategory on the basis of Option 5 which requires zero discharge with no overflow from the production area and Option 3 which requires zero discharge of pollutants to groundwater which has a direct hydrological connection to surface water, with the ground water monitoring or hydrological assessment requirements described above. EPA believes that a zero discharge standard without any overflow will promote the use of covered lagoons, anaerobic digesters or other types of manure treatment systems. Additionally, this will minimize the use of open air manure storage systems, thus reducing emission of pollutants from CAFOs.

New veal CAFOs would not be expected to modify existing housing conditions since EPA is not aware of any existing veal operations that use dry manure handling systems. New veal CAFOs would be expected to also use covered lagoons to comply with the zero discharge standard. New veal CAFOs would be required to line their liquid manure treatment or storage structures with either synthetic material or compacted clay to prevent the discharge of pollutants to ground water which has a direct hydrological connection to surface water. In addition, the CAFO would have to monitor the groundwater beneath the production area to ensure compliance with the zero discharge requirement. The CAFO would not need to install liners or monitor ground water if it demonstrates that there is no direct hydrologic link between the ground water and any surface waters.

In addition to the seven options considered for both existing and new sources, EPA also investigated a new source option for dairies that would prohibit all discharges of manure and process wastewater to surface waters, eliminating the current allowance for the discharge of the overflow of runoff from the production area. To comply with a zero discharge requirement, dairies would need to transform the operation so they could have full control over the amount of manure and wastewater, including any runoff, entering impoundments. Many dairies have drylot areas where calves, heifers, and bulls are confined, as well as similar drylot areas where the0 mature cows are allowed access. EPA estimated compliance costs for a zero discharge requirements assuming that the following changes would occur at new dairies:

(1) Freestall barns for mature cows would be constructed with six months underpit manure storage, rather than typical flush systems with lagoon storage;

(2) Freestall barns with six months underpit manure storage would be constructed to house heifers;
(3) Calf barns with a scrape system would be constructed with a scrape system and six months of adjacent manure storage; and
(4) New dairies would include covered walkways, exercise areas, parlor holding, and handling areas.

Drylot areas are continually exposed to precipitation. The amount of contaminated runoff from such areas that must be captured is directly related to the size of the exposed area and the amount of precipitation. Under the current regulations, dairies use the 25-year, 24-hour rainfall event (in addition to other considerations) when determining the necessary storage capacity for a facility. Imposing a zero discharge requirement that prevents any discharge from impoundments would force dairies to reconfigure in a way that provides complete control over all sources of wastewater. EPA considered the structural changes in dairy design described here to create a facility that eliminates the potential for contaminated runoff.

While EPA believes that confining all mature and immature dairy cattle is technically feasible, the costs of zero discharge relative to the costs for Option 3 are very high. Capital costs associated with the construction of the additional barn space to comply with zero discharge increase the overall cost for this option by two orders of magnitude over the selected option. For dairies that send their heifers off-site and use hutches for their calves, the costs associated with this options would be considerably less. EPA estimates annual operating and maintenance costs would rise between one to two orders of magnitude above the costs for Option 3. These costs may create a barrier to entry for new sources. In addition, EPA believes selecting this option could have the unintended consequence of encouraging dairies to shift calves and heifers offsite to standalone heifer raising operations (either on land owned by the dairy or at contract operations) to avoid building calf and heifer barns. If these offsite calf/heifer operations are of a size that they avoid being defined as a CAFO, the manure from the immature animals would not be subject to the effluent guidelines.

EPA is not basing requirements for new dairies on the zero discharge option for the reasons discussed above. As an alternative to underpit manure storage, dairies could achieve zero discharge for parlor wastes and barn flush water by constructing systems such as anaerobic digesters and covered lagoons. These covered systems, if properly operated, can facilitate treatment of the manure and offer opportunities to reduce air emissions. The resulting liquid and solid wastes would be more stable than untreated manure. EPA has not identified any basis for rejecting the zero discharge option for dairies solely due to animal health reasons.

10.2.8 Pretreatment Standards for New or Existing Sources (PSES AND PSNS)

EPA is not proposing to establish Pretreatment Standards for either new or existing sources. Further, EPA is withdrawing the existing provisions entitled “Pretreatment standards for existing sources” at §§412.14, 412.16, 412.24, 412.26. Those existing provisions establish no limitations.

The vast majority of CAFOs are located in rural areas that do not have access to municipal treatment systems. EPA is not aware of any existing CAFOs that discharge wastewater to POTWs at present and does not expect new sources to be constructed in areas where POTW access will be available. For those reasons, EPA is not establishing national pretreatment standards. However, EPA also wants to make it clear that if a CAFO discharged wastewater to a POTW, local pretreatment limitations could be established by the Control Authority. These local limits are similar to BPJ requirements in an NPDES permit.

CHAPTER 11

MODEL FARMS AND COSTS OF TECHNOLOGY BASES FOR REGULATION

11.0 INTRODUCTION

This Chapter describes the methodology used to estimate engineering compliance costs associated with implementing the regulatory options proposed for the concentrated animal feeding operations (CAFOs) industry. Chapter 8 describes in detail the technologies and practices used as the bases for these options. Chapter 10 describes the regulatory options considered by the Agency. The results of the economic impact assessment for the regulation are found in the *Economic Analysis of the Proposed Revisions to the National Pollutant Discharge Eliminations System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations* (EA) for the proposed final rulemaking.

The information contained in this Chapter provides an overview of the methodology and assumptions built into the cost models. More detailed information on the cost methodology and specific technologies and practices is contained in the following cost model reports: *Cost Methodology Report for Beef and Dairy Animal Feeding Operations* (ERG, 2000a) and *Cost Model for Swine and Poultry Sectors* (Tetra Tech, Inc., 2000a).

The following information is discussed in this section:

- Section 11.1: Overview of cost methodology;
- Section 11.2: Development of model farm operations;
- Section 11.3: Design and cost of waste and nutrient management technologies;
- Section 11.4: Development of frequency factors;
- Section 11.5: Summary of estimated model farm costs by regulatory option; and
- Section 11.6: References.

11.1 Overview of Cost Methodology

To assess the economic impact of the effluent limitations guidelines and standards on the CAFOs industry, EPA estimated the costs associated with regulatory compliance for each of the regulatory options described in Chapter 10. The economic burden is a function of the estimated costs of compliance to achieve the proposed requirements, which may include initial fixed and capital costs, as well as annual operating and maintenance (O&M) costs. Estimation of these costs typically begins by identifying the practices and technologies that can be used to meet a particular requirement. The Agency then develops a cost model to estimate costs for their implementation.

EPA used the following approach to estimate compliance costs for the CAFOs industry:

- EPA collected data from published research, meetings with industry organizations, discussions with USDA cooperative extension agencies, review of USDA's Census of Agriculture data, and site visits to swine, poultry, beef, veal, and dairy CAFOs. These data were used to define model farms and to determine waste generation and nutrient concentration, current waste and nutrient practices, and the viability of waste management technologies for the model farms.

- EPA identified candidate waste and nutrient management practices and grouped appropriate technologies into regulatory options. The regulatory options serve as the bases of compliance cost and pollutant loading calculations.

- EPA developed cost equations for estimating capital, fixed, 3-year recurring, and annual O&M costs for the implementation and use of the different waste and nutrient practices targeted under the proposed regulatory options. Cost equations were developed from information collected during the site visits, published information, vendor contacts, and engineering judgment.

- EPA developed and used computer cost models to estimate compliance costs and nutrient loads for each regulatory option.

- EPA used output from the cost model to estimate total annualized costs and the economic impact of each regulatory option on the CAFOs industry (presented in the EA).

EPA estimated facility compliance costs for eight regulatory options. Table 11-1 presents the regulatory options and the waste and nutrient management components that make up each option.

To assess the incremental costs attributable to the proposed rules, EPA evaluated current federal and state requirements for animal feeding operations and calculated compliance costs of the proposed requirements that exceed the current requirements. Operations located in states whose requirements meet or exceed the proposed regulatory changes would already be in compliance with the proposed regulations and would not incur any additional cost. A review of current state waste management requirements for determining baseline conditions is included in the record (See *State Compendium: Programs and Regulatory Activities Related to Animal Feeding Operations* compiled by EPA).

11.2 Development of Model Farm Operations

For the purpose of estimating total costs and economic impacts, EPA calculated the costs of compliance for CAFOs to implement each of the regulatory options being considered. These costs reflect the range of capital costs, annual operating and maintenance costs, start-up or first-year costs, as well as recurring costs that may be associated with complying with the proposed regulations. EPA traditionally develops either *facility-specifi*c or *model facility* costs. Facility-specific compliance costs require detailed process information about many, if not all, facilities in the industry. These data typically include production, capacity, water use, wastewater generation, waste management operations (including design and cost data), monitoring data, geographic location, financial conditions, and any other industry-specific data that may be required for the analyses. EPA then uses each facility's information to determine how the potential regulatory options will impact that facility, and to estimate the cost of installing new pollution controls.

When facility-specific data are not available, EPA develops model facilities to provide a reasonable representation of the industry. Model facilities are developed to reflect the different characteristics found in the industry, such as the size or capacity of operations, types of operation, geographic locations, modes of operation, and types of waste management operations. These models are based on data gathered during site visits, information provided by industry members and their trade associations, and other available information. EPA estimates the number of facilities that are represented by each model. Cost and financial impacts are estimated for each model farm, then industry-level costs are calculated by multiplying model farm costs by the number of facilities represented by each particular model. Because of the amount and type of information that is available for the CAFOs industry, EPA has chosen a model-facility approach to estimate compliance costs.

EPA estimated compliance costs using a representative facility approach based on more than 170 farm-level models that were developed to depict conditions and to evaluate compliance costs for select representative CAFOs. The major factors used to differentiate individual model CAFOs include the commodity sector, the farm production region, and the facility size (based on herd or flock size or the number of animals on site). EPA's model CAFOs primarily reflect the major animal sector groups, including beef cattle, dairy, hog, broiler, turkey, and egg laying operations. Practices at other subsector operations are also reflected by the cost models, such as replacement heifer operations, veal operations, flushed caged layers, and hog grow-finish and farrow-to-finish facilities. Model facilities with similar waste management and production practices were used to depict operations in regions that were not separately modeled.

Table 11-1. Summary of Regulatory Options for CAFOs

Technology or Practice	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Feedlot best management practices (BMPs), including storm water diversions, lagoon/pond depth markers, periodic inspections, and records	✓	✓	✓	✓	✓	✓	✓	✓
Mortality handling requirements (e.g., rendering, composting)[1]	✓	✓	✓	✓	✓	✓	✓	✓
Nutrient management planning and recordkeeping (sample soils once every 3 years, sample manure twice per year)	✓	✓	✓	✓	✓	✓	✓	✓
Land application limited to nitrogen-based agronomic application rates	✓							
Land application limited to phosphorus-based agronomic application rates where dictated by site-specific conditions, and nitrogen-based application elsewhere		✓	✓	✓	✓	✓	✓	✓
No manure application within 100 feet of any surface water, tile drain inlet, or sinkhole	✓	✓	✓	✓	✓	✓	✓	✓
Ground water requirements, including assessment of hydrologic link, monitoring wells (four per facility), impermeable pads under storage, impermeable lagoon/pond liners, and temporary/modified storage during upgrade			✓	✓				✓
Surface water monitoring requirement, including four total grab samples upstream and downstream of both feedlot and land application areas, 12 times per year. One composite sample collected once per year at stockpile and surface impoundments. Samples are analyzed for nitrogen, phosphorus, and total suspended solids.				✓				
Drier manure technology basis[2,3]					✓			
Anaerobic digestion						✓		
Timing requirements for land application							✓	
Diminished Potential for Discharge for Dairies (underpit storage for heifers and dairy cows; confinement barns for calves with covered storage; covered walkways and handling areas at dairy operations; 100-year, 24-hour storm capacity requirement at beef and stand-alone heifer operations)								✓

[1] There are no additional compliance costs expected for beef and dairy operations related to mortality handling requirements.
[2] Option 5 mandates “drier waste management.” For beef feedlots and dairies, this technology basis is composting. For swine, poultry, and veal operations, drier systems include covered lagoons.
[3] Option 5B mandates “no overflow” systems. For swine operations, the technology basis is high-rise housing for hogs, and for poultry operations the technology basis is dry systems.
(ERG, 2000a; Tetra Tech, Inc., 2000a).

Another key distinguishing factor incorporated into EPA's model CAFOs is the availability of cropland and pastureland to apply manure nutrients to land. For this analysis, nitrogen and phosphorus rates of land application are evaluated for three categories of cropland use: Category 1 CAFOs have sufficient land for all on-farm nutrients generated, Category 2 CAFOs have insufficient land, and Category 3 CAFOs have no land. The number of CAFOs within a given category of land availability is drawn from 1997 USDA data and varies depending on which nutrient (nitrogen or phosphorus) is used as the basis to assess land application and nutrient management costs. For Category 2 and 3 CAFOs, EPA evaluated additional technologies that may be necessary to balance on-farm nutrients. These technologies may also be used to reduce off-site hauling costs associated with excess on-farm nutrients, as well as to address ammonia volatilization, pathogens, trace metals, and antibiotic residuals. Such technologies may include best management practices (BMPs) and various farm production technologies, such as feed management strategies, solid-liquid separation, composting, anaerobic digestion, and other retrofits to existing farm technologies.

EPA's model CAFOs also take into account such production factors as climate and farmland geography, as well as land application and waste management practices and other major production practices typically found in the key producing regions of the country. Required practices under existing state regulations are also taken into account. Model facilities reflect major production practices used by larger confined animal farms, generally those with more than 300 animal units. Therefore, the models do not reflect pasture and grazing type farms, nor do they reflect typical costs to small farms. EPA's cost models also reflect cost differences within sectors, depending on manure composition, bedding use, and process water volumes.

11.2.1 Swine Operations

EPA developed the parameters describing the model swine farm using information from the U.S. Department of Agriculture National Agricultural Statistics Service (NASS), site visits to swine farms across the country, discussions with the National Pork Producers Council, and the USDA Natural Resources Conservation Service (NRCS). A description of the various components that make up the model farm is presented in the following discussion, and the sources of the information used to develop each piece of the model farm are noted. The *Cost Model for Swine and Poultry Sectors* provides more detailed information on the development of the swine model farm (Tetra Tech, Inc., 2000a).

11.2.1.1 *Housing*

Swine are typically housed in total confinement barns, and less commonly in other housing configurations such as open buildings with or without outside access and pastures (USDA, 1995). On many farms, small numbers of pigs (fewer than the number covered by this regulation) are raised outdoors; however, the trend in the industry is toward larger confinement farms at which pigs are raised indoors (North Carolina State University, 1998). For these reasons, the model swine farm is assumed to house its animals in total confinement barns.

11.2.1.2 *Waste Management Systems*

The waste produced at an operation depends on the type of animals that are present. In farrow-to-finish operations, the pigs are born and raised at the same facility. In grow-finish facilities, young pigs are first born and cared for at a nursery, and then brought onto the finishing farm. These are the two predominant types of swine operations in the United States for the size classes that would be covered under this proposed regulation (North Carolina State University, 1998).

Swine houses typically use slatted floors to separate manure and wastes from the animal. For example, approximately 40 percent of swine barns have slatted floors directly above a storage pit or flush alley (USDA, 1995; USDA APHIS, 1996b). This configuration allows the manure to be worked through the slats and drop into the area below for removal without disturbing or moving the animals.

The manure collects in a pit under the slats. In the southeast, it is common to allow manure to collect in the pit, and wash the pit once a day or more with a large volume of water to move the waste from the pit to a lagoon. The waste is stored in the lagoon until it is applied to land or transported off site. Storing the waste in an anaerobic lagoon provides some treatment during storage, conditioning the wastewater for later land application, and reducing odors (North Carolina State University, 1998).

In the Midwest, a deep pit storage system is more common. Deep pit systems start with several inches of water in the pit, and the manure is collected and stored under the house until it is pumped out for field application, typically twice a year. This system uses less water, creating a manure slurry that has higher nutrient concentrations than the liquid manure systems.

A 1995 survey of swine operations shows that both lagoons and deep pits are commonly used for waste storage in the Midwest region (USDA APHIS, 1996c). However, other than a general increase in the use of deep pits in the northern areas, the extent of the use for each system could not be determined. EPA intended to model the Mid-Atlantic region as having lagoons, and the Midwest region as having under house pits. However, the retrofits required for lagoon systems are more expensive than those for deep pit systems. Therefore, EPA decided to assume that all facilities use lagoon systems to avoid undercosting retrofit requirements. This is also consistent with the concept that the Midwest region model represents the Midwest region plus a portion of all the other regions except the Mid-Atlantic region. In other words, the Midwest region model reflects parts of the South, Central, and Pacific regions because census data could not be obtained for all desired regions and size groups (USDA NASS, 1999).

EPA proposes another model farm under Option 5B to provide a dry manure option—the high-rise swine house, which is a two-story confinement housing design that allows manure to fall though open slats onto the first floor where it is combined with carbon-rich material. The two waste management systems used for the model swine farms in this cost model are shown in Figure 11-1.

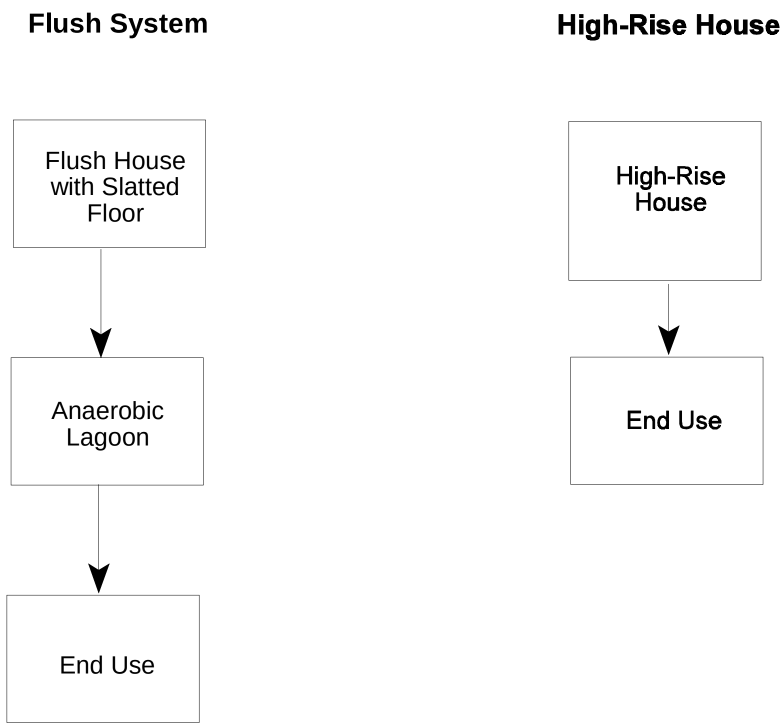


Figure 11-1. Model Swine Farms

11.2.1.3 *Size Group*

The general trend in the U.S. swine industry is toward a smaller number of large operations that have a larger number of animals on site. The number of smaller facilities, which tend to house the animals outdoors, has significantly decreased over the past 10 years (North Carolina State University, 1998). The trend in the larger operations is toward extended use of confinement operations.

For this proposed regulation, four size groups were modeled for each type of model farm. The size groups are provided in Table 11-2.

Table 11-2. Size Classes for Model Swine Farms

Region [a]	Operation Type [b]	Average Swine Animal Counts (Operation Size Presented by Number of Head)			
		Medium 1	**Medium 2**	**Large 1**	**Large 2**
		>750-1,875	**>1,875-2,500**	**>2,500-5,000**	**>5,000-10,000**
Mid-Atlantic	combined	1,182	2,165	3,509	33,787
	slaughter	1,242	2,184	3,554	20,530
Midwest	combined	1,137	2,152	3,444	34,164
	slaughter	1,161	2,124	3,417	26,398
Other	combined	1,255	2,150	3,455	66,224
	slaughter	1,291	2,215	3,626	21,731
National	**combined**	**1,147**	**2,153**	**3,453**	**37,922**
	slaughter	**1,176**	**2,146**	**3,491**	**22,184**

[a] Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Other=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK, WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL;.
[b] Operation type: Combined=breeding inventory, finishing (average of inventory and sold/2.8), and feeders (sold/10); Slaughter=finishing (average of inventory and sold/2.8).
Source: USDA NASS, 1999.

11.2.4.4 *Region*

Data from site visits and North Carolina State University's draft *Swine and Poultry Industry Characterization* indicate that the predominant type of waste management system at swine operations varies from region to region (North Carolina State University, 1998). As previously mentioned, in the southeast, flush systems are common; in the Midwest, deep-pit storage systems are more common. Given the regional variances in waste management systems, swine operations were modeled in two regions across the country: the Midwest and Mid-Atlantic. Facility totals in other regions were combined into the two regions modeled to account for all facilities nationwide.

11.2.2 Poultry Operations

EPA developed three model farms to represent poultry operations in the United States. The model farms are broiler, dry layer, and wet layer operations. The parameters describing the model poultry farms were developed using information from NASS, site visits to poultry farms across the country, and the USDA NRCS. A description of the various components of each model farm is presented in the following discussion, and the sources of the information used to develop each piece of the model farm are noted. The *Cost Model for Swine and Poultry Sectors* provides more detailed information on the development of the model poultry farms (Tetra Tech, Inc., 2000a).

11.2.2.1 *Housing*

The poultry sector includes broilers and layers (layers, pullets, and layer/pullets). Broilers are typically housed in long barns (approximately 40 feet wide and 400 to 500 feet long; North Carolina State University, 1998) and are grown on the floor of the house. The floor of the barn is covered with a layer of bedding, such as wood shavings, and the broilers deposit manure directly onto the bedding. Approximately 4 inches of bedding are initially added to the houses and top dressed with about 1 inch of new bedding between flocks.

Layers are typically confined in cages in high-rise housing or shallow pit flush housing. In a high-rise house, the layer cages are suspended over a bottom story, where the manure is deposited and stored. In shallow pit flush housing, a single layer of cages is suspended over a shallow pit. Manure drops directly into the pit, where it is flushed out periodically using recycled lagoon water.

These poultry housing systems are considered typical systems in the broiler and layer industry (North Carolina State University, 1998). Therefore, the cost model uses these housing systems in the model broiler and wet and dry layer farms.

11.2.2.2 *Waste Management Systems*

Manure from broiler operations accumulates on the floor where it is mixed with bedding, forming litter. Litter close to drinking water forms a cake that is removed between flocks. The rest of the litter in a broiler house is removed periodically (6 months to 2 years) from the barns, and then transported off site or applied to land. Typically, broiler operations are completely dry waste management systems (North Carolina State University, 1998).

Layer operations may operate as a wet or a dry system. Approximately 12 percent of layer houses use a liquid flush system, in which waste is removed from the house and stored in a lagoon (USDA APHIS, 2000). The remaining layer operations typically operate as dry systems, with manure stored in the house for up to a year. A scraper is used to remove waste from the collection pit or cage area (North Carolina State University, 1998). The lagoon wastewater and dry manure are stored until they are applied to land or transported off site.

Figure 11-2 presents the waste management systems for broilers and layers.

11.2.2.2 *Size Group*

For the proposed regulation, EPA modeled four size groups for broiler and dry layer operations, and two size groups for wet layer operations. The size groups are presented in Table 11-3 and Table 11-4.

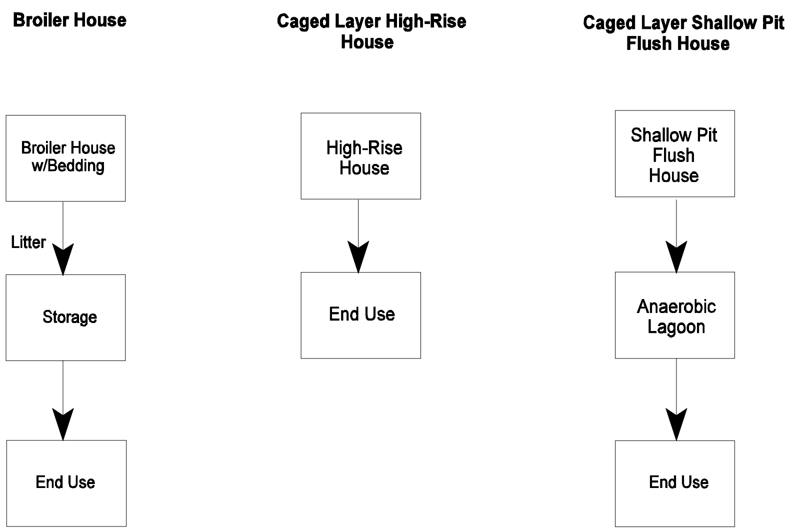


Figure 11-2. Model Broiler and Layer Farms

11.2.2.3 *Region*

Data from site visits and North Carolina State University's draft *Swine and Poultry Industry Characterization* indicate that the predominant type of waste management system at poultry operations varies from region to region (North Carolina State University, 1998). Most of the broiler operations in the United States are located in the South and Mid-Atlantic regions, while most of the egg-laying operations are located in the Midwest and South regions. Therefore, the model broiler farm reflects the South and Mid-Atlantic regions, and the model layer farm reflects the Midwest and South regions.

Table 11-3. Size Classes for Model Broiler Farms

Region [a]	Average Chicken Broiler Animal Counts [b]			
	Medium 1	Medium 2	Large 1	Large 2
	>30,000-60,000	>60,000-90,000	>90,000-180,000	>180,000
Central	44,224	73,084	119,026	332,030
Mid-Atlantic	44,193	73,590	115,281	303,155
Midwest	47,357	75,821	118,611	414,945
Pacific	44,041	73,695	132,560	624,380
South	43,998	73,776	117,581	281,453
National	**44,187**	**73,717**	**117,347**	**332,073**

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
[b] Broilers are young chickens of the meat-type breeds, raised for the purpose of meat production. Estimates cover a 12-month period (Dec. 1 through Nov. 30) and exclude states with fewer than 500,000 broilers.
Source: USDA NASS, 1999.

Table 11-4. Size Classes for Model Dry Layer Farms

Region [a]	Average Chicken Egg Layer Counts			
	Medium 1	Medium 2	Large 1	Large 2
	>30,000-62,500	>62,500-180,000	>180,000-600,000	>600,000
Central	42,360	89,688	317,725	733,354
Mid-Atlantic	42,588	95,585	286,946	1,007,755
Midwest	45,244	97,848	279,202	1,229,095
Pacific	43,613	99,354	277,755	813,356
South	38,642	97,413	293,512	884,291
National	**41,786**	**96,595**	**287,740**	**1,027,318**

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Pacific=WA, OR, CA, AK, HI; South=AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS, 1999.

11.2.3 Turkey Operations

EPA developed one model turkey farm to represent turkey operations in the United States. The parameters describing the model farm were developed using information from USDA NASS, site visits to turkey farms across the country, and USDA NRCS. A description of the various components of the model farm is presented in the following discussion, and the sources of the information used to develop that piece of the model farm are noted. The *Cost Model for Swine and Poultry Sectors* provides more detailed information on the development of the model turkey farm (Tetra Tech, Inc., 2000a).

11.2.3.1 *Housing*

Turkeys are typically housed in long barns (approximately 40 feet wide and 400 to 500 feet long), similar to broiler systems (North Carolina State University, 1998). The floor of the barn is covered in a layer of bedding, such as wood shavings, and the turkeys deposit manure directly onto the bedding. Approximately 4 inches of bedding are initially added to the houses and top dressed with about 1 inch of new bedding between flocks.

11.2.3.2 *Waste Management Systems*

The waste management system at a turkey operation is similar to that at a broiler operation. Manure from turkey operations accumulates on the floor where it is mixed with bedding, forming litter. Litter close to drinking water forms a cake that is periodically removed between flocks. The rest of the litter in the turkey house is removed periodically (6 months to 2 years) from the barns, and then transported off site or applied to land. Typically, turkey operations are completely dry waste management systems, and the waste management system at the model turkey farm is based on this dry system, as shown in Figure 11-3 (North Carolina State University, 1998).

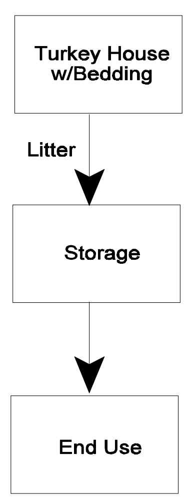


Figure 11-3. Model Turkey Farm

11.2.3.3 *Size Groups*

Three size groups were modeled for each type of facility. The size groups are presented in Table 11-5.

11.2.3.4 *Region*

State-level data from the 1997 Census of Agriculture indicate that states in the Midwest and Mid-Atlantic regions of the United States account for over 70 percent of all turkey turkeys produced. For this reason, model turkey farms are located in the Mid-Atlantic and Midwest regions (USDA NASS, 1999).

Table 11-5. Size Classes for Model Turkey Farms

Region [a]	Average Turkey Counts by Operation Size		
	Medium 1	Medium 2	Large 1
	>16,500-38,500	>38,500-55,000	>55,000
Central	25,420	47,310	172,416
Mid-Atlantic	24,903	45,193	97,111
Midwest	24,303	45,469	158,365
Other	26,310	45,520	116,295
National	**24,936**	**45,486**	**133,340**

[a] Central=ID, MT, WY, NV, UT, CO, AZ, NM, TX, OK; Mid-Atlantic=ME, NH, VT, NY, MA, RI, CT, NJ, PA, DE, MD, VA, WV, KY, TN, NC; Midwest=ND, SD, MN, MI, WI, OH, IN, IL, IA, MO, NE, KS; Other=WA, OR, CA, AK, HI, AR, LA, MS, AL, GA, SC, FL
Source: USDA NASS 1999.

11.2.4 Dairy Operations

EPA developed two model farms to represent dairy operations in the United States. The model farms are a complete flush dairy and a hose/scrape dairy. The parameters describing the model dairy farms were developed using information from NASS, Census of Agriculture, site visits to dairy farms across the country, meetings with USDA extension agents, and meetings with the National Milk Producers Federation. A description of the various components that make up the model farms is presented below, with the sources of the information used to develop that piece of the model farm. The *Cost Methodology Report for Beef and Dairy Animal Feeding Operations* provides more detailed information of the development of the model dairy farm (ERG, 2000a).

11.2.4.1 *Housing*

To determine the type of housing used at the model farm, the type of animals on the farm must be considered. In addition to the mature dairy herd (including lactating, dry, and close-up cows), there are often other animals on site, including calves, heifers, and bulls. The number of immature animals (calves and heifers) at the operation is assumed to be proportional to the number of mature cows in the herd and depends on the farm's management. For example, the operation may house virtually no immature animals on site, and obtain replacement heifers from stand-alone operations, or could have close to a 1:1 ratio of immature animals to mature animals. The percentage of immature animals on site varies with the size and location of the operation. For farms with more than 200 dairy cows, there is typically one calf or heifer for every 1.7 mature cows, or 0.6 immature animals for every mature dairy cow (Stull et al., 1998).

For the model farm, EPA estimates the number of calves on site to be 30 percent of the mature cows, and another 30 percent of the mature cows is used to estimate the number of heifers on site. The percentage of bulls on site is typically small. For this reason, EPA assumes that their impact on the model farm waste management system is insignificant, and these animals are not considered in the model farm.

The most common types of housing for mature cows include freestall barns, tie stalls/stanchions, pasture, drylots, freestall barns, and combinations of these (Stull et al., 1998). Based on site visits, most medium to large dairies (>200 mature dairy cows) house their mature cows in freestall barns; therefore, EPA assumes that mature dairy cows are housed in freestall barns for the dairy model.

The most common types of calf and heifer housing are drylots, multiple animal pens, and pasture (USDA APHIS, 1996a). Based on site visits, most moderate to large facilities use drylots to house their heifers and calves, so drylots were used in the model farm definition as the housing for calves and heifers at dairy operations. The size of the drylot for the model farm was calculated using animal space requirements suggested by Midwest Plan Service (Midwest Plan Service, 1987).

Under the NSPS Option 8, the model dairy farm is required to eliminate the potential for discharge; therefore, EPA costed confinement barns for heifer and calf housing to avoid contaminated runoff from drylots (ERG, 2000a).

11.2.4.2 *Waste Management Systems*

Waste is generated in two main areas at dairy operations: the milking parlor and the housing areas. Waste from the milking parlor includes manure and wash water from cleaning the equipment and the parlor after each milking. Waste from the confinement barns includes bedding and manure for all barns, and wash water if the barns are flushed for cleaning. Waste generated from the drylots includes manure and runoff from any precipitation that falls on the drylot.

Site visits showed that most dairy operations send their wastewater from the parlor and flush barns to a lagoon for storage and treatment. The wastewater is sometimes passed through a solids separator to remove solids before the wastewater enters the lagoon. The operator removes solids from the separator frequently to prevent buildup, and the solids are stockpiled on site. Solid waste scraped from a barn is typically stacked on the feedlot for storage for later use or transport. Solid waste on the drylot is often mounded and is later removed for transport off site or land application. Wastewater in the lagoon is held in storage for later use as fertilizer on site or transportation off site. The waste management systems used for the model dairy farm in this cost model are shown in Figure 11-4.

Under the NSPS Option 8, the dairy waste management system is contained in three separate areas for each animal: the mature dairy cow freestall barn with underpit storage, the heifer freestall barn with underpit storage, and the calf barn with adjacent manure storage. All manure and wastewater generated in the milking parlor are channeled to the mature cow manure storage pit. The manure pits provide storage for the waste until it is applied to the land or transported off site. The calves at this model farm are also housed in a confinement barn; however, the barn has a solid floor and the manure waste is scraped to a covered storage area, where is its stored until the waste is applied to the land or transported off site.

The amount of waste generated at a facility depends on how the operation cleans the barn and parlor on a daily basis. Some dairy operations flush the waste (a flush dairy); others use less water, hosing down the parlor and scraping the manure from the barns (a hose/scrape dairy). The number of facilities that operate as a flush dairy or a hose/scrape dairy was estimated from site visits. Both flush and hose/scrape dairy systems were modeled as part of the model farm, and then the results of each were ultimately weighted to reflect the percentage of operations that are assumed to be flush versus hose/scrape for a single model farm.

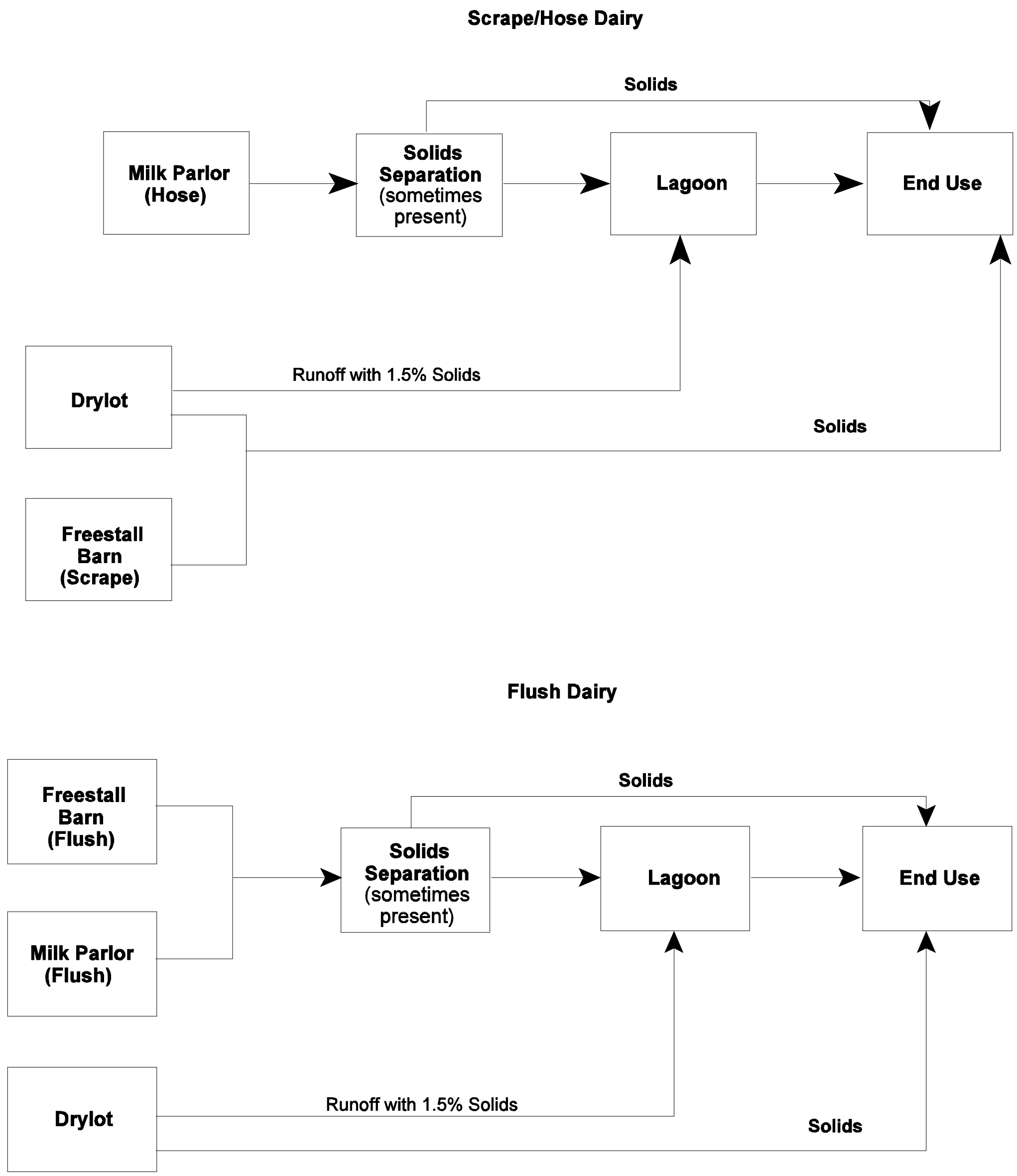


Figure 11-4. Model Dairy Farms

11.2.4.3 *Size Group*

Data collected during site visits indicate that dairies operate differently depending on their size. For example, larger dairies tend to already have lagoon storage, while moderate-sized dairies may have only a small amount of storage. Also, because feedlots with more than 700 animals are already regulated under the current rule, it was assumed for the cost model that these facilities are already in compliance for many components of the proposed rule. Therefore, three different size groups were used to model dairy operations with more than 200 animals. The size groups are presented in Table 11-6.

Table 11-6. Size Classes for Model Dairy Farms

Size Class	Size Range	Average Head
Medium 1	200-350	235
Medium 2	350-700	460
Large 1	>700	1,419

11.2.4.4 *Region*

Data from site visits indicate that dairies in various regions of the country have different characteristics primarily related to climate. For example, a dairy in the Pacific region receives a high amount of rainfall annually, and therefore will produce a high amount of runoff from drylots. A dairy in the Central region may not have as high rainfall, and will therefore produce less runoff from drylots. Because operating characteristics may vary between regions, dairies were modeled in five separate regions: Central, Pacific, South, Mid-Atlantic, and Midwest.

In the Large 1 size group, more than 80 percent of dairy operations are located in the Central and Pacific regions. In the medium-sized groups, most operations are located in the Midwest and Mid-Atlantic regions.

11.2.5 Beef Feedlots

EPA developed one model farm to represent beef feedlot operations in the United States. The parameters describing the beef model were developed using information from NASS, site visits to beef feedlots across the country, meetings with USDA extension agents, and meetings with the National Cattlemen's Beef Association. A description of the various components of the model farm is presented below, and the sources of the information used to develop that piece of the model farm are referenced. The *Cost Methodology Report for Beef and Dairy Animal Feeding Operations* provides more detailed information of the development of the model beef farm. (ERG, 2000a).

11.2.5.1 *Housing*

The large majority of beef feedlot operations in the United States house the cattle on drylots (USDA, 1996a). There is a small number of operations that use confinement barns at beef feedlots, but the vast majority use open lots as do most new operations. Therefore, drylots were assumed as the housing for the model beef farm. The size of the drylot was calculated using animal space requirements suggested by Midwest Plan Service (Midwest Plan Service, 1987).

11.2.5.2 *Waste Management System*

The drylot is the main area where waste is produced at beef operations. Waste from the drylot includes solid manure, which has dried on the drylot, and runoff, which results from precipitation that falls on the drylot.

Most beef operations in the United States divert runoff from the drylot to a storage pond (USDA, 1996a). A solids separator is sometimes used to remove solids from the waste stream before it enters the lagoon. Solid waste on the drylot is often mounded to promote drainage away from the lot to provide consistently dry areas for the cattle to rest, and is later moved from the drylot for transportation off site or land application on site (USDA APHIS, 1996a).

The beef model farm was developed following these typical characteristics of beef operations. Figure 11-5 presents the waste management system used as part of the model beef farm.

11.2.5.3 *Size Group*

Data collected during site visits indicate that beef feedlots operate differently depending on their size. For example, larger feedlots frequently put waste through a solid separators before transferring it to a holding pond, and moderate sized facilities are less frequently equipped with solids separators. Moreover, feedlots with more than 1,000 beef cattle are already regulated under the current rule. EPA therefore assumes that these facilities are already in compliance for many components of the proposed rule. To account for these differences, four different size groups were used to model beef operations with more than 300 animal units. The size groups are presented in Table 11-7.

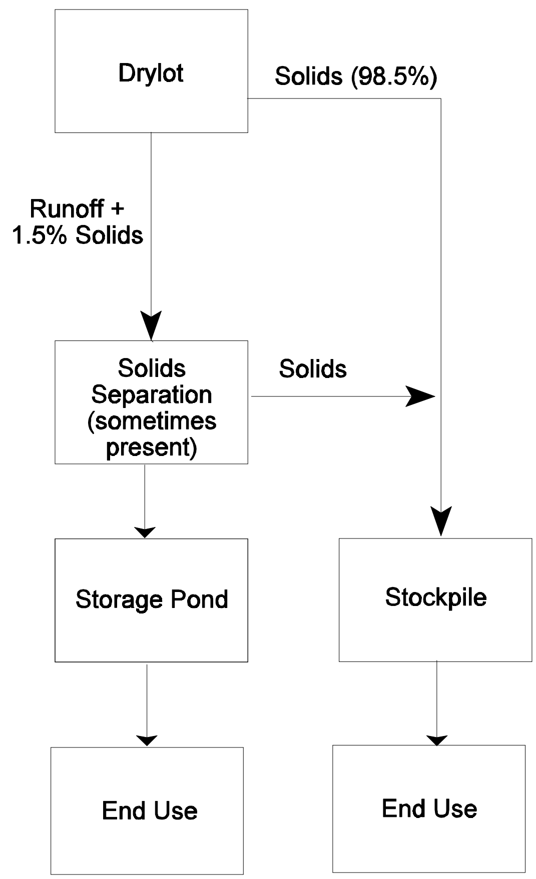


Figure 11-5. Model Beef Farm

Table 11-7. Size Classes for Model Beef Farms

Size Class	Size Range	Average Head
Medium 1	300-500	600
Medium 2	500-1,000	1,088
Large 1	1,000-8,000	2,628
Large 2	> 8,000	43,805

11.2.5.4 *Region*

Data from site visits to beef feedlots indicate that beef operations in various regions of the country have different characteristics primarily related to climate. For example, a beef feedlot in the Pacific region receives a high amount of rainfall annually, and therefore will generate a higher volume of runoff than an operation that receives less annual precipitation. To accommodate these climatological differences, beef feedlots were modeled for five separate regions: Central, Pacific, South, Mid-Atlantic, and Midwest.

Approximately 95 percent of Large 1 and Large 2 operations are located in the Central and Midwest regions. Of the Medium 2 facilities, nearly 75 percent are located in the Midwest region.

11.2.6 Veal Operations

EPA developed one model farm to represent veal operations in the United States. The parameters describing the veal model farm were developed using information collected during site visits to veal operations in Indiana and discussions with the American Veal Association. A description of the various components of the model farm is presented below, and the sources of the information used to develop that piece of the model farm are referenced. The *Cost Methodology Report for Beef and Dairy Animal Feeding Operations* provides more detailed information of the development of the model veal farm (ERG, 2000a).

11.2.6.1 *Housing*

Veal calves are generally grouped by age in an environmentally controlled building. The majority of veal operations in the United States are equipped with individual stalls or pens with slotted floors, which allow for efficient removal of waste (Crouch, 1999). Since this type of housing is the predominant type of housing used in the veal producing industry, environmentally controlled buildings with individual stalls were designated as the housing for the model veal farm.

11.2.6.2 *Waste Management Systems*

Based on site visits, the only significant source of waste at veal operations is from the veal confinement areas. Veal feces are very fluid; therefore, manure is typically handled in a liquid waste management system. Manure and waste that fall through the slotted floor are flushed regularly out of the barn. (Typically, flushing occurs twice daily.) Most veal operations have a lagoon to receive and treat their wastewater from flushing, although some operations have a holding pit system in which the manure drops directly into the pit, which provides storage until land application or transport off site. Wastewater in the lagoon is held in storage for later use as fertilizer on site or for off-site transportation.

EPA developed the veal model farm used in this cost methodology from these general characteristics. The animals are totally confined, and therefore the only source of wastewater is from flushing the manure and waste from the barns. Figure 11-6 presents a diagram of the model veal farm waste management system.

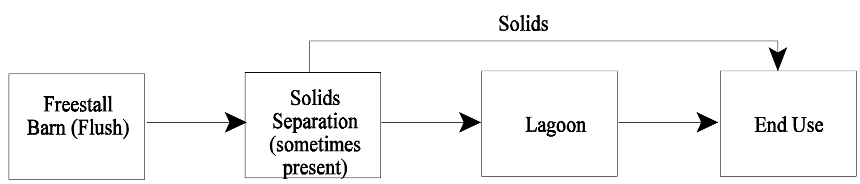


Figure 11-6. Model Veal Farm

11.2.6.3 *Size Group*

The veal industry standard operating procedures do not vary significantly based on the size of the operation, according to data collected during site visits and discussions with the American Veal Association (Crouch, 1999). Two size groups were used to model the industry, as presented in Table 11-8.

Table 11-8. Size Classes for Model Veal Farm

Size Class	Size Range	Average Head
Medium 1	300-500	400
Medium 2	>500	540

11.2.6.4 *Region*

The American Veal Association indicates that veal producers are located predominantly in the Midwest and Central regions (Crouch, 1999). Therefore, only these two regions were incorporated in the model veal farm.

11.2.7 Heifer Grower Operations

EPA developed one model farm to describe heifer grower operations in the United States. The parameters describing the heifer model farm were developed from information collected during meetings with the National Milk Producers Federation and discussions with the Professional Heifer Growers Association. A description of the various components of the model farm is presented below, and the sources of the information used to develop each piece of the model farm are noted. The *Cost Methodology Report for Beef and Dairy Animal Feeding Operations* provides more detailed information of the development of the heifer model farm (ERG, 2000a).

11.2.7.1 *Housing*

Stand-alone heifer raising operations use two primary methods of housing the animals. One method is to raise the heifers on pasture, and the second method is to raise the heifers on confined drylots. Because this regulation addresses only confined operations, the model heifer farm accounts for animals housed on drylots.

11.2.7.2 *Waste Management System*

The drylot is the main area where waste is produced at heifer operations. Waste from the drylot includes solid manure, which has dried on the drylot, and runoff, which results from precipitation that falls on the drylot.

Heifer operations typically operate like beef feedlots (Cady, 2000). As such, it is assumed that runoff from the drylot is channeled to a storage pond, sometimes passing through a solids separator before entering the pond, while solid waste from the drylot is mounded on the drylot, and is later removed for transportation off site or land application on site.

The waste management system of the model heifer farm is identical to the model beef farm waste management system, which is presented in Figure 11-5.

11.2.7.3 *Size Group*

There is very little information available on the number of operations raising heifers in confinement. It is believed that most large heifer raising operations (more than 1,000 head) are confinement-based, while smaller operations are often pasture-based (Cady, 2000). The average size of heifer grower operations ranges from 50 head to 25,000 head, and varies geographically. The average size of a heifer operation located west of the Mississippi River is 1,000 to 5,000 head, while the average size in the upper Midwest, Northeast, and South is 50 to 200 head. Nationally, the median size of a dairy heifer raising operation is approximately 200 head (Cady, 2000).

Because of the lack of information on the size distribution of confined heifer grower operations, EPA chose three size groups for consistency with the model beef farm size groups, as presented in Table 11-9. The average head for each size group was calculated as the median on the size group range.

Table 11-9. Size Classes for Model Heifer Farm

Size Class	Size Range	Average Head
Medium 1	300-500 animals	400
Medium 2	500-1,000 animals	750
Large 1	>1,000 animals	1,500

11.2.7.4 *Region*

There is very little information on the location of heifer grower operations in the United States; however, since they directly support the dairy industry, it can be assumed that they are concentrated in areas where the dairy industry is moving toward specialization (Bocher, 2000). EPA estimates that heifer grower operations are located in four areas of the country: 70 percent in the west, 20 percent in the south/southeast, 7 percent in the northeast, and 3 percent in the upper Midwest.

11.3 Design and Cost of Waste and Nutrient Management Technologies

EPA developed computer cost models to estimate compliance costs for each model farm and regulatory option.

The cost models calculates model farm costs in three major steps:

1) Costs are calculated for each technology or practice that makes up each regulatory option for each model farm, based on model farm characteristics, including number of head, waste characteristics, and facility characteristics.

2) The costs for each technology or practice are then weighted for the entire model farm population, using frequency factors to indicate the portion of the model farm population that will incur that cost.

3) The weighted costs for each model farm population are summed, resulting in an average model farm cost for each model population.

The resulting model farm cost represents the average cost that all of the operations within that model population are expected to incur. The compliance costs that a single model farm incurs may be more or less than this average cost.

The cost estimates generated contain the following types of costs:

- Capital costs—Costs for facility upgrades (e.g., construction projects);

- Fixed costs—One-time costs for items that cannot be amortized (e.g., training);

- Annual operating and maintenance (O&M) costs—Annually recurring costs, which may be positive or negative. A positive O&M cost indicates an annual cost to operate, and a negative O&M cost indicates a benefit to operate, due to cost offsets;

- Three-year recurring O&M costs—Costs that occur only once every three years; and

- Annual fertilizer costs—Costs for additional commercial nitrogen fertilizer needed to supplement the nutrients available from manure application.

These costs provide the basis for evaluating the total annualized costs, cost effectiveness, and economic impact of the regulatory options proposed for the CAFOs industry.

The following sections discuss the six primary components of the costing methodology:

- The calculation of manure and nutrient production at each operation;
- Cropland acreage;
- Nutrient management planning;
- Facility upgrades;
- Land application; and
- Off-site transportation of manure.

Further detail on the cost methodology may be found in the *Cost Methodology Report for Beef and Dairy Animal Feeding Operations* and the report on the *Cost Model for Swine and Poultry Sectors* (ERG, 2000a; Tetra Tech, Inc. 2000a).

11.3.1 Manure and Nutrient Production

The manure produced at each model farm provides the basis for the design of the technology components and model farm parameters, including determining farm acreage, nutrient management practices, equipment sizes, and the agronomic rate of applying waste to land. The quantity and characteristics of the waste for each model farm are calculated from values provided in the *Agriculture Waste Management Field Handbook* for beef and dairy operations, and from values in *Nutrients Available from Livestock Manure Relative to Crop Growth* for swine and poultry operations (USDA NRCS, 1992; USDA NRCS, 1998).

The quantity of manure generated from a feedlot operation depends on the animal type and the number of mature and immature animals that are present. Nutrient production at each model farm is calculated using waste characteristics data for excreted manure for each animal type. The mass production of each of these nutrients is calculated using the average weight of the animal while housed at the model farm, the waste concentration data, and the number of animals on site. The total daily rate of manure and nutrient production for each model farm is presented in Table 11-10, and an example of these calculations is shown in Figure 11-7.

Table 11-10. Manure and Nutrient Production by Model Farm

Animal Type	Size Class	Average Head	Total Manure (lbs/day)	Nitrogen Production (lb/day)	Phosphorus Production (lb/day)
Beef	Medium 1	600	33,151	179	48
	Medium 2	1,088	60,113	324	88
	Large 1	2,628	145,200	784	212
	Large 2	43,805	2,420,270	13,062	3,534
Dairy	Medium 1	235	30,673	155.45	28.11
	Medium 2	460	60,041	304.29	55.02
	Large 1	1,419	185,214	938.67	169.73
Dairy-Heifer	Medium 1	71	2,559	8	2
	Medium 2	138	5,009	15	3
	Large 1	426	15,453	47	10
Dairy-Calves	Medium 1	71	1,624	5	1
	Medium 2	138	3,178	10	2
	Large 1	426	9,804	30	6
Veal	Medium 1	400	6,710	30	7
	Medium 2	540	9,059	40	10
Heifers	Medium 1	400	14,520	44	9
	Medium 2	750	27,225	83	18
	Large 1	1,500	54,450	165	35
Swine:GF	Medium 1	1,176	16,937	72	21
	Medium 2	2,146	30,906	132	38
	Large 1	3,491	50,277	214	62
	Large 2	22,184	319,490	1,363	395
Swine:FF	Medium 1	1,147	12,463	93	27
	Medium 2	2,153	23,395	175	51
	Large 1	3,453	37,521	281	82
	Large 2	37,922	412,066	3,082	901
Layers:All	Medium 1	41,786	9,083	130	48
	Medium 2	96,595	20,997	302	112
	Large 1	287,740	62,547	899	333
	Large 2	1,027,318	223,313	3,208	1,190
Broiler	Medium 1	44,187	18,835	267	78
	Medium 2	73,717	31,422	446	130
	Large 1	117,347	50,019	710	206
	Large 2	332,073	141,546	2,009	584
Turkey	Medium 1	24,936	12,764	192	75
	Medium 2	45,486	23,284	350	136
	Large 1	133,340	68,255	1,025	399

GF = Grower-Finisher
FF = Farrow-to-Finish
Source: Calculated from manure nutrient values presented in USDA NRCS, 1998 and model farm average head.

Mature dairy cattle (DAIRY, MEDIUM 2 MODEL FARM, 460 head) produce:

83.5 lb manure /day-1,000 lb live weight
0.45 lb nitrogen (TKN)/day-1,000 lb live weight
0.08 lb phosphorus/day-1,000 lb live weight
Average weight = 1,350 pounds

Mature cattle manure (lb/day) $= \frac{\text{83.5 lb}}{\text{day}} * \frac{\text{1,350 lb}}{\text{1,000 lb}} * \frac{\text{460 head}}{\text{farm}} = \frac{\text{51,854 lb/day}}{\text{farm}}$

Nitrogen production from mature cattle (lb/day)$= \frac{\text{0.45 lb}}{\text{day}} * \frac{\text{1350 lb}}{\text{1,000 lb}} * \frac{\text{460 head}}{\text{farm}} = \frac{\text{279 lb/day}}{\text{farm}}$

Phosphorus production from mature cattle (lb/day)$= \frac{\text{0.08 lb}}{\text{day}} * \frac{\text{1,350 lb}}{\text{1,000 lb}} * \frac{\text{460 head}}{\text{farm}} = \frac{\text{50 lb/day}}{\text{farm}}$

Heifers on site (138 head) produce:

66 lb manure/day-1,000 lb live weight
0.2 lb nitrogen (TKN)/day-1,000 lb live weight
0.04 lb phosphorus/day-1,000 lb live weight
Average weight = 550 pounds

Heifer manure (lb/day) $= \frac{\text{66 lb}}{\text{day}} * \frac{\text{550 lb}}{\text{1,000 lb}} * \frac{\text{138 head}}{\text{farm}} = \frac{\text{5,009 lb/day}}{\text{farm}}$

Nitrogen production from heifers (lb/day)$= \frac{\text{0.2 lb}}{\text{day}} * \frac{\text{550 lb}}{\text{1,000 lb}} * \frac{\text{138 head}}{\text{farm}} = \frac{\text{15 1b/day}}{\text{farm}}$

Phosphorus production from heifers (lb/day) $= \frac{\text{0.04 lb}}{\text{day}} * \frac{\text{550 lb}}{\text{1,000 lb}} * \frac{\text{138 head}}{\text{farm}} = \frac{\text{3 lb/day}}{\text{farm}}$

Calves on site (136 head) produce:

65.8 lb manure/day-1,000 lb live weight
0.2 lb nitrogen (TKN)/day-1,000 lb live weight
0.04 lb phosphorus/day-1,000 lb live weight
Average weight =350 pounds

Calf manure (lb/day) $= \frac{\text{65.8 lb}}{\text{day}} * \frac{\text{350 lb}}{\text{1,000 lb}} * \frac{\text{138 head}}{\text{farm}} = \frac{\text{3,178 lb/day}}{\text{farm}}$

Nitrogen production from calves (lb/day)$= \frac{\text{0.2 lb}}{\text{day}} * \frac{\text{350 lb}}{\text{1,000 lb}} * \frac{\text{138 head}}{\text{farm}} = \frac{\text{10 lb/day}}{\text{farm}}$

Phosphorus production from calves (lb/day) $= \frac{\text{0.04 lb}}{\text{day}} * \frac{\text{350 lb}}{\text{1,000 lb}} * \frac{\text{138 head}}{\text{farm}} = \frac{\text{2 lb/day}}{\text{farm}}$

TOTAL MANURE PRODUCTION = 51,854 lb + 5,009 lb + 3,178 lb = 60,041 lb/day
TOTAL NITROGEN PRODUCTION = 279 lb+ 15 lb + 10 lb = 304 lb/day
TOTAL PHOSPHORUS PRODUCTION = 50 lb + 3 lb + 2 lb = 55 lb/day

Figure 11-7. Sample Calculation of Manure and Nutrient Production at Model Farm

11.3.2 Available Acreage

Data on the amount of cropland and pastureland available to facilities for land application of manure are limited. Therefore, EPA classified the model farms into three categories that define how much land they have available and how the operation ultimately manages its waste:

Category 1: Facilities with sufficient land to apply all of their generated manure at appropriate agronomic rates. No manure is transported off site.

Category 2: Facilities without sufficient land to apply all of their generated manure at appropriate agronomic rates. The excess manure after agronomic application is transported off site.

Category 3: Facilities without any available land for manure application. All of the manure is transported off site regardless of the regulatory options considered by EPA.

EPA defines Category 1 operations as having a sufficient amount of land, and at a minimum, the available land equals the amount of land required to agronomically apply all of the manure generated at the operation. Category 2 acreages are based on a 1999 USDA analysis that calculated the amount of nutrients present in manure that exceeded the amount that could be applied agronomically (Kellogg et al., 2000). These calculations are discussed in detail below. EPA assumes Category 3 operations have no available land.

11.3.2.1 *Agronomic Application Rates*

Under all regulatory options considered, all operations are required to implement nitrogen-based agronomic application rates when applying animal waste or wastewater. Under Options 2 through 8, however, operations that are located in areas with certain site conditions (e.g., phosphorus-saturated soils) are required to follow more stringent phosphorus-based agronomic application rates. Costs for nitrogen-based application are different than costs for phosphorus-based application. These costs are weighted for a model farm using a "nutrient-based application factor" to account for these different costs, based on the percent of facilities in that region that would apply on a phosphorus-basis verses a nitrogen-basis. The nutrient-based application factors vary according to the type of facility (beef, dairy, swine, or poultry), and they are presented in the cost methodology reports (ERG, 2000a; Tetra Tech, Inc., 2000a).

Agronomic application rates are calculated using crop yields, crop uptakes, and crop utilization factors. These crops vary by region and animal type. EPA selected representative crops for each model farm by contacting USDA state and county cooperative extension services and incorporating data from USDA's *Agriculture Waste Management Field Handbook* (USDA NRCS, 1992). The methods used to calculate nutrient requirements and application rates for the beef and dairy subsectors and the swine and poultry subsectors are described below.

Beef and Dairy

For the beef and dairy cost model, extension agents identified typical crops grown by dairy and beef feedlots in that state, specifying the type of crops grown and typical yields. Crop nutrient requirements are calculated by multiplying the expected crop yields (obtained from state cooperative extension services or Census of Agriculture data) by the crop uptake (Lander, 1998) for both nitrogen (N) and phosphorus (P).

$$\text{Crop N Requirements (lb/acre)} = \text{Crop Yield (tons/acre)} \times \text{Crop Uptake (lb/ton)}_{\text{nitrogen}}$$

$$\text{Crop P Requirements (lb/acre)} = \text{Crop Yield (tons/acre)} \times \text{Crop Uptake (lb/ton)}_{\text{phosphorus}}$$

Table 11-11 presents the representative crops, crop yields, crop uptakes, and crop nutrient (nitrogen and phosphorus) requirements for all animal types by region. EPA does not expect crops to vary significantly based on the size of the animal operation. Because veal operations are located predominantly in the Midwest, EPA developed only one set of crop assumptions for veal that reflect the Midwest region.

When more than one crop is grown on the land over the year (double or triple cropping), EPA set the total crop nutrient requirement for that land equal to the sum of the individual crop nutrient requirements.

EPA assumed that 70 percent of the nitrogen and 100 percent of the phosphorus in cattle manure that is applied to the land would be available for crop uptake and utilization over time (Lander, 1998). Therefore, the agronomic application rate is calculated as the total crop nutrient requirement divided by the appropriate utilization factor.

$$\text{Nitrogen-Based Manure Application Rate (lb/acre)} = \text{Total Crop Nitrogen Requirements (lb/acre)} / 70\%$$

$$\text{Phosphorus-Based Manure Application Rate (lb/acre)} = \text{Total Crop Phosphorus Requirements (lb/acre)} / 100\%$$

Table 11-11. Crop Information

Animal Type	Region	Crops	Crop Yield*	Crop Uptake (lb/ton)		Crop Requirement (lb/ton)	
				Nitrogen	Phosphorus	Nitrogen	Phosphorus
Beef/ Heifers	Central	Corn-silage	20 tpa	7.1	1.1	142	21
		Hay	3 tpa	25.6	4.5	77	13
	Mid-Atlantic	Corn-silage	27 tpa	7.1	1.1	191	28
		Alfalfa	6 tpa	0	4.7	0	28
	Midwest	Corn-silage	20 tpa	7.1	1.1	142	21
		Alfalfa	6 tpa	0	4.7	0	28
	Pacific	Corn-silage	24 tpa	7.1	1.1	170	25
		Alfalfa	8 tpa	0	4.7	0	38
		Winter wheat	18 tpa	0.03	0.01	0.5	0.1
	South	Corn-silage	17 tpa	7.1	1.1	121	18
		Hay	2 tpa	19.8	15.3	40	31
		Rye	3 tpa	0.03	0.01	0.1	0.02
Dairy	Central	Corn-silage	20 tpa	7.1	1.1	142	21
		Hay	3 tpa	25.6	4.5	77	13
	Mid-Atlantic	Corn-silage	17 tpa	7.1	1.15	121	18
		Hay	2 tpa	19.8	15.3	40	31
	Midwest	Corn-silage	17 tpa	7.1	1.1	121	18
		Hay	2 tpa	19.8	15.3	40	31
	Pacific	Corn-silage	24 tpa	7.1	1.1	170	25
		Alfalfa	8 tpa	0	4.7	0	38
		Winter wheat	18 tpa	0.03	0.01	1	0.1
	South	Corn-silage	17 tpa	7.1	1.1	121	18
		Hay	2 tpa	19.8	15.3	40	31
		Rye	3 tpa	0.03	0.01	0.1	0.02
Swine	Central	Corn	162 bpa	Not calculated	Not calculated	129	24
	Mid-Atlantic	Corn	83 bpa	Not calculated	Not calculated	67	12
		Soybean	28 bpa			100	10
		Rye	25 bpa			26	4
	Midwest	Corn	135 bpa	Not calculated	Not calculated	108	20
		Soybean	48 bpa			170	17
	Pacific	Corn chop	23 tpa	Not calculated	Not calculated	160	24
		Oats	90 bpa			53	10
		Alfalfa	7 bpa			356	33
	South	Bermuda	8 tpa	Not calculated	Not calculated	150	15
Poultry	Central	Bermuda	8 tpa	Not calculated	Not calculated	150	15
	Mid-Atlantic	Corn	123 bpa	Not calculated	Not calculated	98	18
		Soybean	27 bpa			94	10
		Wheat	63 bpa			64	13
	Midwest	Fescue	5 bpa	Not calculated	Not calculated	99	10
	Pacific	Corn chop	23 tpa	Not calculated	Not calculated	165	24
		Oats	102 bpa			60	11
		Alfalfa	7 tpa			352	33
	South	Fescue	5 tpa	Not calculated	Not calculated	99	10
Veal	All (based on Midwest)	Corn-silage**	138 bpa	0.8 (lb/bu)	0.2 (lb/bu)	110	67
		Soybeans	42 bpa	3.6 (lb/bu)	0.4 (lb/bu)	150	
		Winter wheat	46 bpa	1.0 (lb/bu)	0.2 (lb/bu)	47	

* tpa = tons per acre; bpa = bushels per acre
** Veal crops based on corn-silage 50%, soybeans 50%, and winter wheat 100%
Source: ERG, 2000a; Tetra Tech, 2000a.

Swine and Poultry

For the swine and poultry model, EPA used published 1997 Census of Agriculture data to determine the cropland acres of selected crops as a percentage of total harvested crop acres. EPA determined crop yields by dividing the harvested quantity by the acreage obtained from the 1997 Census of Agriculture and from the yields found in USDA's *Agriculture Waste Management Field Handbook*. Using the actual yield data, nutrient requirements and nutrient removal rates were determined from USDA's *Agriculture Waste Management Field Handbook.* The average annual nitrogen and phosphorus crop removal and application rates were calculated by dividing the total crop requirements over the time to complete a full crop rotation.

11.3.2.2 *Category 1 and 2 Acreage*

Category 1 acreages are calculated using the agronomic application rates, number of animals, manure generation estimates, nutrient content of the manure, and manure recoverability factors:

$$\text{Category 1 Acreage} = \frac{\text{\#Animals} \times \text{Manure Generation (tons/head)} \times \text{Nutrient Content (lbs/ton manure)} \times \text{Recoverability Factor}}{\text{Agronomic application rate (lb/acre)}}$$

EPA defines recoverability factors as the percentage of manure, based on solids content, that it would be practical to recover. Recoverability factors are developed for each region, using USDA state-specific recoverability factors, and are based on the assumption that the decrease in nutrient value per ton of manure mirrors the reduction in solids content of the recoverable manure (USDA NRCS, 1998).

Category 2 acreages are estimated using excess manure from USDA's analysis of acres required to apply excess manure (Kellogg et al., 2000) and, in some cases, Category 1 acreage.

11.3.3 Nutrient Management Planning

To minimize the release of nutrients to surface and ground waters, confined animal feeding operations must prevent excess application of manure nutrients on cropland through the process of nutrient management planning. Confined animal feeding operations apply manure nutrients to the land in the form of solid, liquid, or slurry. Manure is also stored prior to application in stockpiles, tanks, pits, storage ponds, or lagoons. Confined animal feeding operations prevent excess application by developing and abiding by appropriate manure application rates that are designed to add only the nutrients required by the planned crops at the expected yields. Nutrient management planning may also minimize releases of nutrients by specifying the timing and location of manure application.

Five nutrient management practices are included in the costing methodology:

1. **Nutrient management plan—**a documented plan developed for each facility to ensure agronomic application of nutrients on cropland and management of waste on site. The

plan includes costs for development of the plan, training and certification, manure sampling and analysis (collecting samples from solid and liquid waste before each land application period), soil sampling and analysis (once every 3 years for all phosphorus-based options), hydrogeologic assessment for facilities located in ground water protection areas, periodic inspections of on-site facility upgrades, identification and protection of crop setback areas to protect waterfront areas, calibration of the manure spreader before each application period, and ongoing recordkeeping and recording. The plan must be updated at least once every 5 years.

2. **Surface water monitoring—**a practice in which surface water samples are periodically collected and analyzed for indications of contaminated runoff into adjacent waters. Costs account for 12 sampling events per year, including 4 grab samples and 1 quality assurance sample per event, measuring for nitrate-nitrite, total Kjeldahl nitrogen, total phosphorus, and total suspended solids.

3. **Ground water monitoring**—a practice for operations where ground water has a direct hydrogeologic link to surface water. Costs include installation of four 50-foot ground water wells and the collection of a sample from each well twice annually for indications of ground water contamination from the feedlot operation.

4. **Feeding strategies**—a practice in which the animal feed is monitored and adjusted to reduce the quantity of nutrients that are excreted from the animal. Costs include feeding strategies to reduce nitrogen and phosphorus in excrement from poultry and swine.

5. **Timing restrictions**—a practice in which manure is land applied only when the land and crops are most amenable to nutrient utilization. Costs for this practice are calculated for all animal sectors.

Each of these practices is discussed in Section 8.0 of this report, and further detail on the design of each practice may be found in the *Cost Methodology Report for Beef and Dairy Animal Feeding Operations* and the report on the *Cost Model for Swine and Poultry Sectors* (ERG, 2000a; Tetra Tech, Inc., 2000a).

11.3.4 Facility Upgrades

Section 8.0 of this report describes treatment technologies and facility upgrades that are presented as part of this cost methodology. These facility upgrades include:

- Anaerobic digestion with energy recovery;
- Anaerobic lagoons;
- Confinement barns for immature animals;
- Covered walkways;
- Field runoff controls;

- Lagoon covers;
- Liners for lagoons and ponds;
- Manure composting equipment;
- Manure storage;
- Solids separation (settling basin);
- Storage ponds;
- Storm water diversions (berms); and,
- Underpit storage.

An overview of the costs and applicability of each of these upgrades to each of the animal sectors is presented below:

Anaerobic digestion with energy recovery: Option 6 requires the use of anaerobic digestion for the largest dairy and swine operations, prior to discharge to a storage lagoon. The digester is designed to receive waste from all flushing, hose, and scrape operations, and combines this waste into a reactor to produce methane for energy use at the operation. Covered lagoon digesters are costed for large flush dairies and swine operations, and complete mix digesters are costed for large hose dairies. Runoff from the dairy feedlot is collected separately into a storage pond or lagoon.

Anaerobic lagoons: Costs for anaerobic lagoons are included for facilities that collect mixtures of water and manure, such as dairies, veal operations, swine, and wet layer operations. Lagoons receive wastewater from flush barns, flush and hose milking parlors (for dairies), and runoff from drylots. They are designed to accommodate a 25-year, 24-hour storm event and average rainfall for the storage period. The dairy cost model assumes a minimum depth of 10 feet for an anaerobic lagoon and adjusts this depth to account for direct precipitation and freeboard, and to optimize the cut-and-fill ratios for constructing the lagoon. The swine and poultry models design all lagoons as 12 feet deep.

Confinement barns for immature animals: Under NSPS Option 8 for dairies, all immature animals are housed in confinement barns. This eliminates the need for drylots and therefore contaminated runoff from the drylots. For calf barns, additional storage area is included for manure storage.

Covered walkways: Under NSPS Option 8 for dairies, all potential sources of contaminated runoff are eliminated. Therefore, costs are included to cover animal walkways and handling areas. The cost to cover holding areas and silage areas per barn are also included for dairies in this option.

Field runoff controls: Under all options, costs are included to implement and maintain setbacks along waterbodies contained within land-applied cropland for all animal operations. The size and therefore the cost of the setback were calculated based on national estimates of land area and stream miles and the average size and cost of filter strips (USEPA, 2000; USEPA, 1993).

Lagoon covers: Under Option 5, the regulation requires that facilities have zero potential for discharge from the feedlot. This requirement may be met by covering liquid storage basins and preventing direct precipitation from entering and adding to the storage volume. Swine, wet layers, and veal operations under Option 5 have costs for lagoon covers.

Liners for lagoons and ponds: The regulation requires that operations that store animal waste (e.g., runoff and/or process water) in a lagoon or pond have a liner in place if they are located in an area where ground water has a hydrogeologic connection to surface water. The liner is composed of two parts: a synthetic portion and a clay portion. The liner is designed to cover the floor of the pond or lagoon, including sloped side walls. Costs are calculated for all animal sectors to install liners in their lagoons and ponds.

Manure composting equipment: EPA designed windrow composting systems to treat and manage manure waste from drylots, separated solids, and scraped manure under Option 5 for beef, dairy, and heifer operations. Mortality composting systems are designed for swine and poultry operations to manage mortality waste under all options.

Manure storage: The cost model includes costs for the installation and maintenance of concrete pads as part of the waste management system for beef, heifer, and dairy operations under Options 3 and 4. The pads are designed to store waste from drylots, separated solids, and scraped manure. The cost model also includes costs for dry storage of poultry manure as part of all regulatory options. Storage for poultry litter includes a storage structure with a roof, a foundation, and a floor; and the structure receives poultry manure and bedding waste from the poultry house after each cleanout.

Solids separation (settling basin): The cost model includes solids separation as part of facility upgrades for beef and dairy operations, to facilitate the management of manure waste by separating the solid portion from the liquid portion. EPA costed earthen separators for beef feedlots, where runoff is the largest expected flow through the separator, and concrete-lined separators for dairy operations, where large amounts of flush water pass through the separator. Concrete is used to prevent erosion of the side slopes of the separator.

Storage ponds: The cost model includes the costs of storage ponds for facilities that collect runoff from the feedlot, such as beef facilities in which the cattle are confined on dry lots. The storage pond receives waste from drylot runoff only and is designed to accomodate a 25-year, 24-hour storm event and average rainfall for the storage period.

Storm water diversions (berms): Under all regulatory options, EPA requires that all animal operations contain any runoff collecting in potentially contaminated areas. EPA assumes that large facilities already have storm water diversions in place, because it is required by the current regulation.

Underpit storage: Under NSPS Option 8 for dairies, the cost model includes the costs of underpit storage as the waste management system for the mature cow confinement barns and the heifer barns. The cost model includes a barn designed with a slatted floor, and the cows work the manure through the slats into a storage pit underneath the barn. Ventilation in the pit is required for the pit to remove toxic gases, and the manure is stored in the pit until it can be agronomically applied to the land or transported off-site.

EPA calculated the costs of facility upgrades using design specifications in combination with cost estimates for each portion of the upgrade (e.g., excavation, compaction, gravel fill, etc.). Design specifications were obtained from various sources, including the Natural Resources Conservation Service (Conservation Practice Standards), the Midwest Plan Service, the *Agricultural Waste Management Field Handbook,* and other engineering design sources. EPA combined these design specifications with model-farm information—such as the animal type, manure generation, housing methods, and the type of farm—to calculate the required size of the component as well as the materials and labor required to construct and operate the upgrade. Then cost-estimation guides—including *Means Building Construction Cost Data, Means Heavy Construction Cost Data, Richardson's,* EPA's *FarmWare* Model, and vendor-supplied cost data—were used to determine the costs of each component of the upgrade.

11.3.5 Land Application

The cost model calculates costs for land application of manure and other waste for those operations which have land, but are not currently applying their waste. Based on site visits, EPA estimates that all beef, dairy, veal, and heifer operations that have land already have equipment to apply dry waste. Operations that have ponds or lagoons in place similarly have some form of liquid application method available. However, operations that are estimated to build lagoons or ponds in response to the regulation are costed for new equipment to apply liquid waste. These costs are based on installation and operation of a center pivot irrigation system from vendor supplied cost data (Zimmatic, Inc., 1999). For swine and poultry operations, EPA estimated (based on site visits) that all facilities already apply their waste to the land, and no additional costs would be incurred under the regulatory options.

11.3.6 Off-Site Transport of Manure

Animal feeding operations use different methods of transportation to remove excess manure waste and wastewater from the feedlot operation. The costs associated with transporting excess waste off site were calculated using two methods: contract hauling waste or purchasing transportation equipment. For poultry and swine operations, EPA based transportation costs on operations contract hauling their waste. For beef and dairy operations, EPA based transportation costs on either contract hauling or purchasing equipment to self-haul waste (whichever was least expensive).

Contract Hauling: EPA evaluated contract hauling as a method of transporting manure waste off site. In this method, the animal feeding operation hires an outside company to transport the excess waste. This method is advantageous to facilities that do not have the capacity to store excess waste on site, or the cropland acreage to agronomically apply the material. In addition, this method is useful for facilities that do not generate enough excess waste to warrant purchasing their own waste transportation trucks.

No capital costs are associated with contract hauling—only the operating cost to haul the waste. For beef and dairy operations, EPA calculated a set rate per mile for solid waste and for liquid waste, using vendor-supplied quotations and the average hauling distance for each region (ERG, 2000b; Tetra Tech, Inc., 2000b). For swine and poultry operations, EPA extracted the costs of contract hauling solid waste and liquid waste from many published articles (Tetra Tech, Inc., 1999).

Purchase Equipment: Another method evaluated for the transport of manure waste off site involves purchasing transportation equipment. In this method, the feedlot owner is responsible for purchasing the necessary trucks and hauling the waste to an off-site location. Depending on the type of waste to be transported, a solid waste truck, a liquid tanker truck, or both types of trucks would be required. In addition, the feedlot owner is responsible for determining a suitable location to transport the waste, as well as all costs associated with loading and unloading the trucks, driving the trucks to the off-site location, and maintaining the trucks. EPA did not base compliance costs for swine and poultry operations on purchasing transportation equipment, and therefore no costs are calculated for these facilities under this transportation option.

The capital and annual costs associated with the purchase and operation of a truck for waste transport depend on the type of waste (solid or liquid) and the quantity of waste to be transported. The cost model includes an evaluation of the amount of solid and/or liquid waste the operation will ship off site, and a determination of the capital costs based on that information. Annual costs are also calculated using the quantity of liquid or solid waste, as well as the hauling distance, maintenance costs, labor, fuel rates, and other parameters (ERG, 2000b).

11.4 Development of Frequency Factors

EPA recognizes that individual farms have already implemented certain waste management techniques or practices described in Section 11.3. When estimating costs for the implementation of the proposed options, EPA did not include costs for practices or techniques already in place at the farm.

To do this, EPA estimated the current frequency of existing waste management practices at swine, poultry, beef, veal, heifer, and dairy operations to estimate the portion of the operations that would incur costs to comply with the new regulation. EPA used the frequency information to estimate compliance costs for specific model farms for the regulatory options being considered. For example, based on site visits, all broiler operations are assumed to own or have access to tractors with front-end loaders for use in cleaning out the broiler houses (the frequency factor is 100 percent); therefore, no costs are included for cleaning out the broiler houses. As another example, 40 percent of large beef feedlots are estimated to have settling basins (based on site visits); therefore, only 60 percent of large beef feedlots incur a cost for a settling basin.

Applying the frequency factors to the unit component costs reduces the effective cost of that component for the model farm. Essentially, EPA adjusts the component cost to account for those facilities which already have the component in place, and would not have to install and operate a new component as a result of the proposed regulation.

EPA estimated frequency factors based on the sources below (each source was considered along with its limitations):

- **EPA site visit information—**This information was used to assess general practices of animal feeding operations and how they vary between regions and size classes.

- **Observations by industry experts—**Experts on animal feeding operations were contacted to provide insight into operations and practices, especially where data were limited or not publicly available.

- **USDA NASS—**The data currently available from NASS were used to determine the distribution of animal feeding operations across the regions by size class.

- **USDA APHIS National Animal Health Monitoring System (NAHMS)—**This source provides information on animal housing practices, facility size, and waste system components sorted by size class and region. These data have limited use because of the small number of respondents in the size classes of interest.

- ***State Compendium: Programs and Regulatory Activities Related to AFOs*—**This summary of state regulatory programs was used to estimate frequency factors based on current waste-handling requirements that already apply to animal operations in various states and in specific size classes.

11.5 Summary of Estimated Model Farm Costs by Regulatory Option

A summary of the estimated regulatory compliance costs is provided in the following tables. Capital, fixed, annual, and 3-year recurring (and, in some cases, 5-year) costs are included for each animal sector and each of the eight regulatory options. Costs are presented in 1997 dollars.

Table 11-12: Regulatory Compliance Costs for Swine Operations
Table 11-13: Regulatory Compliance Costs for Poultry Operations
Table 11-14: Regulatory Compliance Costs for Turkey Operations
Table 11-15: Regulatory Compliance Costs for Dairy Operations
Table 11-16: Regulatory Compliance Costs for Beef Operations
Table 11-17: Regulatory Compliance Costs for Veal Operations
Table 11-18: Regulatory Compliance Costs for Heifer Operations

11.6 References

Bocher, L.W. 2000. Custom Heifer Grower...Specialize in Providing Replacements for Dairy Herds. *Hoards Dairyman*. January 10, 2000.

Cady, R. 2000. Telephone conversation with Dr. Roger Cady, Monsanto Company and Founder of the Professional Dairy Heifer Growers Association. February 18, 2000.

Crouch, A. 1999. Telephone conversation with Alexa Crouch, American Veal Association. October 14, 1999.

ERG. 2000a. *Cost Methodology Report for Beef and Dairy Animal Feeding Operations.* Prepared for U.S. Environmental Protection Agency, Office of Water, Washington, DC. December 2000.

ERG. 2000b. *Transportation of Waste Off Site for Beef and Dairy Cost Model*. Memorandum prepared for U.S. Environmental Protection Agency, Office of Water, Washington, DC. December 2000.

Kellogg, R., C. H. Lander, D. Moffitt, and N. Gollehon. 2000. *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the U.S.* U.S. Department of Agriculture, National Resource Conservation Service, Washington, DC.

Midwest Plan Service. 1987. *Beef Housing and Equipment Handbook.* Fourth Edition, MWPS-6, Iowa State University, Ames, Iowa. February 1987.

NCSU. 1998. *Draft Swine and Poultry Industry Characterization, Waste Management Practices and Model Detailed Analysis of Predominantly Used Systems.* Prepared for

Environmental Protection Agency (WA 1-27) by North Carolina State University, September 30, 1998.

Stull, C. E., Steven B., and E. DePeters, eds. 1998. *Animal Care Series: Dairy Care Practices*. 2nd ed. Dairy Workgroup, University of California Cooperative Extension, Davis, California. June 1998.

Tetra Tech. 2000a. *Cost Model for Swine and Poultry Sectors*. Prepared for U.S. Environmental Protection Agency, Office of Water, Washington, DC. November 2000.

Tetra Tech. 2000b. *Revised Transportation Distances for Category 2 and 3 Type Operations*. Memorandum prepared for U.S. Environmental Protection Agency, Office of Water, Washington, DC. January 7, 2000.

Tetra Tech. 1999. *Costs of Storage, Transportation, and Land Application of Manure.* Memorandum prepared for U.S. Environmental Protection Agency, Office of Water, Washington, DC. February 1999.

USDA APHIS. 2000. *Part II: Reference of 1999 Table Egg Layer Management in the United States (Layer '99).* U.S. Department of Agriculture, Animal Plant Health Inspection Service, Fort Collins, CO.

USDA APHIS. 1996a. *National Animal Health Monitoring System, Part I: Feedlot Management Practices*. http://www.aphis.usda.gov/vs/ceah/cahm/ File cofdes1.pdf. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington, DC.

USDA APHIS. 1996b. *Swine '95: Part II: Reference of 1995 Grower/Finisher Health and Management*. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington, DC.

USDA APHIS. 1996c. *National Animal Health Monitoring System, Part 1: Reference of 1996 Dairy Management Practices*. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington, DC.

USDA APHIS. 1995. *Swine '95: Part I: Reference of 1995 Swine Management Practices.* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington, DC.

USDA NASS. 1999. Queries run by NASS for USEPA on the 1997 Census of Agriculture data. U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

USDA NRCS. 1992. *Agricultural Waste Management Field Handbook*, *National Engineering Handbook (NEH), Part 651*. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC.

USDA NRCS. 1998. *Nutrients Available from Livestock Manure Relative to Crop Growth Requirements*. Resource Assessment and Strategic Planning Working Paper 98-1.

USEPA. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA840-B-92-002. U.S. Environmental Protection Agency, Office of Water Washington, DC.

USEPA. 2000. *Water Quality Conditions in the United States.* EPA#841-F-00-006. U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Zimmatic, Inc. 1999. *Cost Estimate for Center Pivot Irrigation Systems*, <http://www.Zimmatic.com>.

Table 11-12. Regulatory Compliance Costs for Swine (FF, farrow-to-finish; GF, grower-finisher) Industry

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
1	Swine	Liquid	FF	Mid-Atlantic	1	187	Large1	640	736	181	253	0
1	Swine	Liquid	FF	Midwest	1	868	Large1	635	742	180	254	0
1	Swine	Liquid	FF	Mid-Atlantic	2	31	Large1	11,597	668	397	181	153,926
1	Swine	Liquid	FF	Midwest	2	145	Large1	11,495	739	395	251	979
1	Swine	Liquid	FF	Mid-Atlantic	3	35	Large1	118,315	580	22,431	0	0
1	Swine	Liquid	FF	Midwest	3	163	Large1	116,232	580	22,021	0	0
1	Swine	Liquid	FF	Mid-Atlantic	1	144	Large2	1,139	1,340	200	905	0
1	Swine	Liquid	FF	Midwest	1	306	Large2	1,040	1,228	192	762	0
1	Swine	Liquid	FF	Mid-Atlantic	2	69	Large2	394,727	808	8,613	331	0
1	Swine	Liquid	FF	Midwest	2	147	Large2	24,943	976	664	498	547,498
1	Swine	Liquid	FF	Mid-Atlantic	3	86	Large2	554,131	580	108,310	0	0
1	Swine	Liquid	FF	Midwest	3	182	Large2	448,511	580	87,492	0	0
1	Swine	Liquid	FF	Mid-Atlantic	1	304	Medium1a	1,242	672	392	214	0
1	Swine	Liquid	FF	Midwest	1	2731	Medium1a	1,196	644	567	184	0
1	Swine	Liquid	FF	Mid-Atlantic	2	22	Medium1a	7,500	689	526	232	0
1	Swine	Liquid	FF	Midwest	2	194	Medium1a	7,419	709	723	252	0
1	Swine	Liquid	FF	Mid-Atlantic	3	34	Medium1a	33,260	580	5,745	0	0
1	Swine	Liquid	FF	Midwest	3	310	Medium1a	32,228	580	5,742	0	0
1	Swine	Liquid	FF	Mid-Atlantic	1	203	Medium1b	1,449	745	440	291	0
1	Swine	Liquid	FF	Midwest	1	1821	Medium1b	1,370	695	596	237	0
1	Swine	Liquid	FF	Mid-Atlantic	2	14	Medium1b	8,999	685	554	227	55,197
1	Swine	Liquid	FF	Midwest	2	129	Medium1b	8,883	709	752	252	0
1	Swine	Liquid	FF	Mid-Atlantic	3	23	Medium1b	54,889	580	9,988	0	0
1	Swine	Liquid	FF	Midwest	3	207	Medium1b	53,024	580	9,820	0	0
1	Swine	Liquid	FF	Mid-Atlantic	1	135	Medium2	1,621	816	485	365	0
1	Swine	Liquid	FF	Midwest	1	696	Medium2	1,526	750	627	294	0
1	Swine	Liquid	FF	Mid-Atlantic	2	13	Medium2	10,285	720	600	264	89,706
1	Swine	Liquid	FF	Midwest	2	68	Medium2	10,266	752	801	297	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
1	Swine	Liquid	FF	Mid-Atlantic	3	20	Medium2	75,688	580	14,073	0	0
1	Swine	Liquid	FF	Midwest	3	104	Medium2	75,270	580	14,189	0	0
1	Swine	Liquid	GF	Mid-Atlantic	1	288	Large1	643	738	181	255	0
1	Swine	Liquid	GF	Midwest	1	356	Large1	634	740	180	252	0
1	Swine	Liquid	GF	Mid-Atlantic	2	89	Large1	11,666	648	398	159	207,255
1	Swine	Liquid	GF	Midwest	2	110	Large1	11,452	699	394	209	85,939
1	Swine	Liquid	GF	Mid-Atlantic	3	81	Large1	119,757	580	29,432	0	0
1	Swine	Liquid	GF	Midwest	3	101	Large1	115,367	580	28,308	0	0
1	Swine	Liquid	GF	Mid-Atlantic	1	154	Large2	883	975	189	511	0
1	Swine	Liquid	GF	Midwest	1	78	Large2	920	1,050	188	576	0
1	Swine	Liquid	GF	Mid-Atlantic	2	180	Large2	19,006	760	545	279	498,323
1	Swine	Liquid	GF	Midwest	2	92	Large2	20,421	892	573	410	342,942
1	Swine	Liquid	GF	Mid-Atlantic	3	94	Large2	290,778	580	73,215	0	0
1	Swine	Liquid	GF	Midwest	3	48	Large2	327,157	580	82,531	0	0
1	Swine	Liquid	GF	Mid-Atlantic	1	247	Medium1a	1,281	685	401	227	0
1	Swine	Liquid	GF	Midwest	1	1432	Medium1a	1,222	651	571	191	0
1	Swine	Liquid	GF	Mid-Atlantic	2	30	Medium1a	7,735	639	502	180	41,347
1	Swine	Liquid	GF	Midwest	2	171	Medium1a	7,586	653	698	194	0
1	Swine	Liquid	GF	Mid-Atlantic	3	51	Medium1a	37,029	580	8,304	0	0
1	Swine	Liquid	GF	Midwest	3	294	Medium1a	34,999	580	7,986	0	0
1	Swine	Liquid	GF	Mid-Atlantic	1	44	Medium1b	1,449	746	440	292	0
1	Swine	Liquid	GF	Midwest	1	256	Medium1b	1,360	692	595	234	0
1	Swine	Liquid	GF	Mid-Atlantic	2	5	Medium1b	41,311	639	1,327	180	0
1	Swine	Liquid	GF	Midwest	2	30	Medium1b	8,755	651	720	191	50,244
1	Swine	Liquid	GF	Mid-Atlantic	3	9	Medium1b	54,985	580	12,882	0	0
1	Swine	Liquid	GF	Midwest	3	53	Medium1b	51,801	580	12,268	0	0
1	Swine	Liquid	GF	Mid-Atlantic	1	122	Medium2	1,626	818	487	368	0
1	Swine	Liquid	GF	Midwest	1	314	Medium2	1,520	748	625	292	0
1	Swine	Liquid	GF	Mid-Atlantic	2	24	Medium2	10,311	709	594	253	100,722

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
1	Swine	Liquid	GF	Midwest	2	62	Medium2	10,199	734	790	278	15,133
1	Swine	Liquid	GF	Mid-Atlantic	3	29	Medium2	76,299	580	18,320	0	0
1	Swine	Liquid	GF	Midwest	3	74	Medium2	74,370	580	18,027	0	0
2	Swine	Liquid	FF	Mid-Atlantic	1	112	Large1	674	2,105	202	1,729	0
2	Swine	Liquid	FF	Midwest	1	521	Large1	657	2,251	193	1,832	0
2	Swine	Liquid	FF	Mid-Atlantic	2	19	Large1	85,724	1,134	14,957	682	0
2	Swine	Liquid	FF	Midwest	2	87	Large1	11,507	1,541	10,272	1,089	0
2	Swine	Liquid	FF	Mid-Atlantic	3	21	Large1	118,315	580	5,187	0	0
2	Swine	Liquid	FF	Midwest	3	98	Large1	116,232	580	5,097	0	0
2	Swine	Liquid	FF	Mid-Atlantic	1	86	Large2	1,303	8,018	300	8,106	0
2	Swine	Liquid	FF	Midwest	1	184	Large2	1,126	7,286	245	7,094	0
2	Swine	Liquid	FF	Mid-Atlantic	2	41	Large2	394,750	1,724	71,313	1,319	0
2	Swine	Liquid	FF	Midwest	2	88	Large2	319,864	2,566	51,436	2,160	0
2	Swine	Liquid	FF	Mid-Atlantic	3	52	Large2	554,131	580	24,192	0	0
2	Swine	Liquid	FF	Midwest	3	109	Large2	448,511	580	19,586	0	0
2	Swine	Liquid	FF	Mid-Atlantic	1	182	Medium1a	2,053	1,482	890	1,067	0
2	Swine	Liquid	FF	Midwest	1	1639	Medium1a	1,701	1,244	878	811	0
2	Swine	Liquid	FF	Mid-Atlantic	2	13	Medium1a	7,939	1,127	1,435	693	0
2	Swine	Liquid	FF	Midwest	2	116	Medium1a	7,858	1,231	993	797	731
2	Swine	Liquid	FF	Mid-Atlantic	3	20	Medium1a	33,260	580	1,588	0	0
2	Swine	Liquid	FF	Midwest	3	186	Medium1a	32,228	580	1,742	0	0
2	Swine	Liquid	FF	Mid-Atlantic	1	122	Medium1b	2,904	2,199	1,334	1,822	0
2	Swine	Liquid	FF	Midwest	1	1093	Medium1b	2,276	1,771	1,153	1,362	0
2	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium1b	41,731	1,127	7,184	693	0
2	Swine	Liquid	FF	Midwest	2	77	Medium1b	9,322	1,231	9,843	797	0
2	Swine	Liquid	FF	Mid-Atlantic	3	14	Medium1b	54,889	580	2,529	0	0
2	Swine	Liquid	FF	Midwest	3	124	Medium1b	53,024	580	2,646	0	0
2	Swine	Liquid	FF	Mid-Atlantic	1	81	Medium2	3,696	2,889	1,760	2,549	0
2	Swine	Liquid	FF	Midwest	1	418	Medium2	2,862	2,336	1,447	1,952	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
2	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium2	56,904	1,544	10,128	1,132	0
2	Swine	Liquid	FF	Midwest	2	41	Medium2	11,086	1,726	2,931	1,315	0
2	Swine	Liquid	FF	Mid-Atlantic	3	12	Medium2	75,688	580	3,434	0	0
2	Swine	Liquid	FF	Midwest	3	62	Medium2	75,270	580	3,614	0	0
2	Swine	Liquid	GF	Mid-Atlantic	1	173	Large1	677	2,124	202	1,750	0
2	Swine	Liquid	GF	Midwest	1	214	Large1	655	2,238	193	1,818	0
2	Swine	Liquid	GF	Mid-Atlantic	2	53	Large1	86,744	1,041	16,038	582	0
2	Swine	Liquid	GF	Midwest	2	66	Large1	83,631	1,379	13,896	920	0
2	Swine	Liquid	GF	Mid-Atlantic	3	49	Large1	119,757	580	6,146	0	0
2	Swine	Liquid	GF	Midwest	3	61	Large1	115,367	580	5,920	0	0
2	Swine	Liquid	GF	Mid-Atlantic	1	92	Large2	968	4,444	241	4,252	0
2	Swine	Liquid	GF	Midwest	1	47	Large2	982	5,447	227	5,172	0
2	Swine	Liquid	GF	Mid-Atlantic	2	108	Large2	208,015	1,219	39,504	775	0
2	Swine	Liquid	GF	Midwest	2	55	Large2	233,808	1,689	39,975	1,244	0
2	Swine	Liquid	GF	Mid-Atlantic	3	56	Large2	290,778	580	14,948	0	0
2	Swine	Liquid	GF	Midwest	3	29	Large2	327,157	580	16,821	0	0
2	Swine	Liquid	GF	Mid-Atlantic	1	148	Medium1a	2,204	1,607	968	1,198	0
2	Swine	Liquid	GF	Midwest	1	859	Medium1a	1,780	1,314	914	884	0
2	Swine	Liquid	GF	Mid-Atlantic	2	18	Medium1a	28,955	1,026	5,056	586	0
2	Swine	Liquid	GF	Midwest	2	103	Medium1a	7,971	1,110	1,842	671	0
2	Swine	Liquid	GF	Mid-Atlantic	3	31	Medium1a	37,029	580	1,995	0	0
2	Swine	Liquid	GF	Midwest	3	176	Medium1a	34,999	580	2,089	0	0
2	Swine	Liquid	GF	Mid-Atlantic	1	26	Medium1b	2,907	2,202	1,336	1,825	0
2	Swine	Liquid	GF	Midwest	1	154	Medium1b	2,243	1,740	1,137	1,329	0
2	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium1b	41,698	1,026	7,518	586	0
2	Swine	Liquid	GF	Midwest	2	18	Medium1b	39,438	1,110	6,639	671	0
2	Swine	Liquid	GF	Mid-Atlantic	3	5	Medium1b	54,985	580	2,916	0	0
2	Swine	Liquid	GF	Midwest	3	32	Medium1b	51,801	580	2,951	0	0
2	Swine	Liquid	GF	Mid-Atlantic	1	73	Medium2	3,719	2,909	1,772	2,570	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
2	Swine	Liquid	GF	Midwest	1	188	Medium2	2,839	2,313	1,435	1,928	0
2	Swine	Liquid	GF	Mid-Atlantic	2	14	Medium2	57,112	1,319	10,619	896	0
2	Swine	Liquid	GF	Midwest	2	37	Medium2	55,744	1,459	9,597	1,035	0
2	Swine	Liquid	GF	Mid-Atlantic	3	17	Medium2	76,299	580	4,011	0	0
2	Swine	Liquid	GF	Midwest	3	44	Medium2	74,370	580	4,110	0	0
3	Swine	Liquid	FF	Mid-Atlantic	1	18	Large1	24,532	736	2,240	253	2,703
3	Swine	Liquid	FF	Midwest	1	95	Large1	27,640	742	2,524	254	2,370
3	Swine	Liquid	FF	Mid-Atlantic	2	3	Large1	28,915	668	2,130	181	156,629
3	Swine	Liquid	FF	Midwest	2	16	Large1	31,082	739	2,372	251	3,349
3	Swine	Liquid	FF	Mid-Atlantic	3	3	Large1	142,206	580	24,489	0	2,703
3	Swine	Liquid	FF	Midwest	3	18	Large1	143,237	580	24,364	0	2,370
3	Swine	Liquid	FF	Mid-Atlantic	1	27	Large1	24,565	2,105	2,260	1,729	2,703
3	Swine	Liquid	FF	Midwest	1	143	Large1	27,661	2,251	2,537	1,832	2,370
3	Swine	Liquid	FF	Mid-Atlantic	2	4	Large1	103,041	1,134	16,690	682	2,703
3	Swine	Liquid	FF	Midwest	2	24	Large1	31,094	1,541	12,248	1,089	2,370
3	Swine	Liquid	FF	Mid-Atlantic	3	5	Large1	142,206	580	7,246	0	2,703
3	Swine	Liquid	FF	Midwest	3	27	Large1	143,237	580	7,440	0	2,370
3	Swine	Liquid	FF	Mid-Atlantic	1	14	Large2	101,273	1,340	5,934	905	2,703
3	Swine	Liquid	FF	Midwest	1	34	Large2	95,118	1,228	5,770	762	2,370
3	Swine	Liquid	FF	Mid-Atlantic	2	7	Large2	464,669	808	12,853	331	2,703
3	Swine	Liquid	FF	Midwest	2	16	Large2	90,865	976	4,848	498	549,868
3	Swine	Liquid	FF	Mid-Atlantic	3	8	Large2	654,265	580	114,045	0	2,703
3	Swine	Liquid	FF	Midwest	3	20	Large2	542,589	580	93,070	0	2,370
3	Swine	Liquid	FF	Mid-Atlantic	1	21	Large2	101,437	8,018	6,035	8,106	2,703
3	Swine	Liquid	FF	Midwest	1	50	Large2	95,203	7,286	5,823	7,094	2,370
3	Swine	Liquid	FF	Mid-Atlantic	2	10	Large2	464,692	1,724	75,553	1,319	2,703
3	Swine	Liquid	FF	Midwest	2	24	Large2	385,787	2,566	55,620	2,160	2,370
3	Swine	Liquid	FF	Mid-Atlantic	3	12	Large2	654,265	580	29,927	0	2,703
3	Swine	Liquid	FF	Midwest	3	30	Large2	542,589	580	25,164	0	2,370

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3	Swine	Liquid	FF	Mid-Atlantic	1	29	Medium1a	9,170	672	1,680	214	2,854
3	Swine	Liquid	FF	Midwest	1	300	Medium1a	10,066	644	2,035	184	3,048
3	Swine	Liquid	FF	Mid-Atlantic	2	2	Medium1a	13,667	689	1,727	232	2,854
3	Swine	Liquid	FF	Midwest	2	21	Medium1a	14,336	709	2,094	252	3,048
3	Swine	Liquid	FF	Mid-Atlantic	3	3	Medium1a	41,187	580	7,033	0	2,854
3	Swine	Liquid	FF	Midwest	3	34	Medium1a	41,098	580	7,209	0	3,048
3	Swine	Liquid	FF	Mid-Atlantic	1	44	Medium1a	9,981	1,482	2,178	1,067	2,854
3	Swine	Liquid	FF	Midwest	1	450	Medium1a	10,572	1,244	2,345	811	3,048
3	Swine	Liquid	FF	Mid-Atlantic	2	3	Medium1a	14,106	1,127	2,636	693	2,854
3	Swine	Liquid	FF	Midwest	2	32	Medium1a	14,775	1,231	2,364	797	3,779
3	Swine	Liquid	FF	Mid-Atlantic	3	5	Medium1a	41,187	580	2,876	0	2,854
3	Swine	Liquid	FF	Midwest	3	51	Medium1a	41,098	580	3,209	0	3,048
3	Swine	Liquid	FF	Mid-Atlantic	1	19	Medium1b	13,551	745	1,930	291	2,854
3	Swine	Liquid	FF	Midwest	1	200	Medium1b	14,864	695	2,287	237	3,048
3	Swine	Liquid	FF	Mid-Atlantic	2	1	Medium1b	18,100	685	1,895	227	58,051
3	Swine	Liquid	FF	Midwest	2	14	Medium1b	19,050	709	2,278	252	3,048
3	Swine	Liquid	FF	Mid-Atlantic	3	2	Medium1b	66,992	580	11,478	0	2,854
3	Swine	Liquid	FF	Midwest	3	23	Medium1b	66,517	580	11,512	0	3,048
3	Swine	Liquid	FF	Mid-Atlantic	1	29	Medium1b	15,006	2,199	2,823	1,822	2,854
3	Swine	Liquid	FF	Midwest	1	300	Medium1b	15,770	1,771	2,844	1,362	3,048
3	Swine	Liquid	FF	Mid-Atlantic	2	2	Medium1b	50,832	1,127	8,525	693	2,854
3	Swine	Liquid	FF	Midwest	2	21	Medium1b	19,489	1,231	11,369	797	3,048
3	Swine	Liquid	FF	Mid-Atlantic	3	3	Medium1b	66,992	580	4,018	0	2,854
3	Swine	Liquid	FF	Midwest	3	34	Medium1b	66,517	580	4,337	0	3,048
3	Swine	Liquid	FF	Mid-Atlantic	1	13	Medium2	17,618	816	2,163	365	2,854
3	Swine	Liquid	FF	Midwest	1	76	Medium2	19,809	750	2,549	294	3,048
3	Swine	Liquid	FF	Mid-Atlantic	2	1	Medium2	22,108	720	2,071	264	92,560
3	Swine	Liquid	FF	Midwest	2	7	Medium2	23,782	752	2,487	297	3,048
3	Swine	Liquid	FF	Mid-Atlantic	3	2	Medium2	91,685	580	15,750	0	2,854

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3	Swine	Liquid	FF	Midwest	3	11	Medium2	93,553	580	16,111	0	3,048
3	Swine	Liquid	FF	Mid-Atlantic	1	19	Medium2	19,693	2,889	3,437	2,549	2,854
3	Swine	Liquid	FF	Midwest	1	115	Medium2	21,145	2,336	3,369	1,952	3,048
3	Swine	Liquid	FF	Mid-Atlantic	2	2	Medium2	68,727	1,544	11,599	1,132	2,854
3	Swine	Liquid	FF	Midwest	2	11	Medium2	24,602	1,726	4,618	1,315	3,048
3	Swine	Liquid	FF	Mid-Atlantic	3	3	Medium2	91,685	580	5,111	0	2,854
3	Swine	Liquid	FF	Midwest	3	17	Medium2	93,553	580	5,536	0	3,048
3	Swine	Liquid	GF	Mid-Atlantic	1	28	Large1	24,796	738	2,252	255	2,703
3	Swine	Liquid	GF	Midwest	1	39	Large1	27,458	740	2,515	252	2,370
3	Swine	Liquid	GF	Mid-Atlantic	2	9	Large1	29,165	648	2,140	159	209,958
3	Swine	Liquid	GF	Midwest	2	12	Large1	30,914	699	2,364	209	88,309
3	Swine	Liquid	GF	Mid-Atlantic	3	8	Large1	143,910	580	31,503	0	2,703
3	Swine	Liquid	GF	Midwest	3	11	Large1	142,191	580	30,643	0	2,370
3	Swine	Liquid	GF	Mid-Atlantic	1	41	Large1	24,830	2,124	2,273	1,750	2,703
3	Swine	Liquid	GF	Midwest	1	59	Large1	27,479	2,238	2,528	1,818	2,370
3	Swine	Liquid	GF	Mid-Atlantic	2	13	Large1	104,243	1,041	17,780	582	2,703
3	Swine	Liquid	GF	Midwest	2	18	Large1	103,093	1,379	15,866	920	2,370
3	Swine	Liquid	GF	Mid-Atlantic	3	12	Large1	143,910	580	8,217	0	2,703
3	Swine	Liquid	GF	Midwest	3	17	Large1	142,191	580	8,255	0	2,370
3	Swine	Liquid	GF	Mid-Atlantic	1	15	Large2	55,373	975	3,724	511	2,703
3	Swine	Liquid	GF	Midwest	1	9	Large2	70,800	1,050	4,600	576	2,370
3	Swine	Liquid	GF	Mid-Atlantic	2	17	Large2	57,498	760	3,288	279	501,026
3	Swine	Liquid	GF	Midwest	2	10	Large2	69,666	892	3,963	410	345,312
3	Swine	Liquid	GF	Mid-Atlantic	3	9	Large2	345,269	580	76,750	0	2,703
3	Swine	Liquid	GF	Midwest	3	5	Large2	397,037	580	86,942	0	2,370
3	Swine	Liquid	GF	Mid-Atlantic	1	22	Large2	55,459	4,444	3,776	4,252	2,703
3	Swine	Liquid	GF	Midwest	1	13	Large2	70,862	5,447	4,638	5,172	2,370
3	Swine	Liquid	GF	Mid-Atlantic	2	26	Large2	246,507	1,219	42,247	775	2,703
3	Swine	Liquid	GF	Midwest	2	15	Large2	283,053	1,689	43,365	1,244	2,370

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3	Swine	Liquid	GF	Mid-Atlantic	3	13	Large2	345,269	580	18,483	0	2,703
3	Swine	Liquid	GF	Midwest	3	8	Large2	397,037	580	21,232	0	2,370
3	Swine	Liquid	GF	Mid-Atlantic	1	24	Medium1a	9,951	685	1,724	227	2,854
3	Swine	Liquid	GF	Midwest	1	157	Medium1a	10,721	651	2,069	191	3,048
3	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium1a	14,425	639	1,727	180	44,201
3	Swine	Liquid	GF	Midwest	2	19	Medium1a	14,947	653	2,091	194	3,048
3	Swine	Liquid	GF	Mid-Atlantic	3	5	Medium1a	45,698	580	9,628	0	2,854
3	Swine	Liquid	GF	Midwest	3	32	Medium1a	44,498	580	9,484	0	3,048
3	Swine	Liquid	GF	Mid-Atlantic	1	35	Medium1a	10,874	1,607	2,291	1,198	2,854
3	Swine	Liquid	GF	Midwest	1	236	Medium1a	11,279	1,314	2,412	884	3,048
3	Swine	Liquid	GF	Mid-Atlantic	2	4	Medium1a	35,645	1,026	6,282	586	2,854
3	Swine	Liquid	GF	Midwest	2	28	Medium1a	15,332	1,110	3,234	671	3,048
3	Swine	Liquid	GF	Mid-Atlantic	3	7	Medium1a	45,698	580	3,318	0	2,854
3	Swine	Liquid	GF	Midwest	3	48	Medium1a	44,498	580	3,587	0	3,048
3	Swine	Liquid	GF	Mid-Atlantic	1	4	Medium1b	13,570	746	1,931	292	2,854
3	Swine	Liquid	GF	Midwest	1	28	Medium1b	14,587	692	2,273	234	3,048
3	Swine	Liquid	GF	Mid-Atlantic	2	0	Medium1b	50,425	639	2,669	180	2,854
3	Swine	Liquid	GF	Midwest	2	3	Medium1b	18,735	651	2,238	191	53,292
3	Swine	Liquid	GF	Mid-Atlantic	3	1	Medium1b	67,106	580	14,372	0	2,854
3	Swine	Liquid	GF	Midwest	3	6	Medium1b	65,028	580	13,946	0	3,048
3	Swine	Liquid	GF	Mid-Atlantic	1	6	Medium1b	15,028	2,202	2,826	1,825	2,854
3	Swine	Liquid	GF	Midwest	1	42	Medium1b	15,470	1,740	2,815	1,329	3,048
3	Swine	Liquid	GF	Mid-Atlantic	2	1	Medium1b	50,812	1,026	8,859	586	2,854
3	Swine	Liquid	GF	Midwest	2	5	Medium1b	49,418	1,110	8,157	671	3,048
3	Swine	Liquid	GF	Mid-Atlantic	3	1	Medium1b	67,106	580	4,407	0	2,854
3	Swine	Liquid	GF	Midwest	3	9	Medium1b	65,028	580	4,629	0	3,048
3	Swine	Liquid	GF	Mid-Atlantic	1	12	Medium2	17,737	818	2,170	368	2,854
3	Swine	Liquid	GF	Midwest	1	34	Medium2	19,612	748	2,539	292	3,048
3	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium2	22,212	709	2,069	253	103,576

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3	Swine	Liquid	GF	Midwest	2	7	Medium2	23,581	734	2,471	278	18,181
3	Swine	Liquid	GF	Mid-Atlantic	3	3	Medium2	92,409	580	20,003	0	2,854
3	Swine	Liquid	GF	Midwest	3	8	Medium2	92,462	580	19,940	0	3,048
3	Swine	Liquid	GF	Mid-Atlantic	1	18	Medium2	19,830	2,909	3,455	2,570	2,854
3	Swine	Liquid	GF	Midwest	1	52	Medium2	20,930	2,313	3,348	1,928	3,048
3	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium2	69,013	1,319	12,094	896	2,854
3	Swine	Liquid	GF	Midwest	2	10	Medium2	69,126	1,459	11,277	1,035	3,048
3	Swine	Liquid	GF	Mid-Atlantic	3	4	Medium2	92,409	580	5,694	0	2,854
3	Swine	Liquid	GF	Midwest	3	12	Medium2	92,462	580	6,023	0	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	1	57	Large1	640	736	181	253	2,703
3.1	Swine	Liquid	FF	Midwest	1	252	Large1	635	742	180	254	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	2	9	Large1	11,597	668	397	181	156,629
3.1	Swine	Liquid	FF	Midwest	2	42	Large1	11,495	739	395	251	3,349
3.1	Swine	Liquid	FF	Mid-Atlantic	3	11	Large1	118,315	580	22,431	0	2,703
3.1	Swine	Liquid	FF	Midwest	3	47	Large1	116,232	580	22,021	0	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	1	85	Large1	674	2,105	202	1,729	2,703
3.1	Swine	Liquid	FF	Midwest	1	378	Large1	657	2,251	193	1,832	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	2	14	Large1	85,724	1,134	14,957	682	2,703
3.1	Swine	Liquid	FF	Midwest	2	63	Large1	11,507	1,541	10,272	1,089	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	3	16	Large1	118,315	580	5,187	0	2,703
3.1	Swine	Liquid	FF	Midwest	3	71	Large1	116,232	580	5,097	0	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	1	44	Large2	1,139	1,340	200	905	2,703
3.1	Swine	Liquid	FF	Midwest	1	89	Large2	1,040	1,228	192	762	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	2	21	Large2	394,727	808	8,613	331	2,703
3.1	Swine	Liquid	FF	Midwest	2	43	Large2	24,943	976	664	498	549,868
3.1	Swine	Liquid	FF	Mid-Atlantic	3	26	Large2	554,131	580	108,310	0	2,703
3.1	Swine	Liquid	FF	Midwest	3	53	Large2	448,511	580	87,492	0	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	1	66	Large2	1,303	8,018	300	8,106	2,703
3.1	Swine	Liquid	FF	Midwest	1	133	Large2	1,126	7,286	245	7,094	2,370

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3.1	Swine	Liquid	FF	Mid-Atlantic	2	32	Large2	394,750	1,724	71,313	1,319	2,703
3.1	Swine	Liquid	FF	Midwest	2	64	Large2	319,864	2,566	51,436	2,160	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	3	39	Large2	554,131	580	24,192	0	2,703
3.1	Swine	Liquid	FF	Midwest	3	79	Large2	448,511	580	19,586	0	2,370
3.1	Swine	Liquid	FF	Mid-Atlantic	1	93	Medium1a	1,242	672	392	214	2,854
3.1	Swine	Liquid	FF	Midwest	1	792	Medium1a	1,196	644	567	184	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	2	7	Medium1a	7,500	689	526	232	2,854
3.1	Swine	Liquid	FF	Midwest	2	56	Medium1a	7,419	709	723	252	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	3	10	Medium1a	33,260	580	5,745	0	2,854
3.1	Swine	Liquid	FF	Midwest	3	90	Medium1a	32,228	580	5,742	0	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	1	139	Medium1a	2,053	1,482	890	1,067	2,854
3.1	Swine	Liquid	FF	Midwest	1	1189	Medium1a	1,701	1,244	878	811	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	2	10	Medium1a	7,939	1,127	1,435	693	2,854
3.1	Swine	Liquid	FF	Midwest	2	84	Medium1a	7,858	1,231	993	797	3,779
3.1	Swine	Liquid	FF	Mid-Atlantic	3	16	Medium1a	33,260	580	1,588	0	2,854
3.1	Swine	Liquid	FF	Midwest	3	135	Medium1a	32,228	580	1,742	0	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	1	62	Medium1b	1,449	745	440	291	2,854
3.1	Swine	Liquid	FF	Midwest	1	528	Medium1b	1,370	695	596	237	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	2	4	Medium1b	8,999	685	554	227	58,051
3.1	Swine	Liquid	FF	Midwest	2	37	Medium1b	8,883	709	752	252	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	3	7	Medium1b	54,889	580	9,988	0	2,854
3.1	Swine	Liquid	FF	Midwest	3	60	Medium1b	53,024	580	9,820	0	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	1	93	Medium1b	2,904	2,199	1,334	1,822	2,854
3.1	Swine	Liquid	FF	Midwest	1	793	Medium1b	2,276	1,771	1,153	1,362	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	2	6	Medium1b	41,731	1,127	7,184	693	2,854
3.1	Swine	Liquid	FF	Midwest	2	56	Medium1b	9,322	1,231	9,843	797	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	3	11	Medium1b	54,889	580	2,529	0	2,854
3.1	Swine	Liquid	FF	Midwest	3	90	Medium1b	53,024	580	2,646	0	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	1	41	Medium2	1,621	816	485	365	2,854

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3.1	Swine	Liquid	FF	Midwest	1	202	Medium2	1,526	750	627	294	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	2	4	Medium2	10,285	720	600	264	92,560
3.1	Swine	Liquid	FF	Midwest	2	20	Medium2	10,266	752	801	297	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	3	6	Medium2	75,688	580	14,073	0	2,854
3.1	Swine	Liquid	FF	Midwest	3	30	Medium2	75,270	580	14,189	0	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	1	62	Medium2	3,696	2,889	1,760	2,549	2,854
3.1	Swine	Liquid	FF	Midwest	1	303	Medium2	2,862	2,336	1,447	1,952	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	2	6	Medium2	56,904	1,544	10,128	1,132	2,854
3.1	Swine	Liquid	FF	Midwest	2	30	Medium2	11,086	1,726	2,931	1,315	3,048
3.1	Swine	Liquid	FF	Mid-Atlantic	3	9	Medium2	75,688	580	3,434	0	2,854
3.1	Swine	Liquid	FF	Midwest	3	45	Medium2	75,270	580	3,614	0	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	1	88	Large1	643	738	181	255	2,703
3.1	Swine	Liquid	GF	Midwest	1	103	Large1	634	740	180	252	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	2	27	Large1	11,666	648	398	159	209,958
3.1	Swine	Liquid	GF	Midwest	2	32	Large1	11,452	699	394	209	88,309
3.1	Swine	Liquid	GF	Mid-Atlantic	3	25	Large1	119,757	580	29,432	0	2,703
3.1	Swine	Liquid	GF	Midwest	3	29	Large1	115,367	580	28,308	0	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	1	131	Large1	677	2,124	202	1,750	2,703
3.1	Swine	Liquid	GF	Midwest	1	155	Large1	655	2,238	193	1,818	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	2	41	Large1	86,744	1,041	16,038	582	2,703
3.1	Swine	Liquid	GF	Midwest	2	48	Large1	83,631	1,379	13,896	920	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	3	37	Large1	119,757	580	6,146	0	2,703
3.1	Swine	Liquid	GF	Midwest	3	44	Large1	115,367	580	5,920	0	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	1	47	Large2	883	975	189	511	2,703
3.1	Swine	Liquid	GF	Midwest	1	23	Large2	920	1,050	188	576	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	2	55	Large2	19,006	760	545	279	501,026
3.1	Swine	Liquid	GF	Midwest	2	27	Large2	20,421	892	573	410	345,312
3.1	Swine	Liquid	GF	Mid-Atlantic	3	29	Large2	290,778	580	73,215	0	2,703
3.1	Swine	Liquid	GF	Midwest	3	14	Large2	327,157	580	82,531	0	2,370

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3.1	Swine	Liquid	GF	Mid-Atlantic	1	70	Large2	968	4,444	241	4,252	2,703
3.1	Swine	Liquid	GF	Midwest	1	34	Large2	982	5,447	227	5,172	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	2	82	Large2	208,015	1,219	39,504	775	2,703
3.1	Swine	Liquid	GF	Midwest	2	40	Large2	233,808	1,689	39,975	1,244	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	3	43	Large2	290,778	580	14,948	0	2,703
3.1	Swine	Liquid	GF	Midwest	3	21	Large2	327,157	580	16,821	0	2,370
3.1	Swine	Liquid	GF	Mid-Atlantic	1	75	Medium1a	1,281	685	401	227	2,854
3.1	Swine	Liquid	GF	Midwest	1	416	Medium1a	1,222	651	571	191	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	2	9	Medium1a	7,735	639	502	180	44,201
3.1	Swine	Liquid	GF	Midwest	2	50	Medium1a	7,586	653	698	194	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	3	16	Medium1a	37,029	580	8,304	0	2,854
3.1	Swine	Liquid	GF	Midwest	3	85	Medium1a	34,999	580	7,986	0	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	1	113	Medium1a	2,204	1,607	968	1,198	2,854
3.1	Swine	Liquid	GF	Midwest	1	623	Medium1a	1,780	1,314	914	884	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	2	14	Medium1a	28,955	1,026	5,056	586	2,854
3.1	Swine	Liquid	GF	Midwest	2	74	Medium1a	7,971	1,110	1,842	671	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	3	23	Medium1a	37,029	580	1,995	0	2,854
3.1	Swine	Liquid	GF	Midwest	3	128	Medium1a	34,999	580	2,089	0	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	1	13	Medium1b	1,449	746	440	292	2,854
3.1	Swine	Liquid	GF	Midwest	1	74	Medium1b	1,360	692	595	234	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium1b	41,311	639	1,327	180	2,854
3.1	Swine	Liquid	GF	Midwest	2	9	Medium1b	8,755	651	720	191	53,292
3.1	Swine	Liquid	GF	Mid-Atlantic	3	3	Medium1b	54,985	580	12,882	0	2,854
3.1	Swine	Liquid	GF	Midwest	3	15	Medium1b	51,801	580	12,268	0	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	1	20	Medium1b	2,907	2,202	1,336	1,825	2,854
3.1	Swine	Liquid	GF	Midwest	1	111	Medium1b	2,243	1,740	1,137	1,329	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium1b	41,698	1,026	7,518	586	2,854
3.1	Swine	Liquid	GF	Midwest	2	13	Medium1b	39,438	1,110	6,639	671	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	3	4	Medium1b	54,985	580	2,916	0	2,854

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
3.1	Swine	Liquid	GF	Midwest	3	23	Medium1b	51,801	580	2,951	0	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	1	37	Medium2	1,626	818	487	368	2,854
3.1	Swine	Liquid	GF	Midwest	1	91	Medium2	1,520	748	625	292	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	2	7	Medium2	10,311	709	594	253	103,576
3.1	Swine	Liquid	GF	Midwest	2	18	Medium2	10,199	734	790	278	18,181
3.1	Swine	Liquid	GF	Mid-Atlantic	3	9	Medium2	76,299	580	18,320	0	2,854
3.1	Swine	Liquid	GF	Midwest	3	21	Medium2	74,370	580	18,027	0	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	1	56	Medium2	3,719	2,909	1,772	2,570	2,854
3.1	Swine	Liquid	GF	Midwest	1	137	Medium2	2,839	2,313	1,435	1,928	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	2	11	Medium2	57,112	1,319	10,619	896	2,854
3.1	Swine	Liquid	GF	Midwest	2	27	Medium2	55,744	1,459	9,597	1,035	3,048
3.1	Swine	Liquid	GF	Mid-Atlantic	3	13	Medium2	76,299	580	4,011	0	2,854
3.1	Swine	Liquid	GF	Midwest	3	32	Medium2	74,370	580	4,110	0	3,048
4	Swine	Liquid	FF	Mid-Atlantic	1	18	Large1	24,532	1,128	7,373	253	2,703
4	Swine	Liquid	FF	Midwest	1	95	Large1	27,640	1,134	7,031	254	2,370
4	Swine	Liquid	FF	Mid-Atlantic	2	3	Large1	28,915	1,060	7,263	181	156,629
4	Swine	Liquid	FF	Midwest	2	16	Large1	31,082	1,131	6,879	251	3,349
4	Swine	Liquid	FF	Mid-Atlantic	3	3	Large1	142,206	972	29,622	0	2,703
4	Swine	Liquid	FF	Midwest	3	18	Large1	143,237	972	28,872	0	2,370
4	Swine	Liquid	FF	Mid-Atlantic	1	27	Large1	24,565	2,497	7,393	1,729	2,703
4	Swine	Liquid	FF	Midwest	1	143	Large1	27,661	2,643	7,045	1,832	2,370
4	Swine	Liquid	FF	Mid-Atlantic	2	4	Large1	103,041	1,526	21,823	682	2,703
4	Swine	Liquid	FF	Midwest	2	24	Large1	31,094	1,933	16,756	1,089	2,370
4	Swine	Liquid	FF	Mid-Atlantic	3	5	Large1	142,206	972	12,379	0	2,703
4	Swine	Liquid	FF	Midwest	3	27	Large1	143,237	972	11,948	0	2,370
4	Swine	Liquid	FF	Mid-Atlantic	1	14	Large2	101,273	1,732	11,067	905	2,703
4	Swine	Liquid	FF	Midwest	1	34	Large2	95,118	1,620	10,278	762	2,370
4	Swine	Liquid	FF	Mid-Atlantic	2	7	Large2	464,669	1,200	17,986	331	2,703
4	Swine	Liquid	FF	Midwest	2	16	Large2	90,865	1,368	9,355	498	549,868

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4	Swine	Liquid	FF	Mid-Atlantic	3	8	Large2	654,265	972	119,178	0	2,703
4	Swine	Liquid	FF	Midwest	3	20	Large2	542,589	972	97,578	0	2,370
4	Swine	Liquid	FF	Mid-Atlantic	1	21	Large2	101,437	8,410	11,168	8,106	2,703
4	Swine	Liquid	FF	Midwest	1	50	Large2	95,203	7,678	10,331	7,094	2,370
4	Swine	Liquid	FF	Mid-Atlantic	2	10	Large2	464,692	2,116	80,686	1,319	2,703
4	Swine	Liquid	FF	Midwest	2	24	Large2	385,787	2,958	60,127	2,160	2,370
4	Swine	Liquid	FF	Mid-Atlantic	3	12	Large2	654,265	972	35,060	0	2,703
4	Swine	Liquid	FF	Midwest	3	30	Large2	542,589	972	29,672	0	2,370
4	Swine	Liquid	FF	Mid-Atlantic	1	29	Medium1a	9,170	1,064	7,576	214	2,854
4	Swine	Liquid	FF	Midwest	1	300	Medium1a	10,066	1,036	5,373	184	3,048
4	Swine	Liquid	FF	Mid-Atlantic	2	2	Medium1a	13,667	1,081	7,622	232	2,854
4	Swine	Liquid	FF	Midwest	2	21	Medium1a	14,336	1,101	5,433	252	3,048
4	Swine	Liquid	FF	Mid-Atlantic	3	3	Medium1a	41,187	972	12,929	0	2,854
4	Swine	Liquid	FF	Midwest	3	34	Medium1a	41,098	972	10,548	0	3,048
4	Swine	Liquid	FF	Mid-Atlantic	1	44	Medium1a	9,981	1,874	8,074	1,067	2,854
4	Swine	Liquid	FF	Midwest	1	450	Medium1a	10,572	1,636	5,684	811	3,048
4	Swine	Liquid	FF	Mid-Atlantic	2	3	Medium1a	14,106	1,519	8,532	693	2,854
4	Swine	Liquid	FF	Midwest	2	32	Medium1a	14,775	1,623	5,702	797	3,779
4	Swine	Liquid	FF	Mid-Atlantic	3	5	Medium1a	41,187	972	8,771	0	2,854
4	Swine	Liquid	FF	Midwest	3	51	Medium1a	41,098	972	6,548	0	3,048
4	Swine	Liquid	FF	Mid-Atlantic	1	19	Medium1b	13,551	1,137	7,825	291	2,854
4	Swine	Liquid	FF	Midwest	1	200	Medium1b	14,864	1,087	5,626	237	3,048
4	Swine	Liquid	FF	Mid-Atlantic	2	1	Medium1b	18,100	1,077	7,790	227	58,051
4	Swine	Liquid	FF	Midwest	2	14	Medium1b	19,050	1,101	5,617	252	3,048
4	Swine	Liquid	FF	Mid-Atlantic	3	2	Medium1b	66,992	972	17,373	0	2,854
4	Swine	Liquid	FF	Midwest	3	23	Medium1b	66,517	972	14,850	0	3,048
4	Swine	Liquid	FF	Mid-Atlantic	1	29	Medium1b	15,006	2,591	8,719	1,822	2,854
4	Swine	Liquid	FF	Midwest	1	300	Medium1b	15,770	2,163	6,182	1,362	3,048
4	Swine	Liquid	FF	Mid-Atlantic	2	2	Medium1b	50,832	1,519	14,421	693	2,854

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4	Swine	Liquid	FF	Midwest	2	21	Medium1b	19,489	1,623	14,708	797	3,048
4	Swine	Liquid	FF	Mid-Atlantic	3	3	Medium1b	66,992	972	9,914	0	2,854
4	Swine	Liquid	FF	Midwest	3	34	Medium1b	66,517	972	7,676	0	3,048
4	Swine	Liquid	FF	Mid-Atlantic	1	13	Medium2	17,618	1,208	8,059	365	2,854
4	Swine	Liquid	FF	Midwest	1	76	Medium2	19,809	1,142	5,888	294	3,048
4	Swine	Liquid	FF	Mid-Atlantic	2	1	Medium2	22,108	1,112	7,967	264	92,560
4	Swine	Liquid	FF	Midwest	2	7	Medium2	23,782	1,144	5,826	297	3,048
4	Swine	Liquid	FF	Mid-Atlantic	3	2	Medium2	91,685	972	21,646	0	2,854
4	Swine	Liquid	FF	Midwest	3	11	Medium2	93,553	972	19,450	0	3,048
4	Swine	Liquid	FF	Mid-Atlantic	1	19	Medium2	19,693	3,281	9,333	2,549	2,854
4	Swine	Liquid	FF	Midwest	1	115	Medium2	21,145	2,728	6,708	1,952	3,048
4	Swine	Liquid	FF	Mid-Atlantic	2	2	Medium2	68,727	1,936	17,495	1,132	2,854
4	Swine	Liquid	FF	Midwest	2	11	Medium2	24,602	2,118	7,956	1,315	3,048
4	Swine	Liquid	FF	Mid-Atlantic	3	3	Medium2	91,685	972	11,007	0	2,854
4	Swine	Liquid	FF	Midwest	3	17	Medium2	93,553	972	8,875	0	3,048
4	Swine	Liquid	GF	Mid-Atlantic	1	28	Large1	24,796	1,130	7,385	255	2,703
4	Swine	Liquid	GF	Midwest	1	39	Large1	27,458	1,132	7,023	252	2,370
4	Swine	Liquid	GF	Mid-Atlantic	2	9	Large1	29,165	1,040	7,273	159	209,958
4	Swine	Liquid	GF	Midwest	2	12	Large1	30,914	1,091	6,872	209	88,309
4	Swine	Liquid	GF	Mid-Atlantic	3	8	Large1	143,910	972	36,636	0	2,703
4	Swine	Liquid	GF	Midwest	3	11	Large1	142,191	972	35,151	0	2,370
4	Swine	Liquid	GF	Mid-Atlantic	1	41	Large1	24,830	2,516	7,406	1,750	2,703
4	Swine	Liquid	GF	Midwest	1	59	Large1	27,479	2,630	7,036	1,818	2,370
4	Swine	Liquid	GF	Mid-Atlantic	2	13	Large1	104,243	1,433	22,912	582	2,703
4	Swine	Liquid	GF	Midwest	2	18	Large1	103,093	1,771	20,374	920	2,370
4	Swine	Liquid	GF	Mid-Atlantic	3	12	Large1	143,910	972	13,350	0	2,703
4	Swine	Liquid	GF	Midwest	3	17	Large1	142,191	972	12,763	0	2,370
4	Swine	Liquid	GF	Mid-Atlantic	1	15	Large2	55,373	1,367	8,857	511	2,703
4	Swine	Liquid	GF	Midwest	1	9	Large2	70,800	1,442	9,108	576	2,370

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4	Swine	Liquid	GF	Mid-Atlantic	2	17	Large2	57,498	1,152	8,421	279	501,026
4	Swine	Liquid	GF	Midwest	2	10	Large2	69,666	1,284	8,471	410	345,312
4	Swine	Liquid	GF	Mid-Atlantic	3	9	Large2	345,269	972	81,882	0	2,703
4	Swine	Liquid	GF	Midwest	3	5	Large2	397,037	972	91,450	0	2,370
4	Swine	Liquid	GF	Mid-Atlantic	1	22	Large2	55,459	4,836	8,909	4,252	2,703
4	Swine	Liquid	GF	Midwest	1	13	Large2	70,862	5,839	9,146	5,172	2,370
4	Swine	Liquid	GF	Mid-Atlantic	2	26	Large2	246,507	1,611	47,380	775	2,703
4	Swine	Liquid	GF	Midwest	2	15	Large2	283,053	2,081	47,873	1,244	2,370
4	Swine	Liquid	GF	Mid-Atlantic	3	13	Large2	345,269	972	23,615	0	2,703
4	Swine	Liquid	GF	Midwest	3	8	Large2	397,037	972	25,740	0	2,370
4	Swine	Liquid	GF	Mid-Atlantic	1	24	Medium1a	9,951	1,077	7,620	227	2,854
4	Swine	Liquid	GF	Midwest	1	157	Medium1a	10,721	1,043	5,408	191	3,048
4	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium1a	14,425	1,031	7,623	180	44,201
4	Swine	Liquid	GF	Midwest	2	19	Medium1a	14,947	1,045	5,429	194	3,048
4	Swine	Liquid	GF	Mid-Atlantic	3	5	Medium1a	45,698	972	15,523	0	2,854
4	Swine	Liquid	GF	Midwest	3	32	Medium1a	44,498	972	12,822	0	3,048
4	Swine	Liquid	GF	Mid-Atlantic	1	35	Medium1a	10,874	1,999	8,187	1,198	2,854
4	Swine	Liquid	GF	Midwest	1	236	Medium1a	11,279	1,706	5,751	884	3,048
4	Swine	Liquid	GF	Mid-Atlantic	2	4	Medium1a	35,645	1,418	12,178	586	2,854
4	Swine	Liquid	GF	Midwest	2	28	Medium1a	15,332	1,502	6,572	671	3,048
4	Swine	Liquid	GF	Mid-Atlantic	3	7	Medium1a	45,698	972	9,214	0	2,854
4	Swine	Liquid	GF	Midwest	3	48	Medium1a	44,498	972	6,925	0	3,048
4	Swine	Liquid	GF	Mid-Atlantic	1	4	Medium1b	13,570	1,138	7,826	292	2,854
4	Swine	Liquid	GF	Midwest	1	28	Medium1b	14,587	1,084	5,611	234	3,048
4	Swine	Liquid	GF	Mid-Atlantic	2	0	Medium1b	50,425	1,031	8,564	180	2,854
4	Swine	Liquid	GF	Midwest	2	3	Medium1b	18,735	1,043	5,576	191	53,292
4	Swine	Liquid	GF	Mid-Atlantic	3	1	Medium1b	67,106	972	20,268	0	2,854
4	Swine	Liquid	GF	Midwest	3	6	Medium1b	65,028	972	17,285	0	3,048
4	Swine	Liquid	GF	Mid-Atlantic	1	6	Medium1b	15,028	2,594	8,722	1,825	2,854

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4	Swine	Liquid	GF	Midwest	1	42	Medium1b	15,470	2,132	6,153	1,329	3,048
4	Swine	Liquid	GF	Mid-Atlantic	2	1	Medium1b	50,812	1,418	14,755	586	2,854
4	Swine	Liquid	GF	Midwest	2	5	Medium1b	49,418	1,502	11,495	671	3,048
4	Swine	Liquid	GF	Mid-Atlantic	3	1	Medium1b	67,106	972	10,302	0	2,854
4	Swine	Liquid	GF	Midwest	3	9	Medium1b	65,028	972	7,968	0	3,048
4	Swine	Liquid	GF	Mid-Atlantic	1	12	Medium2	17,737	1,210	8,066	368	2,854
4	Swine	Liquid	GF	Midwest	1	34	Medium2	19,612	1,140	5,877	292	3,048
4	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium2	22,212	1,101	7,965	253	103,576
4	Swine	Liquid	GF	Midwest	2	7	Medium2	23,581	1,126	5,809	278	18,181
4	Swine	Liquid	GF	Mid-Atlantic	3	3	Medium2	92,409	972	25,899	0	2,854
4	Swine	Liquid	GF	Midwest	3	8	Medium2	92,462	972	23,278	0	3,048
4	Swine	Liquid	GF	Mid-Atlantic	1	18	Medium2	19,830	3,301	9,351	2,570	2,854
4	Swine	Liquid	GF	Midwest	1	52	Medium2	20,930	2,705	6,687	1,928	3,048
4	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium2	69,013	1,711	17,990	896	2,854
4	Swine	Liquid	GF	Midwest	2	10	Medium2	69,126	1,851	14,615	1,035	3,048
4	Swine	Liquid	GF	Mid-Atlantic	3	4	Medium2	92,409	972	11,589	0	2,854
4	Swine	Liquid	GF	Midwest	3	12	Medium2	92,462	972	9,362	0	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	1	57	Large1	640	1,128	5,314	253	2,703
4.1	Swine	Liquid	FF	Midwest	1	252	Large1	635	1,134	4,688	254	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	2	9	Large1	11,597	1,060	5,530	181	156,629
4.1	Swine	Liquid	FF	Midwest	2	42	Large1	11,495	1,131	4,903	251	3,349
4.1	Swine	Liquid	FF	Mid-Atlantic	3	11	Large1	118,315	972	27,563	0	2,703
4.1	Swine	Liquid	FF	Midwest	3	47	Large1	116,232	972	26,528	0	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	1	85	Large1	674	2,497	5,334	1,729	2,703
4.1	Swine	Liquid	FF	Midwest	1	378	Large1	657	2,643	4,701	1,832	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	2	14	Large1	85,724	1,526	20,090	682	2,703
4.1	Swine	Liquid	FF	Midwest	2	63	Large1	11,507	1,933	14,779	1,089	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	3	16	Large1	118,315	972	10,320	0	2,703
4.1	Swine	Liquid	FF	Midwest	3	71	Large1	116,232	972	9,605	0	2,370

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4.1	Swine	Liquid	FF	Mid-Atlantic	1	44	Large2	1,139	1,732	5,332	905	2,703
4.1	Swine	Liquid	FF	Midwest	1	89	Large2	1,040	1,620	4,700	762	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	2	21	Large2	394,727	1,200	13,746	331	2,703
4.1	Swine	Liquid	FF	Midwest	2	43	Large2	24,943	1,368	5,171	498	549,868
4.1	Swine	Liquid	FF	Mid-Atlantic	3	26	Large2	554,131	972	113,443	0	2,703
4.1	Swine	Liquid	FF	Midwest	3	53	Large2	448,511	972	92,000	0	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	1	66	Large2	1,303	8,410	5,433	8,106	2,703
4.1	Swine	Liquid	FF	Midwest	1	133	Large2	1,126	7,678	4,753	7,094	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	2	32	Large2	394,750	2,116	76,446	1,319	2,703
4.1	Swine	Liquid	FF	Midwest	2	64	Large2	319,864	2,958	55,943	2,160	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	3	39	Large2	554,131	972	29,325	0	2,703
4.1	Swine	Liquid	FF	Midwest	3	79	Large2	448,511	972	24,094	0	2,370
4.1	Swine	Liquid	FF	Mid-Atlantic	1	93	Medium1a	1,242	1,064	6,288	214	2,854
4.1	Swine	Liquid	FF	Midwest	1	792	Medium1a	1,196	1,036	3,906	184	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	2	7	Medium1a	7,500	1,081	6,422	232	2,854
4.1	Swine	Liquid	FF	Midwest	2	56	Medium1a	7,419	1,101	4,062	252	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	3	10	Medium1a	33,260	972	11,641	0	2,854
4.1	Swine	Liquid	FF	Midwest	3	90	Medium1a	32,228	972	9,080	0	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	1	139	Medium1a	2,053	1,874	6,786	1,067	2,854
4.1	Swine	Liquid	FF	Midwest	1	1189	Medium1a	1,701	1,636	4,216	811	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	2	10	Medium1a	7,939	1,519	7,331	693	2,854
4.1	Swine	Liquid	FF	Midwest	2	84	Medium1a	7,858	1,623	4,331	797	3,779
4.1	Swine	Liquid	FF	Mid-Atlantic	3	16	Medium1a	33,260	972	7,484	0	2,854
4.1	Swine	Liquid	FF	Midwest	3	135	Medium1a	32,228	972	5,080	0	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	1	62	Medium1b	1,449	1,137	6,336	291	2,854
4.1	Swine	Liquid	FF	Midwest	1	528	Medium1b	1,370	1,087	3,935	237	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	2	4	Medium1b	8,999	1,077	6,449	227	58,051
4.1	Swine	Liquid	FF	Midwest	2	37	Medium1b	8,883	1,101	4,091	252	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	3	7	Medium1b	54,889	972	15,884	0	2,854

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4.1	Swine	Liquid	FF	Midwest	3	60	Medium1b	53,024	972	13,159	0	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	1	93	Medium1b	2,904	2,591	7,229	1,822	2,854
4.1	Swine	Liquid	FF	Midwest	1	793	Medium1b	2,276	2,163	4,491	1,362	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	2	6	Medium1b	41,731	1,519	13,080	693	2,854
4.1	Swine	Liquid	FF	Midwest	2	56	Medium1b	9,322	1,623	13,182	797	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	3	11	Medium1b	54,889	972	8,424	0	2,854
4.1	Swine	Liquid	FF	Midwest	3	90	Medium1b	53,024	972	5,985	0	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	1	41	Medium2	1,621	1,208	6,381	365	2,854
4.1	Swine	Liquid	FF	Midwest	1	202	Medium2	1,526	1,142	3,965	294	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	2	4	Medium2	10,285	1,112	6,496	264	92,560
4.1	Swine	Liquid	FF	Midwest	2	20	Medium2	10,266	1,144	4,140	297	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	3	6	Medium2	75,688	972	19,968	0	2,854
4.1	Swine	Liquid	FF	Midwest	3	30	Medium2	75,270	972	17,528	0	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	1	62	Medium2	3,696	3,281	7,655	2,549	2,854
4.1	Swine	Liquid	FF	Midwest	1	303	Medium2	2,862	2,728	4,785	1,952	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	2	6	Medium2	56,904	1,936	16,024	1,132	2,854
4.1	Swine	Liquid	FF	Midwest	2	30	Medium2	11,086	2,118	6,270	1,315	3,048
4.1	Swine	Liquid	FF	Mid-Atlantic	3	9	Medium2	75,688	972	9,329	0	2,854
4.1	Swine	Liquid	FF	Midwest	3	45	Medium2	75,270	972	6,953	0	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	1	88	Large1	643	1,130	5,314	255	2,703
4.1	Swine	Liquid	GF	Midwest	1	103	Large1	634	1,132	4,688	252	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	2	27	Large1	11,666	1,040	5,531	159	209,958
4.1	Swine	Liquid	GF	Midwest	2	32	Large1	11,452	1,091	4,902	209	88,309
4.1	Swine	Liquid	GF	Mid-Atlantic	3	25	Large1	119,757	972	34,564	0	2,703
4.1	Swine	Liquid	GF	Midwest	3	29	Large1	115,367	972	32,816	0	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	1	131	Large1	677	2,516	5,335	1,750	2,703
4.1	Swine	Liquid	GF	Midwest	1	155	Large1	655	2,630	4,701	1,818	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	2	41	Large1	86,744	1,433	21,170	582	2,703
4.1	Swine	Liquid	GF	Midwest	2	48	Large1	83,631	1,771	18,404	920	2,370

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4.1	Swine	Liquid	GF	Mid-Atlantic	3	37	Large1	119,757	972	11,279	0	2,703
4.1	Swine	Liquid	GF	Midwest	3	44	Large1	115,367	972	10,428	0	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	1	47	Large2	883	1,367	5,322	511	2,703
4.1	Swine	Liquid	GF	Midwest	1	23	Large2	920	1,442	4,696	576	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	2	55	Large2	19,006	1,152	5,678	279	501,026
4.1	Swine	Liquid	GF	Midwest	2	27	Large2	20,421	1,284	5,081	410	345,312
4.1	Swine	Liquid	GF	Mid-Atlantic	3	29	Large2	290,778	972	78,348	0	2,703
4.1	Swine	Liquid	GF	Midwest	3	14	Large2	327,157	972	87,039	0	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	1	70	Large2	968	4,836	5,374	4,252	2,703
4.1	Swine	Liquid	GF	Midwest	1	34	Large2	982	5,839	4,734	5,172	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	2	82	Large2	208,015	1,611	44,637	775	2,703
4.1	Swine	Liquid	GF	Midwest	2	40	Large2	233,808	2,081	44,483	1,244	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	3	43	Large2	290,778	972	20,081	0	2,703
4.1	Swine	Liquid	GF	Midwest	3	21	Large2	327,157	972	21,329	0	2,370
4.1	Swine	Liquid	GF	Mid-Atlantic	1	75	Medium1a	1,281	1,077	6,296	227	2,854
4.1	Swine	Liquid	GF	Midwest	1	416	Medium1a	1,222	1,043	3,910	191	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	2	9	Medium1a	7,735	1,031	6,397	180	44,201
4.1	Swine	Liquid	GF	Midwest	2	50	Medium1a	7,586	1,045	4,037	194	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	3	16	Medium1a	37,029	972	14,200	0	2,854
4.1	Swine	Liquid	GF	Midwest	3	85	Medium1a	34,999	972	11,324	0	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	1	113	Medium1a	2,204	1,999	6,863	1,198	2,854
4.1	Swine	Liquid	GF	Midwest	1	623	Medium1a	1,780	1,706	4,253	884	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	2	14	Medium1a	28,955	1,418	10,952	586	2,854
4.1	Swine	Liquid	GF	Midwest	2	74	Medium1a	7,971	1,502	5,180	671	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	3	23	Medium1a	37,029	972	7,890	0	2,854
4.1	Swine	Liquid	GF	Midwest	3	128	Medium1a	34,999	972	5,428	0	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	1	13	Medium1b	1,449	1,138	6,336	292	2,854
4.1	Swine	Liquid	GF	Midwest	1	74	Medium1b	1,360	1,084	3,933	234	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium1b	41,311	1,031	7,223	180	2,854

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
4.1	Swine	Liquid	GF	Midwest	2	9	Medium1b	8,755	1,043	4,059	191	53,292
4.1	Swine	Liquid	GF	Mid-Atlantic	3	3	Medium1b	54,985	972	18,777	0	2,854
4.1	Swine	Liquid	GF	Midwest	3	15	Medium1b	51,801	972	15,607	0	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	1	20	Medium1b	2,907	2,594	7,231	1,825	2,854
4.1	Swine	Liquid	GF	Midwest	1	111	Medium1b	2,243	2,132	4,475	1,329	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium1b	41,698	1,418	13,413	586	2,854
4.1	Swine	Liquid	GF	Midwest	2	13	Medium1b	39,438	1,502	9,978	671	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	3	4	Medium1b	54,985	972	8,812	0	2,854
4.1	Swine	Liquid	GF	Midwest	3	23	Medium1b	51,801	972	6,290	0	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	1	37	Medium2	1,626	1,210	6,382	368	2,854
4.1	Swine	Liquid	GF	Midwest	1	91	Medium2	1,520	1,140	3,964	292	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	2	7	Medium2	10,311	1,101	6,490	253	103,576
4.1	Swine	Liquid	GF	Midwest	2	18	Medium2	10,199	1,126	4,129	278	18,181
4.1	Swine	Liquid	GF	Mid-Atlantic	3	9	Medium2	76,299	972	24,216	0	2,854
4.1	Swine	Liquid	GF	Midwest	3	21	Medium2	74,370	972	21,365	0	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	1	56	Medium2	3,719	3,301	7,668	2,570	2,854
4.1	Swine	Liquid	GF	Midwest	1	137	Medium2	2,839	2,705	4,774	1,928	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	2	11	Medium2	57,112	1,711	16,515	896	2,854
4.1	Swine	Liquid	GF	Midwest	2	27	Medium2	55,744	1,851	12,935	1,035	3,048
4.1	Swine	Liquid	GF	Mid-Atlantic	3	13	Medium2	76,299	972	9,906	0	2,854
4.1	Swine	Liquid	GF	Midwest	3	32	Medium2	74,370	972	7,449	0	3,048
5	Swine	Liquid	FF	Mid-Atlantic	1	75	Large1	118,461	736	2,537	253	0
5	Swine	Liquid	FF	Midwest	1	347	Large1	116,376	742	2,495	254	0
5	Swine	Liquid	FF	Mid-Atlantic	2	12	Large1	85,713	668	29,998	181	0
5	Swine	Liquid	FF	Midwest	2	58	Large1	84,236	739	21,380	251	0
5	Swine	Liquid	FF	Mid-Atlantic	3	14	Large1	118,315	580	22,431	0	0
5	Swine	Liquid	FF	Midwest	3	65	Large1	116,232	580	22,021	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	112	Large1	118,494	2,105	2,558	1,729	0
5	Swine	Liquid	FF	Midwest	1	521	Large1	116,398	2,251	2,508	1,832	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5	Swine	Liquid	FF	Mid-Atlantic	2	19	Large1	85,724	1,134	14,738	682	0
5	Swine	Liquid	FF	Midwest	2	87	Large1	84,247	1,541	9,166	1,089	0
5	Swine	Liquid	FF	Mid-Atlantic	3	21	Large1	118,315	580	5,187	0	0
5	Swine	Liquid	FF	Midwest	3	98	Large1	116,232	580	5,097	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	58	Large2	554,292	1,340	11,263	905	0
5	Swine	Liquid	FF	Midwest	1	122	Large2	448,663	1,228	9,145	762	0
5	Swine	Liquid	FF	Mid-Atlantic	2	28	Large2	394,727	808	8,064	331	0
5	Swine	Liquid	FF	Midwest	2	59	Large2	319,841	976	117,607	498	0
5	Swine	Liquid	FF	Mid-Atlantic	3	34	Large2	554,131	580	108,310	0	0
5	Swine	Liquid	FF	Midwest	3	73	Large2	448,511	580	87,492	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	86	Large2	554,456	8,018	11,363	8,106	0
5	Swine	Liquid	FF	Midwest	1	184	Large2	448,748	7,286	9,197	7,094	0
5	Swine	Liquid	FF	Mid-Atlantic	2	41	Large2	394,750	1,724	70,764	1,319	0
5	Swine	Liquid	FF	Midwest	2	88	Large2	319,864	2,566	50,959	2,160	0
5	Swine	Liquid	FF	Mid-Atlantic	3	52	Large2	554,131	580	24,192	0	0
5	Swine	Liquid	FF	Midwest	3	109	Large2	448,511	580	19,586	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	122	Medium1a	33,877	672	1,045	214	0
5	Swine	Liquid	FF	Midwest	1	1092	Medium1a	32,807	644	1,200	184	0
5	Swine	Liquid	FF	Mid-Atlantic	2	9	Medium1a	25,944	689	896	232	0
5	Swine	Liquid	FF	Midwest	2	78	Medium1a	25,212	709	1,080	252	0
5	Swine	Liquid	FF	Mid-Atlantic	3	14	Medium1a	33,260	580	5,745	0	0
5	Swine	Liquid	FF	Midwest	3	124	Medium1a	32,228	580	5,742	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	182	Medium1a	34,688	1,482	1,543	1,067	0
5	Swine	Liquid	FF	Midwest	1	1639	Medium1a	33,312	1,244	1,510	811	0
5	Swine	Liquid	FF	Mid-Atlantic	2	13	Medium1a	26,383	1,127	1,806	693	0
5	Swine	Liquid	FF	Midwest	2	116	Medium1a	25,651	1,231	1,965	797	0
5	Swine	Liquid	FF	Mid-Atlantic	3	20	Medium1a	33,260	580	1,588	0	0
5	Swine	Liquid	FF	Midwest	3	186	Medium1a	32,228	580	1,742	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	81	Medium1b	55,580	745	1,523	291	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5	Swine	Liquid	FF	Midwest	1	728	Medium1b	53,646	695	1,642	237	0
5	Swine	Liquid	FF	Mid-Atlantic	2	6	Medium1b	41,288	685	13,364	227	0
5	Swine	Liquid	FF	Midwest	2	52	Medium1b	39,968	709	1,375	252	0
5	Swine	Liquid	FF	Mid-Atlantic	3	9	Medium1b	54,889	580	9,988	0	0
5	Swine	Liquid	FF	Midwest	3	83	Medium1b	53,024	580	9,820	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	122	Medium1b	57,035	2,199	2,416	1,822	0
5	Swine	Liquid	FF	Midwest	1	1093	Medium1b	54,552	1,771	2,198	1,362	0
5	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium1b	41,731	1,127	7,032	693	0
5	Swine	Liquid	FF	Midwest	2	77	Medium1b	40,407	1,231	6,334	797	0
5	Swine	Liquid	FF	Mid-Atlantic	3	14	Medium1b	54,889	580	2,529	0	0
5	Swine	Liquid	FF	Midwest	3	124	Medium1b	53,024	580	2,646	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	54	Medium2	76,449	816	1,982	365	0
5	Swine	Liquid	FF	Midwest	1	278	Medium2	75,938	750	2,115	294	0
5	Swine	Liquid	FF	Mid-Atlantic	2	5	Medium2	56,079	720	18,865	264	0
5	Swine	Liquid	FF	Midwest	2	27	Medium2	55,787	752	1,713	297	0
5	Swine	Liquid	FF	Mid-Atlantic	3	8	Medium2	75,688	580	14,073	0	0
5	Swine	Liquid	FF	Midwest	3	42	Medium2	75,270	580	14,189	0	0
5	Swine	Liquid	FF	Mid-Atlantic	1	81	Medium2	78,524	2,889	3,256	2,549	0
5	Swine	Liquid	FF	Midwest	1	418	Medium2	77,274	2,336	2,935	1,952	0
5	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium2	56,904	1,544	9,952	1,132	0
5	Swine	Liquid	FF	Midwest	2	41	Medium2	56,607	1,726	3,844	1,315	0
5	Swine	Liquid	FF	Mid-Atlantic	3	12	Medium2	75,688	580	3,434	0	0
5	Swine	Liquid	FF	Midwest	3	62	Medium2	75,270	580	3,614	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	115	Large1	119,903	738	2,566	255	0
5	Swine	Liquid	GF	Midwest	1	142	Large1	115,511	740	2,478	252	0
5	Swine	Liquid	GF	Mid-Atlantic	2	36	Large1	86,735	648	37,096	159	0
5	Swine	Liquid	GF	Midwest	2	44	Large1	83,621	699	6,641	209	0
5	Swine	Liquid	GF	Mid-Atlantic	3	32	Large1	119,757	580	29,432	0	0
5	Swine	Liquid	GF	Midwest	3	40	Large1	115,367	580	28,308	0	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5	Swine	Liquid	GF	Mid-Atlantic	1	173	Large1	119,937	2,124	2,587	1,750	0
5	Swine	Liquid	GF	Midwest	1	214	Large1	115,532	2,238	2,491	1,818	0
5	Swine	Liquid	GF	Mid-Atlantic	2	53	Large1	86,744	1,041	15,818	582	0
5	Swine	Liquid	GF	Midwest	2	66	Large1	83,631	1,379	13,680	920	0
5	Swine	Liquid	GF	Mid-Atlantic	3	49	Large1	119,757	580	6,146	0	0
5	Swine	Liquid	GF	Midwest	3	61	Large1	115,367	580	5,920	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	62	Large2	290,930	975	5,990	511	0
5	Swine	Liquid	GF	Midwest	1	31	Large2	327,306	1,050	6,716	576	0
5	Swine	Liquid	GF	Mid-Atlantic	2	72	Large2	208,003	760	37,346	279	0
5	Swine	Liquid	GF	Midwest	2	37	Large2	233,797	892	24,071	410	0
5	Swine	Liquid	GF	Mid-Atlantic	3	38	Large2	290,778	580	73,215	0	0
5	Swine	Liquid	GF	Midwest	3	19	Large2	327,157	580	82,531	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	92	Large2	291,015	4,444	6,042	4,252	0
5	Swine	Liquid	GF	Midwest	1	47	Large2	327,368	5,447	6,754	5,172	0
5	Swine	Liquid	GF	Mid-Atlantic	2	108	Large2	208,015	1,219	39,143	775	0
5	Swine	Liquid	GF	Midwest	2	55	Large2	233,808	1,689	39,587	1,244	0
5	Swine	Liquid	GF	Mid-Atlantic	3	56	Large2	290,778	580	14,948	0	0
5	Swine	Liquid	GF	Midwest	3	29	Large2	327,157	580	16,821	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	99	Medium1a	37,659	685	1,128	227	0
5	Swine	Liquid	GF	Midwest	1	573	Medium1a	35,584	651	1,258	191	0
5	Swine	Liquid	GF	Mid-Atlantic	2	12	Medium1a	28,569	639	10,456	180	0
5	Swine	Liquid	GF	Midwest	2	68	Medium1a	27,131	653	1,091	194	0
5	Swine	Liquid	GF	Mid-Atlantic	3	20	Medium1a	37,029	580	8,304	0	0
5	Swine	Liquid	GF	Midwest	3	118	Medium1a	34,999	580	7,986	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	148	Medium1a	38,581	1,607	1,695	1,198	0
5	Swine	Liquid	GF	Midwest	1	859	Medium1a	36,142	1,314	1,601	884	0
5	Swine	Liquid	GF	Mid-Atlantic	2	18	Medium1a	28,955	1,026	4,926	586	0
5	Swine	Liquid	GF	Midwest	2	103	Medium1a	27,516	1,110	2,234	671	0
5	Swine	Liquid	GF	Mid-Atlantic	3	31	Medium1a	37,029	580	1,995	0	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5	Swine	Liquid	GF	Midwest	3	176	Medium1a	34,999	580	2,089	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	18	Medium1b	55,676	746	1,525	292	0
5	Swine	Liquid	GF	Midwest	1	102	Medium1b	52,421	692	1,616	234	0
5	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium1b	41,311	639	1,174	180	0
5	Swine	Liquid	GF	Midwest	2	12	Medium1b	39,051	651	15,442	191	0
5	Swine	Liquid	GF	Mid-Atlantic	3	4	Medium1b	54,985	580	12,882	0	0
5	Swine	Liquid	GF	Midwest	3	21	Medium1b	51,801	580	12,268	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	26	Medium1b	57,134	2,202	2,420	1,825	0
5	Swine	Liquid	GF	Midwest	1	154	Medium1b	53,303	1,740	2,158	1,329	0
5	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium1b	41,698	1,026	7,365	586	0
5	Swine	Liquid	GF	Midwest	2	18	Medium1b	39,438	1,110	6,490	671	0
5	Swine	Liquid	GF	Mid-Atlantic	3	5	Medium1b	54,985	580	2,916	0	0
5	Swine	Liquid	GF	Midwest	3	32	Medium1b	51,801	580	2,951	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	49	Medium2	77,062	818	1,996	368	0
5	Swine	Liquid	GF	Midwest	1	126	Medium2	75,036	748	2,096	292	0
5	Swine	Liquid	GF	Mid-Atlantic	2	10	Medium2	56,501	709	23,148	253	0
5	Swine	Liquid	GF	Midwest	2	25	Medium2	55,134	734	17,748	278	0
5	Swine	Liquid	GF	Mid-Atlantic	3	12	Medium2	76,299	580	18,320	0	0
5	Swine	Liquid	GF	Midwest	3	30	Medium2	74,370	580	18,027	0	0
5	Swine	Liquid	GF	Mid-Atlantic	1	73	Medium2	79,155	2,909	3,281	2,570	0
5	Swine	Liquid	GF	Midwest	1	188	Medium2	76,355	2,313	2,905	1,928	0
5	Swine	Liquid	GF	Mid-Atlantic	2	14	Medium2	57,112	1,319	10,443	896	0
5	Swine	Liquid	GF	Midwest	2	37	Medium2	55,744	1,459	9,422	1,035	0
5	Swine	Liquid	GF	Mid-Atlantic	3	17	Medium2	76,299	580	4,011	0	0
5	Swine	Liquid	GF	Midwest	3	44	Medium2	74,370	580	4,110	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	75	Large1	747,825	736	24,463	253	0
5a	Swine	Liquid	FF	Midwest	1	347	Large1	733,979	742	24,013	254	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	12	Large1	649,731	668	25,565	181	0
5a	Swine	Liquid	FF	Midwest	2	58	Large1	637,703	739	24,234	251	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5a	Swine	Liquid	FF	Mid-Atlantic	3	14	Large1	649,660	580	24,460	0	0
5a	Swine	Liquid	FF	Midwest	3	65	Large1	637,631	580	24,011	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	112	Large1	747,858	2,105	24,484	1,729	0
5a	Swine	Liquid	FF	Midwest	1	521	Large1	734,000	2,251	24,026	1,832	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	19	Large1	649,742	1,134	32,648	682	0
5a	Swine	Liquid	FF	Midwest	2	87	Large1	637,714	1,541	25,741	1,089	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	21	Large1	649,660	580	24,460	0	0
5a	Swine	Liquid	FF	Midwest	3	98	Large1	637,631	580	24,011	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	58	Large2	3,646,138	1,340	118,656	905	0
5a	Swine	Liquid	FF	Midwest	1	122	Large2	2,943,571	1,228	95,820	762	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	28	Large2	3,167,794	808	126,318	331	0
5a	Swine	Liquid	FF	Midwest	2	59	Large2	2,557,406	976	99,594	498	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	34	Large2	3,167,808	580	118,644	0	0
5a	Swine	Liquid	FF	Midwest	3	73	Large2	2,557,404	580	95,814	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	86	Large2	3,646,302	8,018	118,757	8,106	0
5a	Swine	Liquid	FF	Midwest	1	184	Large2	2,943,657	7,286	95,873	7,094	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	41	Large2	3,167,816	1,724	171,037	1,319	0
5a	Swine	Liquid	FF	Midwest	2	88	Large2	2,557,428	2,566	106,414	2,160	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	52	Large2	3,167,808	580	118,644	0	0
5a	Swine	Liquid	FF	Midwest	3	109	Large2	2,557,404	580	95,814	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	122	Medium1a	181,384	672	6,247	214	0
5a	Swine	Liquid	FF	Midwest	1	1092	Medium1a	174,524	644	6,200	184	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	9	Medium1a	173,451	689	6,381	232	0
5a	Swine	Liquid	FF	Midwest	2	78	Medium1a	166,929	709	6,356	252	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	14	Medium1a	157,135	580	6,150	0	0
5a	Swine	Liquid	FF	Midwest	3	124	Medium1a	151,207	580	6,127	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	182	Medium1a	182,195	1,482	6,745	1,067	0
5a	Swine	Liquid	FF	Midwest	1	1639	Medium1a	175,029	1,244	6,510	811	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	13	Medium1a	158,135	1,127	7,818	693	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5a	Swine	Liquid	FF	Midwest	2	116	Medium1a	152,209	1,231	6,633	797	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	20	Medium1a	157,135	580	6,150	0	0
5a	Swine	Liquid	FF	Midwest	3	186	Medium1a	151,207	580	6,127	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	81	Medium1b	324,682	745	10,945	291	0
5a	Swine	Liquid	FF	Midwest	1	728	Medium1b	312,253	695	10,699	237	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	6	Medium1b	282,121	685	11,376	227	0
5a	Swine	Liquid	FF	Midwest	2	52	Medium1b	298,576	709	10,855	252	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	9	Medium1b	281,588	580	10,803	0	0
5a	Swine	Liquid	FF	Midwest	3	83	Medium1b	270,848	580	10,600	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	122	Medium1b	326,137	2,199	11,838	1,822	0
5a	Swine	Liquid	FF	Midwest	1	1093	Medium1b	313,159	1,771	11,256	1,362	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium1b	282,564	1,127	14,910	693	0
5a	Swine	Liquid	FF	Midwest	2	77	Medium1b	271,826	1,231	11,808	797	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	14	Medium1b	281,588	580	10,803	0	0
5a	Swine	Liquid	FF	Midwest	3	124	Medium1b	270,848	580	10,600	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	54	Medium2	462,623	816	15,467	365	0
5a	Swine	Liquid	FF	Midwest	1	278	Medium2	459,759	750	15,518	294	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	5	Medium2	401,935	720	16,098	264	0
5a	Swine	Liquid	FF	Midwest	2	27	Medium2	439,609	752	15,693	297	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	8	Medium2	401,385	580	15,282	0	0
5a	Swine	Liquid	FF	Midwest	3	42	Medium2	398,978	580	15,391	0	0
5a	Swine	Liquid	FF	Mid-Atlantic	1	81	Medium2	464,698	2,889	16,742	2,549	0
5a	Swine	Liquid	FF	Midwest	1	418	Medium2	461,095	2,336	16,339	1,952	0
5a	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium2	402,760	1,544	20,573	1,132	0
5a	Swine	Liquid	FF	Midwest	2	41	Medium2	400,353	1,726	16,960	1,315	0
5a	Swine	Liquid	FF	Mid-Atlantic	3	12	Medium2	401,385	580	15,282	0	0
5a	Swine	Liquid	FF	Midwest	3	62	Medium2	398,978	580	15,391	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	115	Large1	757,409	738	24,775	255	0
5a	Swine	Liquid	GF	Midwest	1	142	Large1	728,228	740	23,826	252	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5a	Swine	Liquid	GF	Mid-Atlantic	2	36	Large1	658,057	648	26,184	159	0
5a	Swine	Liquid	GF	Midwest	2	44	Large1	632,705	699	24,558	209	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	32	Large1	657,987	580	24,772	0	0
5a	Swine	Liquid	GF	Midwest	3	40	Large1	632,635	580	23,824	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	173	Large1	757,443	2,124	24,796	1,750	0
5a	Swine	Liquid	GF	Midwest	1	214	Large1	728,249	2,238	23,839	1,818	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	53	Large1	658,067	1,041	33,898	582	0
5a	Swine	Liquid	GF	Midwest	2	66	Large1	632,715	1,379	25,875	920	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	49	Large1	657,987	580	24,772	0	0
5a	Swine	Liquid	GF	Midwest	3	61	Large1	632,635	580	23,824	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	62	Large2	1,894,502	975	61,729	511	0
5a	Swine	Liquid	GF	Midwest	1	31	Large2	2,136,432	1,050	69,589	576	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	72	Large2	1,645,966	760	64,952	279	0
5a	Swine	Liquid	GF	Midwest	2	37	Large2	1,856,159	892	72,043	410	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	38	Large2	1,645,936	580	61,722	0	0
5a	Swine	Liquid	GF	Midwest	3	19	Large2	1,856,136	580	69,585	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	92	Large2	1,894,588	4,444	61,781	4,252	0
5a	Swine	Liquid	GF	Midwest	1	47	Large2	2,136,494	5,447	69,627	5,172	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	108	Large2	1,645,978	1,219	88,643	775	0
5a	Swine	Liquid	GF	Midwest	2	55	Large2	1,856,170	1,689	78,040	1,244	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	56	Large2	1,645,936	580	61,722	0	0
5a	Swine	Liquid	GF	Midwest	3	29	Large2	1,856,136	580	69,585	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	99	Medium1a	206,336	685	7,065	227	0
5a	Swine	Liquid	GF	Midwest	1	573	Medium1a	192,862	651	6,799	191	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	12	Medium1a	179,313	639	7,404	180	0
5a	Swine	Liquid	GF	Midwest	2	68	Medium1a	184,409	653	6,926	194	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	20	Medium1a	178,806	580	6,960	0	0
5a	Swine	Liquid	GF	Midwest	3	118	Medium1a	167,137	580	6,723	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	148	Medium1a	207,259	1,607	7,632	1,198	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
5a	Swine	Liquid	GF	Midwest	1	859	Medium1a	193,421	1,314	7,142	884	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	18	Medium1a	179,700	1,026	9,337	586	0
5a	Swine	Liquid	GF	Midwest	2	103	Medium1a	168,034	1,110	7,414	671	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	31	Medium1a	178,806	580	6,960	0	0
5a	Swine	Liquid	GF	Midwest	3	176	Medium1a	167,137	580	6,723	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	18	Medium1b	325,321	746	10,966	292	0
5a	Swine	Liquid	GF	Midwest	1	102	Medium1b	304,152	692	10,435	234	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium1b	282,632	639	11,625	180	0
5a	Swine	Liquid	GF	Midwest	2	12	Medium1b	264,302	651	10,864	191	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	4	Medium1b	282,143	580	10,824	0	0
5a	Swine	Liquid	GF	Midwest	3	21	Medium1b	263,811	580	10,337	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	26	Medium1b	326,779	2,202	11,861	1,825	0
5a	Swine	Liquid	GF	Midwest	1	154	Medium1b	305,035	1,740	10,977	1,329	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium1b	283,019	1,026	15,225	586	0
5a	Swine	Liquid	GF	Midwest	2	18	Medium1b	264,688	1,110	11,597	671	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	5	Medium1b	282,143	580	10,824	0	0
5a	Swine	Liquid	GF	Midwest	3	32	Medium1b	263,811	580	10,337	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	49	Medium2	466,674	818	15,600	368	0
5a	Swine	Liquid	GF	Midwest	1	126	Medium2	453,791	748	15,324	292	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	10	Medium2	405,442	709	16,287	253	0
5a	Swine	Liquid	GF	Midwest	2	25	Medium2	394,335	734	15,580	278	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	12	Medium2	404,903	580	15,414	0	0
5a	Swine	Liquid	GF	Midwest	3	30	Medium2	393,794	580	15,197	0	0
5a	Swine	Liquid	GF	Mid-Atlantic	1	73	Medium2	468,767	2,909	16,885	2,570	0
5a	Swine	Liquid	GF	Midwest	1	188	Medium2	455,110	2,313	16,133	1,928	0
5a	Swine	Liquid	GF	Mid-Atlantic	2	14	Medium2	406,052	1,319	21,401	896	0
5a	Swine	Liquid	GF	Midwest	2	37	Medium2	394,945	1,459	16,944	1,035	0
5a	Swine	Liquid	GF	Mid-Atlantic	3	17	Medium2	404,903	580	15,414	0	0
5a	Swine	Liquid	GF	Midwest	3	44	Medium2	393,794	580	15,197		0

Table 11-12. (Continued)												
Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
											0	
6	Swine	Liquid	FF	Mid-Atlantic	1	112	Large1	98,256	42,105	-8,314	1,729	5,000
6	Swine	Liquid	FF	Midwest	1	521	Large1	155,263	42,251	-15	1,832	5,000
6	Swine	Liquid	FF	Mid-Atlantic	2	19	Large1	183,306	41,134	-3,580	682	5,000
6	Swine	Liquid	FF	Midwest	2	87	Large1	168,426	41,541	-5,311	1,089	5,000
6	Swine	Liquid	FF	Mid-Atlantic	3	21	Large1	215,897	40,580	-3,329	0	5,000
6	Swine	Liquid	FF	Midwest	3	98	Large1	273,151	40,580	-3,604	0	5,000
6	Swine	Liquid	FF	Mid-Atlantic	1	86	Large2	286,501	48,018	-32,752	8,106	5,000
6	Swine	Liquid	FF	Midwest	1	184	Large2	362,915	47,286	-43,278	7,094	5,000
6	Swine	Liquid	FF	Mid-Atlantic	2	41	Large2	679,948	41,724	-9,519	1,319	5,000
6	Swine	Liquid	FF	Midwest	2	88	Large2	795,452	42,566	-12,322	2,160	5,000
6	Swine	Liquid	FF	Mid-Atlantic	3	52	Large2	839,329	40,580	-8,860	0	5,000
6	Swine	Liquid	FF	Midwest	3	109	Large2	924,099	40,580	-9,710	0	5,000
6	Swine	Liquid	GF	Mid-Atlantic	1	173	Large1	98,039	27,124	-17,555	1,750	5,000
6	Swine	Liquid	GF	Midwest	1	214	Large1	155,261	27,238	-15,110	1,818	5,000
6	Swine	Liquid	GF	Mid-Atlantic	2	53	Large1	184,106	26,041	-12,464	582	5,000
6	Swine	Liquid	GF	Midwest	2	66	Large1	238,237	26,379	-10,717	920	5,000
6	Swine	Liquid	GF	Mid-Atlantic	3	49	Large1	217,119	25,580	-11,611	0	5,000
6	Swine	Liquid	GF	Midwest	3	61	Large1	269,973	25,580	-9,383	0	5,000
6	Swine	Liquid	GF	Mid-Atlantic	1	92	Large2	173,966	29,444	-42,722	4,252	5,000
6	Swine	Liquid	GF	Midwest	1	47	Large2	362,771	30,447	-43,296	5,172	5,000
6	Swine	Liquid	GF	Mid-Atlantic	2	108	Large2	381,013	26,219	-29,927	775	5,000
6	Swine	Liquid	GF	Midwest	2	55	Large2	595,597	26,689	-30,331	1,244	5,000
6	Swine	Liquid	GF	Mid-Atlantic	3	56	Large2	463,776	25,580	-28,015	0	5,000
6	Swine	Liquid	GF	Midwest	3	29	Large2	688,946	25,580	-26,702	0	5,000
7	Swine	Liquid	FF	Mid-Atlantic	1	75	Large1	640	736	181	253	6
7	Swine	Liquid	FF	Midwest	1	347	Large1	635	742	180	254	6
7	Swine	Liquid	FF	Mid-Atlantic	2	12	Large1	15,128	668	11,320	181	6
7	Swine	Liquid	FF	Midwest	2	58	Large1	14,994	739	11,220	251	6

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
7	Swine	Liquid	FF	Mid-Atlantic	3	14	Large1	118,315	580	22,431	0	6
7	Swine	Liquid	FF	Midwest	3	65	Large1	116,232	580	22,021	0	6
7	Swine	Liquid	FF	Mid-Atlantic	1	112	Large1	674	2,105	202	1,729	6
7	Swine	Liquid	FF	Midwest	1	521	Large1	657	2,251	193	1,832	6
7	Swine	Liquid	FF	Mid-Atlantic	2	19	Large1	89,254	1,134	25,880	682	6
7	Swine	Liquid	FF	Midwest	2	87	Large1	15,005	1,541	21,096	1,089	6
7	Swine	Liquid	FF	Mid-Atlantic	3	21	Large1	118,315	580	5,187	0	6
7	Swine	Liquid	FF	Midwest	3	98	Large1	116,232	580	5,097	0	6
7	Swine	Liquid	FF	Mid-Atlantic	1	58	Large2	1,139	1,340	200	905	6
7	Swine	Liquid	FF	Midwest	1	122	Large2	1,040	1,228	192	762	6
7	Swine	Liquid	FF	Mid-Atlantic	2	28	Large2	403,602	808	36,073	331	6
7	Swine	Liquid	FF	Midwest	2	59	Large2	32,639	976	24,477	498	6
7	Swine	Liquid	FF	Mid-Atlantic	3	34	Large2	554,131	580	108,310	0	6
7	Swine	Liquid	FF	Midwest	3	73	Large2	448,511	580	87,492	0	6
7	Swine	Liquid	FF	Mid-Atlantic	1	86	Large2	1,303	8,018	300	8,106	6
7	Swine	Liquid	FF	Midwest	1	184	Large2	1,126	7,286	245	7,094	6
7	Swine	Liquid	FF	Mid-Atlantic	2	41	Large2	403,625	1,724	98,773	1,319	6
7	Swine	Liquid	FF	Midwest	2	88	Large2	327,560	2,566	75,249	2,160	6
7	Swine	Liquid	FF	Mid-Atlantic	3	52	Large2	554,131	580	24,192	0	6
7	Swine	Liquid	FF	Midwest	3	109	Large2	448,511	580	19,586	0	0
7	Swine	Liquid	FF	Mid-Atlantic	1	122	Medium1a	1,242	672	392	214	0
7	Swine	Liquid	FF	Midwest	1	1092	Medium1a	1,196	644	567	184	0
7	Swine	Liquid	FF	Mid-Atlantic	2	9	Medium1a	10,594	689	6,778	232	0
7	Swine	Liquid	FF	Midwest	2	78	Medium1a	10,476	709	6,900	252	0
7	Swine	Liquid	FF	Mid-Atlantic	3	14	Medium1a	33,260	580	5,745	0	0
7	Swine	Liquid	FF	Midwest	3	124	Medium1a	32,228	580	5,742	0	0
7	Swine	Liquid	FF	Mid-Atlantic	1	182	Medium1a	2,053	1,482	890	1,067	0
7	Swine	Liquid	FF	Midwest	1	1639	Medium1a	1,701	1,244	878	811	0
7	Swine	Liquid	FF	Mid-Atlantic	2	13	Medium1a	11,033	1,127	7,687	693	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
7	Swine	Liquid	FF	Midwest	2	116	Medium1a	10,915	1,231	7,170	797	731
7	Swine	Liquid	FF	Mid-Atlantic	3	20	Medium1a	33,260	580	1,588	0	0
7	Swine	Liquid	FF	Midwest	3	186	Medium1a	32,228	580	1,742	0	0
7	Swine	Liquid	FF	Mid-Atlantic	1	81	Medium1b	1,449	745	440	291	0
7	Swine	Liquid	FF	Midwest	1	728	Medium1b	1,370	695	596	237	0
7	Swine	Liquid	FF	Mid-Atlantic	2	6	Medium1b	12,776	685	8,185	227	55,197
7	Swine	Liquid	FF	Midwest	2	52	Medium1b	12,605	709	8,273	252	0
7	Swine	Liquid	FF	Mid-Atlantic	3	9	Medium1b	54,889	580	9,988	0	0
7	Swine	Liquid	FF	Midwest	3	83	Medium1b	53,024	580	9,820	0	0
7	Swine	Liquid	FF	Mid-Atlantic	1	122	Medium1b	2,904	2,199	1,334	1,822	0
7	Swine	Liquid	FF	Midwest	1	1093	Medium1b	2,276	1,771	1,153	1,362	0
7	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium1b	45,508	1,127	14,816	693	0
7	Swine	Liquid	FF	Midwest	2	77	Medium1b	13,044	1,231	17,364	797	0
7	Swine	Liquid	FF	Mid-Atlantic	3	14	Medium1b	54,889	580	2,529	0	0
7	Swine	Liquid	FF	Midwest	3	124	Medium1b	53,024	580	2,646	0	0
7	Swine	Liquid	FF	Mid-Atlantic	1	54	Medium2	1,621	816	485	365	0
7	Swine	Liquid	FF	Midwest	1	278	Medium2	1,526	750	627	294	0
7	Swine	Liquid	FF	Mid-Atlantic	2	5	Medium2	14,634	720	9,387	264	89,706
7	Swine	Liquid	FF	Midwest	2	27	Medium2	14,604	752	9,566	297	0
7	Swine	Liquid	FF	Mid-Atlantic	3	8	Medium2	75,688	580	14,073	0	0
7	Swine	Liquid	FF	Midwest	3	42	Medium2	75,270	580	14,189	0	0
7	Swine	Liquid	FF	Mid-Atlantic	1	81	Medium2	3,696	2,889	1,760	2,549	0
7	Swine	Liquid	FF	Midwest	1	418	Medium2	2,862	2,336	1,447	1,952	0
7	Swine	Liquid	FF	Mid-Atlantic	2	8	Medium2	61,253	1,544	18,916	1,132	0
7	Swine	Liquid	FF	Midwest	2	41	Medium2	15,424	1,726	11,697	1,315	0
7	Swine	Liquid	FF	Mid-Atlantic	3	12	Medium2	75,688	580	3,434	0	0
7	Swine	Liquid	FF	Midwest	3	62	Medium2	75,270	580	3,614	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	115	Large1	643	738	181	255	0
7	Swine	Liquid	GF	Midwest	1	142	Large1	634	740	180	252	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
7	Swine	Liquid	GF	Mid-Atlantic	2	36	Large1	15,218	648	11,387	159	207,255
7	Swine	Liquid	GF	Midwest	2	44	Large1	14,937	699	11,178	209	85,939
7	Swine	Liquid	GF	Mid-Atlantic	3	32	Large1	119,757	580	29,432	0	0
7	Swine	Liquid	GF	Midwest	3	40	Large1	115,367	580	28,308	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	173	Large1	677	2,124	202	1,750	0
7	Swine	Liquid	GF	Midwest	1	214	Large1	655	2,238	193	1,818	0
7	Swine	Liquid	GF	Mid-Atlantic	2	53	Large1	90,296	1,041	27,027	582	0
7	Swine	Liquid	GF	Midwest	2	66	Large1	87,116	1,379	24,680	920	0
7	Swine	Liquid	GF	Mid-Atlantic	3	49	Large1	119,757	580	6,146	0	0
7	Swine	Liquid	GF	Midwest	3	61	Large1	115,367	580	5,920	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	62	Large2	883	975	189	511	0
7	Swine	Liquid	GF	Midwest	1	31	Large2	920	1,050	188	576	0
7	Swine	Liquid	GF	Mid-Atlantic	2	72	Large2	24,844	760	18,609	279	498,323
7	Swine	Liquid	GF	Midwest	2	37	Large2	26,702	892	20,006	410	342,942
7	Swine	Liquid	GF	Mid-Atlantic	3	38	Large2	290,778	580	73,215	0	0
7	Swine	Liquid	GF	Midwest	3	19	Large2	327,157	580	82,531	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	92	Large2	968	4,444	241	4,252	0
7	Swine	Liquid	GF	Midwest	1	47	Large2	982	5,447	227	5,172	0
7	Swine	Liquid	GF	Mid-Atlantic	2	108	Large2	213,853	1,219	57,568	775	0
7	Swine	Liquid	GF	Midwest	2	55	Large2	240,089	1,689	59,408	1,244	0
7	Swine	Liquid	GF	Mid-Atlantic	3	56	Large2	290,778	580	14,948	0	0
7	Swine	Liquid	GF	Midwest	3	29	Large2	327,157	580	16,821	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	99	Medium1a	1,281	685	401	227	0
7	Swine	Liquid	GF	Midwest	1	573	Medium1a	1,222	651	571	191	0
7	Swine	Liquid	GF	Mid-Atlantic	2	12	Medium1a	10,958	639	7,014	180	41,347
7	Swine	Liquid	GF	Midwest	2	68	Medium1a	10,740	653	7,072	194	0
7	Swine	Liquid	GF	Mid-Atlantic	3	20	Medium1a	37,029	580	8,304	0	0
7	Swine	Liquid	GF	Midwest	3	118	Medium1a	34,999	580	7,986	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	148	Medium1a	2,204	1,607	968	1,198	0

Table 11-12. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3 yr rec	5 yr rec
7	Swine	Liquid	GF	Midwest	1	859	Medium1a	1,780	1,314	914	884	0
7	Swine	Liquid	GF	Mid-Atlantic	2	18	Medium1a	32,178	1,026	11,569	586	0
7	Swine	Liquid	GF	Midwest	2	103	Medium1a	11,125	1,110	8,215	671	0
7	Swine	Liquid	GF	Mid-Atlantic	3	31	Medium1a	37,029	580	1,995	0	0
7	Swine	Liquid	GF	Midwest	3	176	Medium1a	34,999	580	2,089	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	18	Medium1b	1,449	746	440	292	0
7	Swine	Liquid	GF	Midwest	1	102	Medium1b	1,360	692	595	234	0
7	Swine	Liquid	GF	Mid-Atlantic	2	2	Medium1b	45,091	639	8,964	180	0
7	Swine	Liquid	GF	Midwest	2	12	Medium1b	12,441	651	8,169	191	50,244
7	Swine	Liquid	GF	Mid-Atlantic	3	4	Medium1b	54,985	580	12,882	0	0
7	Swine	Liquid	GF	Midwest	3	21	Medium1b	51,801	580	12,268	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	26	Medium1b	2,907	2,202	1,336	1,825	0
7	Swine	Liquid	GF	Midwest	1	154	Medium1b	2,243	1,740	1,137	1,329	0
7	Swine	Liquid	GF	Mid-Atlantic	2	3	Medium1b	45,478	1,026	15,155	586	0
7	Swine	Liquid	GF	Midwest	2	18	Medium1b	43,124	1,110	14,088	671	0
7	Swine	Liquid	GF	Mid-Atlantic	3	5	Medium1b	54,985	580	2,916	0	0
7	Swine	Liquid	GF	Midwest	3	32	Medium1b	51,801	580	2,951	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	49	Medium2	1,626	818	487	368	0
7	Swine	Liquid	GF	Midwest	1	126	Medium2	1,520	748	625	292	0
7	Swine	Liquid	GF	Mid-Atlantic	2	10	Medium2	14,676	709	9,415	253	100,722
7	Swine	Liquid	GF	Midwest	2	25	Medium2	14,513	734	9,508	278	15,133
7	Swine	Liquid	GF	Mid-Atlantic	3	12	Medium2	76,299	580	18,320	0	0
7	Swine	Liquid	GF	Midwest	3	30	Medium2	74,370	580	18,027	0	0
7	Swine	Liquid	GF	Mid-Atlantic	1	73	Medium2	3,719	2,909	1,772	2,570	0
7	Swine	Liquid	GF	Midwest	1	188	Medium2	2,839	2,313	1,435	1,928	0
7	Swine	Liquid	GF	Mid-Atlantic	2	14	Medium2	61,477	1,319	19,440	896	0
7	Swine	Liquid	GF	Midwest	2	37	Medium2	60,058	1,459	18,314	1,035	0
7	Swine	Liquid	GF	Mid-Atlantic	3	17	Medium2	76,299	580	4,011	0	0
7	Swine	Liquid	GF	Midwest	3	44	Medium2	74,370	580	4,110	0	0

Table 11-13. Regulatory Compliance Costs for the Poultry (BR, broiler; LA, dry layers; LW, wet layers) Operations

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
1	Chic	Solid	BR	Mid-Atlantic	1	47	Large1	64,538	2,214	2,249	2,391	0
1	Chic	Solid	BR	South	1	98	Large1	65,498	2,453	2,432	2,740	0
1	Chic	Solid	BR	Mid-Atlantic	2	687	Large1	63,405	890	2,289	536	0
1	Chic	Solid	BR	South	2	1,417	Large1	63,932	851	2,158	496	0
1	Chic	Solid	BR	Mid-Atlantic	3	336	Large1	62,675	580	1,355	0	0
1	Chic	Solid	BR	South	3	694	Large1	63,142	580	1,268	0	0
1	Chic	Solid	BR	Mid-Atlantic	1	7	Large2	168,396	4,878	4,342	6,120	0
1	Chic	Solid	BR	South	1	21	Large2	155,678	5,064	4,659	6,395	0
1	Chic	Solid	BR	Mid-Atlantic	2	132	Large2	165,119	1,047	3,439	756	0
1	Chic	Solid	BR	South	2	301	Large2	151,693	988	3,248	688	0
1	Chic	Solid	BR	Mid-Atlantic	3	53	Large2	164,255	580	2,049	0	0
1	Chic	Solid	BR	South	3	147	Large2	150,769	580	1,927	0	0
1	Chic	Solid	BR	Mid-Atlantic	1	108	Medium1a	21,127	1,075	1,351	791	0
1	Chic	Solid	BR	South	1	170	Medium1a	20,967	1,172	1,383	946	0
1	Chic	Solid	BR	Mid-Atlantic	2	904	Medium1a	20,831	747	1,362	331	0
1	Chic	Solid	BR	South	2	1,430	Medium1a	20,547	736	1,382	336	0
1	Chic	Solid	BR	Mid-Atlantic	3	677	Medium1a	20,239	580	1,043	0	0
1	Chic	Solid	BR	South	3	1,072	Medium1a	19,872	580	992	0	0
1	Chic	Solid	BR	Mid-Atlantic	1	50	Medium1b	29,305	1,274	1,539	1,069	0
1	Chic	Solid	BR	South	1	78	Medium1b	29,076	1,410	1,614	1,279	0
1	Chic	Solid	BR	Mid-Atlantic	2	415	Medium1b	28,830	747	1,559	331	0
1	Chic	Solid	BR	South	2	656	Medium1b	28,427	736	1,614	336	0
1	Chic	Solid	BR	Mid-Atlantic	3	311	Medium1b	28,237	580	1,122	0	0
1	Chic	Solid	BR	South	3	491	Medium1b	27,751	580	1,083	0	0
1	Chic	Solid	BR	Mid-Atlantic	1	61	Medium2	41,467	1,570	1,714	1,483	0
1	Chic	Solid	BR	South	1	122	Medium2	41,417	1,772	1,838	1,786	0
1	Chic	Solid	BR	Mid-Atlantic	2	737	Medium2	40,767	794	1,744	397	0
1	Chic	Solid	BR	South	2	1,467	Medium2	40,467	787	1,772	407	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
1	Chic	Solid	BR	Mid-Atlantic	3	486	Medium2	40,132	580	1,133	0	0
1	Chic	Solid	BR	South	3	967	Medium2	39,743	580	1,092	0	0
1	Chic	Solid	LA	Midwest	1	2	Large1	59,137	2,901	1,123	4,426	0
1	Chic	Solid	LA	South	1	4	Large1	52,774	2,430	1,457	3,441	0
1	Chic	Solid	LA	Midwest	2	102	Large1	58,186	875	1,235	660	0
1	Chic	Solid	LA	South	2	127	Large1	51,323	821	1,315	545	0
1	Chic	Solid	LA	Midwest	3	115	Large1	57,840	580	439	0	0
1	Chic	Solid	LA	South	3	144	Large1	50,843	580	412	0	0
1	Chic	Solid	LA	Midwest	1	0	Large2	259,389	10,799	4,442	19,106	0
1	Chic	Solid	LA	South	1	0	Large2	158,261	6,153	4,120	10,143	0
1	Chic	Solid	LA	Midwest	2	23	Large2	254,878	1,187	3,101	1,239	0
1	Chic	Solid	LA	South	2	40	Large2	153,681	1,076	2,848	1,004	0
1	Chic	Solid	LA	Midwest	3	26	Large2	254,386	580	1,481	0	0
1	Chic	Solid	LA	South	3	45	Large2	152,971	580	1,012	0	0
1	Chic	Solid	LA	Midwest	1	10	Medium1a	8,268	895	272	697	0
1	Chic	Solid	LA	South	1	9	Medium1a	6,146	784	292	478	0
1	Chic	Solid	LA	Midwest	2	84	Medium1a	8,187	722	317	376	0
1	Chic	Solid	LA	South	2	78	Medium1a	6,067	696	307	321	0
1	Chic	Solid	LA	Midwest	3	46	Medium1a	7,913	580	166	0	0
1	Chic	Solid	LA	South	3	43	Medium1a	5,700	580	159	0	0
1	Chic	Solid	LA	Midwest	1	6	Medium1b	11,362	1,017	333	924	0
1	Chic	Solid	LA	South	1	6	Medium1b	8,384	863	338	621	0
1	Chic	Solid	LA	Midwest	2	55	Medium1b	11,224	722	412	376	0
1	Chic	Solid	LA	South	2	52	Medium1b	8,234	696	368	321	0
1	Chic	Solid	LA	Midwest	3	30	Medium1b	10,950	580	192	0	0
1	Chic	Solid	LA	South	3	29	Medium1b	7,867	580	161	0	0
1	Chic	Solid	LA	Midwest	1	18	Medium2	20,828	1,390	470	1,618	0
1	Chic	Solid	LA	South	1	20	Medium2	17,759	1,194	572	1,216	0
1	Chic	Solid	LA	Midwest	2	146	Medium2	20,582	865	610	641	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
1	Chic	Solid	LA	South	2	176	Medium2	17,415	813	640	530	0
1	Chic	Solid	LA	Midwest	3	117	Medium2	20,240	580	221	0	0
1	Chic	Solid	LA	South	3	142	Medium2	16,943	580	212	0	0
1	Chic	Liquid	LW	South	1	24	Large1	1,053	1,128	460	1,097	0
1	Chic	Liquid	LW	South	2	217	Large1	107,287	799	23,262	505	0
1	Chic	Liquid	LW	South	3	119	Large1	106,827	580	7,046	0	0
1	Chic	Liquid	LW	South	1	97	Medium2	415	603	166	153	0
1	Chic	Liquid	LW	South	2	393	Medium2	10,221	590	1,232	130	0
1	Chic	Liquid	LW	South	3	310	Medium2	9,949	580	530	0	0
2	Chic	Solid	BR	Mid-Atlantic	1	28	Large1	65,240	3,036	2,680	3,541	0
2	Chic	Solid	BR	South	1	39	Large1	67,908	4,917	3,912	6,189	0
2	Chic	Solid	BR	Mid-Atlantic	2	412	Large1	63,427	916	6,327	573	0
2	Chic	Solid	BR	South	2	567	Large1	63,964	884	3,538	543	0
2	Chic	Solid	BR	Mid-Atlantic	3	202	Large1	62,675	580	1,355	0	0
2	Chic	Solid	BR	South	3	278	Large1	63,142	580	1,268	0	0
2	Chic	Solid	BR	Mid-Atlantic	1	4	Large2	170,244	7,038	5,476	9,144	0
2	Chic	Solid	BR	South	1	8	Large2	161,445	10,963	8,201	14,653	0
2	Chic	Solid	BR	Mid-Atlantic	2	79	Large2	165,162	1,097	10,330	827	0
2	Chic	Solid	BR	South	2	120	Large2	151,736	1,033	5,286	751	0
2	Chic	Solid	BR	Mid-Atlantic	3	32	Large2	164,255	580	2,049	0	0
2	Chic	Solid	BR	South	3	59	Large2	150,769	580	1,927	0	0
2	Chic	Solid	BR	Mid-Atlantic	1	65	Medium1a	21,351	1,324	1,488	1,139	0
2	Chic	Solid	BR	South	1	68	Medium1a	21,717	1,950	1,844	2,036	0
2	Chic	Solid	BR	Mid-Atlantic	2	542	Medium1a	20,856	774	2,481	369	0
2	Chic	Solid	BR	South	2	572	Medium1a	20,571	761	1,849	371	0
2	Chic	Solid	BR	Mid-Atlantic	3	406	Medium1a	20,239	580	1,043	0	0
2	Chic	Solid	BR	South	3	429	Medium1a	19,872	580	992	0	0
2	Chic	Solid	BR	Mid-Atlantic	1	30	Medium1b	29,619	1,623	1,732	1,557	0
2	Chic	Solid	BR	South	1	31	Medium1b	30,128	2,501	2,261	2,807	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
2	Chic	Solid	BR	Mid-Atlantic	2	249	Medium1b	28,854	774	3,268	369	0
2	Chic	Solid	BR	South	2	262	Medium1b	28,451	761	2,269	371	0
2	Chic	Solid	BR	Mid-Atlantic	3	187	Medium1b	28,237	580	1,122	0	0
2	Chic	Solid	BR	South	3	196	Medium1b	27,751	580	1,083	0	0
2	Chic	Solid	BR	Mid-Atlantic	1	37	Medium2	41,915	2,067	1,990	2,180	0
2	Chic	Solid	BR	South	1	49	Medium2	42,929	3,340	2,766	3,982	0
2	Chic	Solid	BR	Mid-Atlantic	2	442	Medium2	40,791	821	4,249	435	0
2	Chic	Solid	BR	South	2	587	Medium2	40,485	805	2,779	432	0
2	Chic	Solid	BR	Mid-Atlantic	3	292	Medium2	40,132	580	1,133	0	0
2	Chic	Solid	BR	South	3	387	Medium2	39,743	580	1,092	0	0
2	Chic	Solid	LA	Midwest	1	1	Large1	65,120	15,651	4,798	28,125	0
2	Chic	Solid	LA	South	1	2	Large1	61,940	12,589	7,086	21,728	0
2	Chic	Solid	LA	Midwest	2	61	Large1	58,227	962	2,370	822	0
2	Chic	Solid	LA	South	2	51	Large1	51,387	892	3,330	674	0
2	Chic	Solid	LA	Midwest	3	69	Large1	57,840	580	439	0	0
2	Chic	Solid	LA	South	3	58	Large1	50,843	580	412	0	0
2	Chic	Solid	LA	Midwest	1	0	Large2	285,727	66,923	20,617	123,431	0
2	Chic	Solid	LA	South	1	0	Large2	185,877	36,762	21,080	65,239	0
2	Chic	Solid	LA	Midwest	2	14	Large2	254,898	1,230	4,751	1,319	0
2	Chic	Solid	LA	South	2	16	Large2	153,712	1,111	5,955	1,067	0
2	Chic	Solid	LA	Midwest	3	16	Large2	254,386	580	1,481	0	0
2	Chic	Solid	LA	South	3	18	Large2	152,971	580	1,012	0	0
2	Chic	Solid	LA	Midwest	1	6	Medium1a	9,081	2,626	771	3,914	0
2	Chic	Solid	LA	South	1	4	Medium1a	7,157	1,905	913	2,495	0
2	Chic	Solid	LA	Midwest	2	50	Medium1a	8,203	757	499	439	0
2	Chic	Solid	LA	South	2	31	Medium1a	6,092	724	571	371	0
2	Chic	Solid	LA	Midwest	3	28	Medium1a	7,913	580	166	0	0
2	Chic	Solid	LA	South	3	17	Medium1a	5,700	580	159	0	0
2	Chic	Solid	LA	Midwest	1	4	Medium1b	12,489	3,418	1,025	5,387	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
2	Chic	Solid	LA	South	1	2	Medium1b	9,787	2,417	1,199	3,419	0
2	Chic	Solid	LA	Midwest	2	33	Medium1b	11,240	757	639	439	0
2	Chic	Solid	LA	South	2	21	Medium1b	8,259	724	709	371	0
2	Chic	Solid	LA	Midwest	3	18	Medium1b	10,950	580	192	0	0
2	Chic	Solid	LA	South	3	12	Medium1b	7,867	580	161	0	0
2	Chic	Solid	LA	Midwest	1	11	Medium2	22,917	5,842	1,753	9,892	0
2	Chic	Solid	LA	South	1	8	Medium2	20,801	4,566	2,440	7,285	0
2	Chic	Solid	LA	Midwest	2	88	Medium2	20,621	949	1,043	797	0
2	Chic	Solid	LA	South	2	70	Medium2	17,477	881	1,373	654	0
2	Chic	Solid	LA	Midwest	3	70	Medium2	20,240	580	221	0	0
2	Chic	Solid	LA	South	3	57	Medium2	16,943	580	212	0	0
2	Chic	Liquid	LW	South	1	10	Large1	3,767	4,135	2,126	6,511	0
2	Chic	Liquid	LW	South	2	87	Large1	107,325	841	20,209	580	0
2	Chic	Liquid	LW	South	3	48	Large1	106,827	580	2,745	0	0
2	Chic	Liquid	LW	South	1	39	Medium2	529	729	236	380	0
2	Chic	Liquid	LW	South	2	157	Medium2	10,259	632	1,126	205	0
2	Chic	Liquid	LW	South	3	124	Medium2	9,949	580	350	0	0
3	Chic	Solid	BR	Mid-Atlantic	1	4	Large1	69,049	2,214	3,281	2,391	3,082
3	Chic	Solid	BR	South	1	13	Large1	69,793	2,453	3,402	2,740	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	66	Large1	67,916	890	3,321	536	3,082
3	Chic	Solid	BR	South	2	191	Large1	68,226	851	3,128	496	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	32	Large1	67,187	580	2,387	0	3,082
3	Chic	Solid	BR	South	3	93	Large1	67,437	580	2,238	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	7	Large1	69,752	3,036	3,712	3,541	3,082
3	Chic	Solid	BR	South	1	9	Large1	72,202	4,917	4,882	6,189	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	99	Large1	67,938	916	7,359	573	3,082
3	Chic	Solid	BR	South	2	127	Large1	68,259	884	4,508	543	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	48	Large1	67,187	580	2,387	0	3,082
3	Chic	Solid	BR	South	3	62	Large1	67,437	580	2,238	0	3,082

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3	Chic	Solid	BR	Mid-Atlantic	1	1	Large2	178,012	4,878	5,475	6,120	3,082
3	Chic	Solid	BR	South	1	3	Large2	164,153	5,064	5,712	6,395	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	13	Large2	174,735	1,047	4,572	756	3,082
3	Chic	Solid	BR	South	2	41	Large2	160,168	988	4,301	688	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	5	Large2	173,871	580	3,182	0	3,082
3	Chic	Solid	BR	South	3	20	Large2	159,244	580	2,980	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	1	Large2	179,859	7,038	6,609	9,144	3,082
3	Chic	Solid	BR	South	1	2	Large2	169,920	10,963	9,254	14,653	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	19	Large2	174,778	1,097	11,463	827	3,082
3	Chic	Solid	BR	South	2	27	Large2	160,211	1,033	6,338	751	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	8	Large2	173,871	580	3,182	0	3,082
3	Chic	Solid	BR	South	3	13	Large2	159,244	580	2,980	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	10	Medium1a	23,506	1,075	2,340	791	3,082
3	Chic	Solid	BR	South	1	23	Medium1a	23,197	1,172	2,312	946	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	86	Medium1a	23,210	747	2,352	331	3,082
3	Chic	Solid	BR	South	2	193	Medium1a	22,777	736	2,311	336	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	65	Medium1a	22,618	580	2,033	0	3,082
3	Chic	Solid	BR	South	3	144	Medium1a	22,101	580	1,921	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	15	Medium1a	23,730	1,324	2,478	1,139	3,082
3	Chic	Solid	BR	South	1	15	Medium1a	23,947	1,950	2,772	2,036	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	130	Medium1a	23,235	774	3,470	369	3,082
3	Chic	Solid	BR	South	2	128	Medium1a	22,801	761	2,778	371	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	97	Medium1a	22,618	580	2,033	0	3,082
3	Chic	Solid	BR	South	3	96	Medium1a	22,101	580	1,921	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	5	Medium1b	32,086	1,274	2,537	1,069	3,082
3	Chic	Solid	BR	South	1	11	Medium1b	31,682	1,410	2,551	1,279	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	40	Medium1b	31,611	747	2,556	331	3,082
3	Chic	Solid	BR	South	2	88	Medium1b	31,032	736	2,550	336	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	30	Medium1b	31,019	580	2,119	0	3,082

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3	Chic	Solid	BR	South	3	66	Medium1b	30,357	580	2,020	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	7	Medium1b	32,400	1,623	2,730	1,557	3,082
3	Chic	Solid	BR	South	1	7	Medium1b	32,734	2,501	3,197	2,807	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	60	Medium1b	31,636	774	4,266	369	3,082
3	Chic	Solid	BR	South	2	59	Medium1b	31,057	761	3,206	371	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	45	Medium1b	31,019	580	2,119	0	3,082
3	Chic	Solid	BR	South	3	44	Medium1b	30,357	580	2,020	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	6	Medium2	44,846	1,570	2,724	1,483	3,082
3	Chic	Solid	BR	South	1	16	Medium2	44,594	1,772	2,786	1,786	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	70	Medium2	44,146	794	2,753	397	3,082
3	Chic	Solid	BR	South	2	198	Medium2	43,645	787	2,720	407	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	46	Medium2	43,511	580	2,142	0	3,082
3	Chic	Solid	BR	South	3	130	Medium2	42,920	580	2,040	0	3,082
3	Chic	Solid	BR	Mid-Atlantic	1	9	Medium2	45,294	2,067	2,999	2,180	3,082
3	Chic	Solid	BR	South	1	11	Medium2	46,106	3,340	3,714	3,982	3,082
3	Chic	Solid	BR	Mid-Atlantic	2	106	Medium2	44,170	821	5,258	435	3,082
3	Chic	Solid	BR	South	2	132	Medium2	43,662	805	3,726	432	3,082
3	Chic	Solid	BR	Mid-Atlantic	3	70	Medium2	43,511	580	2,142	0	3,082
3	Chic	Solid	BR	South	3	87	Medium2	42,920	580	2,040	0	3,082
3	Chic	Solid	LA	Midwest	1	0	Large1	62,939	2,901	2,281	4,426	2,746
3	Chic	Solid	LA	South	1	1	Large1	55,975	2,430	2,405	3,441	1,849
3	Chic	Solid	LA	Midwest	2	11	Large1	61,988	875	2,393	660	2,746
3	Chic	Solid	LA	South	2	17	Large1	54,524	821	2,263	545	1,849
3	Chic	Solid	LA	Midwest	3	13	Large1	61,642	580	1,597	0	2,746
3	Chic	Solid	LA	South	3	19	Large1	54,044	580	1,360	0	1,849
3	Chic	Solid	LA	Midwest	1	0	Large1	68,922	15,651	5,955	28,125	2,746
3	Chic	Solid	LA	South	1	0	Large1	65,141	12,589	8,034	21,728	1,849
3	Chic	Solid	LA	Midwest	2	17	Large1	62,029	962	3,528	822	2,746
3	Chic	Solid	LA	South	2	11	Large1	54,588	892	4,278	674	1,849

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3	Chic	Solid	LA	Midwest	3	19	Large1	61,642	580	1,597	0	2,746
3	Chic	Solid	LA	South	3	13	Large1	54,044	580	1,360	0	1,849
3	Chic	Solid	LA	Midwest	1	0	Large2	270,735	10,799	5,748	19,106	2,746
3	Chic	Solid	LA	South	1	0	Large2	165,299	6,153	5,144	10,143	1,849
3	Chic	Solid	LA	Midwest	2	3	Large2	266,224	1,187	4,408	1,239	2,746
3	Chic	Solid	LA	South	2	5	Large2	160,718	1,076	3,872	1,004	1,849
3	Chic	Solid	LA	Midwest	3	3	Large2	265,732	580	2,788	0	2,746
3	Chic	Solid	LA	South	3	6	Large2	160,008	580	2,036	0	1,849
3	Chic	Solid	LA	Midwest	1	0	Large2	297,074	66,923	21,924	123,431	2,746
3	Chic	Solid	LA	South	1	0	Large2	192,914	36,762	22,104	65,239	1,849
3	Chic	Solid	LA	Midwest	2	4	Large2	266,244	1,230	6,058	1,319	2,746
3	Chic	Solid	LA	South	2	4	Large2	160,749	1,111	6,979	1,067	1,849
3	Chic	Solid	LA	Midwest	3	4	Large2	265,732	580	2,788	0	2,746
3	Chic	Solid	LA	South	3	4	Large2	160,008	580	2,036	0	1,849
3	Chic	Solid	LA	Midwest	1	1	Medium1a	10,154	895	1,391	697	2,746
3	Chic	Solid	LA	South	1	1	Medium1a	7,652	784	1,207	478	1,849
3	Chic	Solid	LA	Midwest	2	9	Medium1a	10,073	722	1,437	376	2,746
3	Chic	Solid	LA	South	2	11	Medium1a	7,573	696	1,222	321	1,849
3	Chic	Solid	LA	Midwest	3	5	Medium1a	9,798	580	1,285	0	2,746
3	Chic	Solid	LA	South	3	6	Medium1a	7,205	580	1,074	0	1,849
3	Chic	Solid	LA	Midwest	1	2	Medium1a	10,966	2,626	1,890	3,914	2,746
3	Chic	Solid	LA	South	1	1	Medium1a	8,663	1,905	1,828	2,495	1,849
3	Chic	Solid	LA	Midwest	2	14	Medium1a	10,089	757	1,619	439	2,746
3	Chic	Solid	LA	South	2	7	Medium1a	7,598	724	1,486	371	1,849
3	Chic	Solid	LA	Midwest	3	8	Medium1a	9,798	580	1,285	0	2,746
3	Chic	Solid	LA	South	3	4	Medium1a	7,205	580	1,074	0	1,849
3	Chic	Solid	LA	Midwest	1	1	Medium1b	13,364	1,017	1,455	924	2,746
3	Chic	Solid	LA	South	1	1	Medium1b	9,971	863	1,254	621	1,849
3	Chic	Solid	LA	Midwest	2	6	Medium1b	13,226	722	1,534	376	2,746

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3	Chic	Solid	LA	South	2	7	Medium1b	9,821	696	1,284	321	1,849
3	Chic	Solid	LA	Midwest	3	3	Medium1b	12,952	580	1,314	0	2,746
3	Chic	Solid	LA	South	3	4	Medium1b	9,453	580	1,078	0	1,849
3	Chic	Solid	LA	Midwest	1	1	Medium1b	14,491	3,418	2,147	5,387	2,746
3	Chic	Solid	LA	South	1	1	Medium1b	11,374	2,417	2,116	3,419	1,849
3	Chic	Solid	LA	Midwest	2	9	Medium1b	13,242	757	1,761	439	2,746
3	Chic	Solid	LA	South	2	5	Medium1b	9,846	724	1,625	371	1,849
3	Chic	Solid	LA	Midwest	3	5	Medium1b	12,952	580	1,314	0	2,746
3	Chic	Solid	LA	South	3	3	Medium1b	9,453	580	1,078	0	1,849
3	Chic	Solid	LA	Midwest	1	2	Medium2	23,187	1,390	1,599	1,618	2,746
3	Chic	Solid	LA	South	1	3	Medium2	19,687	1,194	1,495	1,216	1,849
3	Chic	Solid	LA	Midwest	2	16	Medium2	22,940	865	1,739	641	2,746
3	Chic	Solid	LA	South	2	24	Medium2	19,343	813	1,563	530	1,849
3	Chic	Solid	LA	Midwest	3	13	Medium2	22,599	580	1,350	0	2,746
3	Chic	Solid	LA	South	3	19	Medium2	18,871	580	1,135	0	1,849
3	Chic	Solid	LA	Midwest	1	3	Medium2	25,276	5,842	2,882	9,892	2,746
3	Chic	Solid	LA	South	1	2	Medium2	22,729	4,566	3,363	7,285	1,849
3	Chic	Solid	LA	Midwest	2	24	Medium2	22,980	949	2,172	797	2,746
3	Chic	Solid	LA	South	2	16	Medium2	19,405	881	2,296	654	1,849
3	Chic	Solid	LA	Midwest	3	19	Medium2	22,599	580	1,350	0	2,746
3	Chic	Solid	LA	South	3	13	Medium2	18,871	580	1,135	0	1,849
3	Chic	Liquid	LW	South	1	3	Large1	18,612	1,128	2,159	1,097	1,849
3	Chic	Liquid	LW	South	2	29	Large1	124,846	799	24,961	505	1,849
3	Chic	Liquid	LW	South	3	16	Large1	124,386	580	8,745	0	1,849
3	Chic	Liquid	LW	South	1	2	Large1	21,326	4,135	3,825	6,511	1,849
3	Chic	Liquid	LW	South	2	19	Large1	124,884	841	21,907	580	1,849
3	Chic	Liquid	LW	South	3	11	Large1	124,386	580	4,444	0	1,849
3	Chic	Liquid	LW	South	1	13	Medium2	3,095	603	1,144	153	1,849
3	Chic	Liquid	LW	South	2	53	Medium2	12,901	590	2,210	130	1,849

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3	Chic	Liquid	LW	South	3	42	Medium2	12,629	580	1,509	0	1,849
3	Chic	Liquid	LW	South	1	9	Medium2	3,209	729	1,214	380	1,849
3	Chic	Liquid	LW	South	2	35	Medium2	12,939	632	2,104	205	1,849
3	Chic	Liquid	LW	South	3	28	Medium2	12,629	580	1,328	0	1,849
3.1	Chic	Solid	BR	Mid-Atlantic	1	14	Large1	64,538	2,214	2,249	2,391	3,082
3.1	Chic	Solid	BR	South	1	46	Large1	65,498	2,453	2,432	2,740	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	209	Large1	63,405	890	2,289	536	3,082
3.1	Chic	Solid	BR	South	2	659	Large1	63,932	851	2,158	496	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	102	Large1	62,675	580	1,355	0	3,082
3.1	Chic	Solid	BR	South	3	323	Large1	63,142	580	1,268	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	21	Large1	65,240	3,036	2,680	3,541	3,082
3.1	Chic	Solid	BR	South	1	30	Large1	67,908	4,917	3,912	6,189	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	314	Large1	63,427	916	6,327	573	3,082
3.1	Chic	Solid	BR	South	2	440	Large1	63,964	884	3,538	543	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	153	Large1	62,675	580	1,355	0	3,082
3.1	Chic	Solid	BR	South	3	215	Large1	63,142	580	1,268	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	2	Large2	168,396	4,878	4,342	6,120	3,082
3.1	Chic	Solid	BR	South	1	10	Large2	155,678	5,064	4,659	6,395	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	40	Large2	165,119	1,047	3,439	756	3,082
3.1	Chic	Solid	BR	South	2	140	Large2	151,693	988	3,248	688	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	16	Large2	164,255	580	2,049	0	3,082
3.1	Chic	Solid	BR	South	3	68	Large2	150,769	580	1,927	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	3	Large2	170,244	7,038	5,476	9,144	3,082
3.1	Chic	Solid	BR	South	1	7	Large2	161,445	10,963	8,201	14,653	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	60	Large2	165,162	1,097	10,330	827	3,082
3.1	Chic	Solid	BR	South	2	93	Large2	151,736	1,033	5,286	751	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	24	Large2	164,255	580	2,049	0	3,082
3.1	Chic	Solid	BR	South	3	46	Large2	150,769	580	1,927	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	33	Medium1a	21,127	1,075	1,351	791	3,082

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3.1	Chic	Solid	BR	South	1	79	Medium1a	20,967	1,172	1,383	946	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	275	Medium1a	20,831	747	1,362	331	3,082
3.1	Chic	Solid	BR	South	2	665	Medium1a	20,547	736	1,382	336	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	206	Medium1a	20,239	580	1,043	0	3,082
3.1	Chic	Solid	BR	South	3	499	Medium1a	19,872	580	992	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	49	Medium1a	21,351	1,324	1,488	1,139	3,082
3.1	Chic	Solid	BR	South	1	53	Medium1a	21,717	1,950	1,844	2,036	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	413	Medium1a	20,856	774	2,481	369	3,082
3.1	Chic	Solid	BR	South	2	444	Medium1a	20,571	761	1,849	371	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	309	Medium1a	20,239	580	1,043	0	3,082
3.1	Chic	Solid	BR	South	3	333	Medium1a	19,872	580	992	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	15	Medium1b	29,305	1,274	1,539	1,069	3,082
3.1	Chic	Solid	BR	South	1	36	Medium1b	29,076	1,410	1,614	1,279	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	126	Medium1b	28,830	747	1,559	331	3,082
3.1	Chic	Solid	BR	South	2	305	Medium1b	28,427	736	1,614	336	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	95	Medium1b	28,237	580	1,122	0	3,082
3.1	Chic	Solid	BR	South	3	228	Medium1b	27,751	580	1,083	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	23	Medium1b	29,619	1,623	1,732	1,557	3,082
3.1	Chic	Solid	BR	South	1	24	Medium1b	30,128	2,501	2,261	2,807	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	189	Medium1b	28,854	774	3,268	369	3,082
3.1	Chic	Solid	BR	South	2	203	Medium1b	28,451	761	2,269	371	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	142	Medium1b	28,237	580	1,122	0	3,082
3.1	Chic	Solid	BR	South	3	152	Medium1b	27,751	580	1,083	0	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	1	19	Medium2	41,467	1,570	1,714	1,483	3,082
3.1	Chic	Solid	BR	South	1	57	Medium2	41,417	1,772	1,838	1,786	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	224	Medium2	40,767	794	1,744	397	3,082
3.1	Chic	Solid	BR	South	2	683	Medium2	40,467	787	1,772	407	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	148	Medium2	40,132	580	1,133	0	3,082
3.1	Chic	Solid	BR	South	3	450	Medium2	39,743	580	1,092	0	3,082

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3.1	Chic	Solid	BR	Mid-Atlantic	1	28	Medium2	41,915	2,067	1,990	2,180	3,082
3.1	Chic	Solid	BR	South	1	38	Medium2	42,929	3,340	2,766	3,982	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	2	336	Medium2	40,791	821	4,249	435	3,082
3.1	Chic	Solid	BR	South	2	455	Medium2	40,485	805	2,779	432	3,082
3.1	Chic	Solid	BR	Mid-Atlantic	3	222	Medium2	40,132	580	1,133	0	3,082
3.1	Chic	Solid	BR	South	3	300	Medium2	39,743	580	1,092	0	3,082
3.1	Chic	Solid	LA	Midwest	1	1	Large1	59,137	2,901	1,123	4,426	2,746
3.1	Chic	Solid	LA	South	1	2	Large1	52,774	2,430	1,457	3,441	1,849
3.1	Chic	Solid	LA	Midwest	2	30	Large1	58,186	875	1,235	660	2,746
3.1	Chic	Solid	LA	South	2	59	Large1	51,323	821	1,315	545	1,849
3.1	Chic	Solid	LA	Midwest	3	33	Large1	57,840	580	439	0	2,746
3.1	Chic	Solid	LA	South	3	67	Large1	50,843	580	412	0	1,849
3.1	Chic	Solid	LA	Midwest	1	1	Large1	65,120	15,651	4,798	28,125	2,746
3.1	Chic	Solid	LA	South	1	1	Large1	61,940	12,589	7,086	21,728	1,849
3.1	Chic	Solid	LA	Midwest	2	44	Large1	58,227	962	2,370	822	2,746
3.1	Chic	Solid	LA	South	2	39	Large1	51,387	892	3,330	674	1,849
3.1	Chic	Solid	LA	Midwest	3	50	Large1	57,840	580	439	0	2,746
3.1	Chic	Solid	LA	South	3	45	Large1	50,843	580	412	0	1,849
3.1	Chic	Solid	LA	Midwest	1	0	Large2	259,389	10,799	4,442	19,106	2,746
3.1	Chic	Solid	LA	South	1	0	Large2	158,261	6,153	4,120	10,143	1,849
3.1	Chic	Solid	LA	Midwest	2	7	Large2	254,878	1,187	3,101	1,239	2,746
3.1	Chic	Solid	LA	South	2	19	Large2	153,681	1,076	2,848	1,004	1,849
3.1	Chic	Solid	LA	Midwest	3	8	Large2	254,386	580	1,481	0	2,746
3.1	Chic	Solid	LA	South	3	21	Large2	152,971	580	1,012	0	1,849
3.1	Chic	Solid	LA	Midwest	1	0	Large2	285,727	66,923	20,617	123,431	2,746
3.1	Chic	Solid	LA	South	1	0	Large2	185,877	36,762	21,080	65,239	1,849
3.1	Chic	Solid	LA	Midwest	2	10	Large2	254,898	1,230	4,751	1,319	2,746
3.1	Chic	Solid	LA	South	2	12	Large2	153,712	1,111	5,955	1,067	1,849
3.1	Chic	Solid	LA	Midwest	3	11	Large2	254,386	580	1,481	0	2,746

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3.1	Chic	Solid	LA	South	3	14	Large2	152,971	580	1,012	0	1,849
3.1	Chic	Solid	LA	Midwest	1	3	Medium1a	8,268	895	272	697	2,746
3.1	Chic	Solid	LA	South	1	4	Medium1a	6,146	784	292	478	1,849
3.1	Chic	Solid	LA	Midwest	2	24	Medium1a	8,187	722	317	376	2,746
3.1	Chic	Solid	LA	South	2	36	Medium1a	6,067	696	307	321	1,849
3.1	Chic	Solid	LA	Midwest	3	13	Medium1a	7,913	580	166	0	2,746
3.1	Chic	Solid	LA	South	3	20	Medium1a	5,700	580	159	0	1,849
3.1	Chic	Solid	LA	Midwest	1	4	Medium1a	9,081	2,626	771	3,914	2,746
3.1	Chic	Solid	LA	South	1	3	Medium1a	7,157	1,905	913	2,495	1,849
3.1	Chic	Solid	LA	Midwest	2	37	Medium1a	8,203	757	499	439	2,746
3.1	Chic	Solid	LA	South	2	24	Medium1a	6,092	724	571	371	1,849
3.1	Chic	Solid	LA	Midwest	3	20	Medium1a	7,913	580	166	0	2,746
3.1	Chic	Solid	LA	South	3	13	Medium1a	5,700	580	159	0	1,849
3.1	Chic	Solid	LA	Midwest	1	2	Medium1b	11,362	1,017	333	924	2,746
3.1	Chic	Solid	LA	South	1	3	Medium1b	8,384	863	338	621	1,849
3.1	Chic	Solid	LA	Midwest	2	16	Medium1b	11,224	722	412	376	2,746
3.1	Chic	Solid	LA	South	2	24	Medium1b	8,234	696	368	321	1,849
3.1	Chic	Solid	LA	Midwest	3	9	Medium1b	10,950	580	192	0	2,746
3.1	Chic	Solid	LA	South	3	13	Medium1b	7,867	580	161	0	1,849
3.1	Chic	Solid	LA	Midwest	1	3	Medium1b	12,489	3,418	1,025	5,387	2,746
3.1	Chic	Solid	LA	South	1	2	Medium1b	9,787	2,417	1,199	3,419	1,849
3.1	Chic	Solid	LA	Midwest	2	24	Medium1b	11,240	757	639	439	2,746
3.1	Chic	Solid	LA	South	2	16	Medium1b	8,259	724	709	371	1,849
3.1	Chic	Solid	LA	Midwest	3	13	Medium1b	10,950	580	192	0	2,746
3.1	Chic	Solid	LA	South	3	9	Medium1b	7,867	580	161	0	1,849
3.1	Chic	Solid	LA	Midwest	1	5	Medium2	20,828	1,390	470	1,618	2,746
3.1	Chic	Solid	LA	South	1	9	Medium2	17,759	1,194	572	1,216	1,849
3.1	Chic	Solid	LA	Midwest	2	42	Medium2	20,582	865	610	641	2,746
3.1	Chic	Solid	LA	South	2	82	Medium2	17,415	813	640	530	1,849

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
3.1	Chic	Solid	LA	Midwest	3	34	Medium2	20,240	580	221	0	2,746
3.1	Chic	Solid	LA	South	3	66	Medium2	16,943	580	212	0	1,849
3.1	Chic	Solid	LA	Midwest	1	8	Medium2	22,917	5,842	1,753	9,892	2,746
3.1	Chic	Solid	LA	South	1	6	Medium2	20,801	4,566	2,440	7,285	1,849
3.1	Chic	Solid	LA	Midwest	2	64	Medium2	20,621	949	1,043	797	2,746
3.1	Chic	Solid	LA	South	2	55	Medium2	17,477	881	1,373	654	1,849
3.1	Chic	Solid	LA	Midwest	3	51	Medium2	20,240	580	221	0	2,746
3.1	Chic	Solid	LA	South	3	44	Medium2	16,943	580	212	0	1,849
3.1	Chic	Liquid	LW	South	1	11	Large1	1,053	1,128	460	1,097	1,849
3.1	Chic	Liquid	LW	South	2	101	Large1	107,287	799	23,262	505	1,849
3.1	Chic	Liquid	LW	South	3	55	Large1	106,827	580	7,046	0	1,849
3.1	Chic	Liquid	LW	South	1	7	Large1	3,767	4,135	2,126	6,511	1,849
3.1	Chic	Liquid	LW	South	2	67	Large1	107,325	841	20,209	580	1,849
3.1	Chic	Liquid	LW	South	3	37	Large1	106,827	580	2,745	0	1,849
3.1	Chic	Liquid	LW	South	1	45	Medium2	415	603	166	153	1,849
3.1	Chic	Liquid	LW	South	2	183	Medium2	10,221	590	1,232	130	1,849
3.1	Chic	Liquid	LW	South	3	144	Medium2	9,949	580	530	0	1,849
3.1	Chic	Liquid	LW	South	1	30	Medium2	529	729	236	380	1,849
3.1	Chic	Liquid	LW	South	2	122	Medium2	10,259	632	1,126	205	1,849
3.1	Chic	Liquid	LW	South	3	96	Medium2	9,949	580	350	0	1,849
4	Chic	Solid	BR	Mid-Atlantic	1	4	Large1	69,049	2,606	9,533	2,391	3,082
4	Chic	Solid	BR	South	1	13	Large1	69,793	2,845	9,654	2,740	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	66	Large1	67,916	1,282	9,573	536	3,082
4	Chic	Solid	BR	South	2	191	Large1	68,226	1,243	9,380	496	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	32	Large1	67,187	972	8,639	0	3,082
4	Chic	Solid	BR	South	3	93	Large1	67,437	972	8,490	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	7	Large1	69,752	3,428	9,964	3,541	3,082
4	Chic	Solid	BR	South	1	9	Large1	72,202	5,309	11,134	6,189	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	99	Large1	67,938	1,308	13,611	573	3,082

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4	Chic	Solid	BR	South	2	127	Large1	68,259	1,276	10,760	543	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	48	Large1	67,187	972	8,639	0	3,082
4	Chic	Solid	BR	South	3	62	Large1	67,437	972	8,490	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	1	Large2	178,012	5,270	11,727	6,120	3,082
4	Chic	Solid	BR	South	1	3	Large2	164,153	5,456	11,964	6,395	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	13	Large2	174,735	1,439	10,824	756	3,082
4	Chic	Solid	BR	South	2	41	Large2	160,168	1,380	10,553	688	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	5	Large2	173,871	972	9,434	0	3,082
4	Chic	Solid	BR	South	3	20	Large2	159,244	972	9,232	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	1	Large2	179,859	7,430	12,861	9,144	3,082
4	Chic	Solid	BR	South	1	2	Large2	169,920	11,355	15,506	14,653	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	19	Large2	174,778	1,489	17,715	827	3,082
4	Chic	Solid	BR	South	2	27	Large2	160,211	1,425	12,590	751	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	8	Large2	173,871	972	9,434	0	3,082
4	Chic	Solid	BR	South	3	13	Large2	159,244	972	9,232	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	10	Medium1a	23,506	1,467	8,592	791	3,082
4	Chic	Solid	BR	South	1	23	Medium1a	23,197	1,564	8,564	946	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	86	Medium1a	23,210	1,139	8,604	331	3,082
4	Chic	Solid	BR	South	2	193	Medium1a	22,777	1,128	8,563	336	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	65	Medium1a	22,618	972	8,285	0	3,082
4	Chic	Solid	BR	South	3	144	Medium1a	22,101	972	8,173	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	15	Medium1a	23,730	1,716	8,730	1,139	3,082
4	Chic	Solid	BR	South	1	15	Medium1a	23,947	2,342	9,024	2,036	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	130	Medium1a	23,235	1,166	9,722	369	3,082
4	Chic	Solid	BR	South	2	128	Medium1a	22,801	1,153	9,030	371	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	97	Medium1a	22,618	972	8,285	0	3,082
4	Chic	Solid	BR	South	3	96	Medium1a	22,101	972	8,173	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	5	Medium1b	32,086	1,666	8,789	1,069	3,082
4	Chic	Solid	BR	South	1	11	Medium1b	31,682	1,802	8,803	1,279	3,082

Table 11-13. (Continued)												
Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4	Chic	Solid	BR	Mid-Atlantic	2	40	Medium1b	31,611	1,139	8,808	331	3,082
4	Chic	Solid	BR	South	2	88	Medium1b	31,032	1,128	8,802	336	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	30	Medium1b	31,019	972	8,371	0	3,082
4	Chic	Solid	BR	South	3	66	Medium1b	30,357	972	8,272	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	7	Medium1b	32,400	2,015	8,982	1,557	3,082
4	Chic	Solid	BR	South	1	7	Medium1b	32,734	2,893	9,449	2,807	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	60	Medium1b	31,636	1,166	10,518	369	3,082
4	Chic	Solid	BR	South	2	59	Medium1b	31,057	1,153	9,458	371	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	45	Medium1b	31,019	972	8,371	0	3,082
4	Chic	Solid	BR	South	3	44	Medium1b	30,357	972	8,272	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	6	Medium2	44,846	1,962	8,976	1,483	3,082
4	Chic	Solid	BR	South	1	16	Medium2	44,594	2,164	9,038	1,786	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	70	Medium2	44,146	1,186	9,005	397	3,082
4	Chic	Solid	BR	South	2	198	Medium2	43,645	1,179	8,972	407	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	46	Medium2	43,511	972	8,394	0	3,082
4	Chic	Solid	BR	South	3	130	Medium2	42,920	972	8,292	0	3,082
4	Chic	Solid	BR	Mid-Atlantic	1	9	Medium2	45,294	2,459	9,251	2,180	3,082
4	Chic	Solid	BR	South	1	11	Medium2	46,106	3,732	9,966	3,982	3,082
4	Chic	Solid	BR	Mid-Atlantic	2	106	Medium2	44,170	1,213	11,510	435	3,082
4	Chic	Solid	BR	South	2	132	Medium2	43,662	1,197	9,978	432	3,082
4	Chic	Solid	BR	Mid-Atlantic	3	70	Medium2	43,511	972	8,394	0	3,082
4	Chic	Solid	BR	South	3	87	Medium2	42,920	972	8,292	0	3,082
4	Chic	Solid	LA	Midwest	1	0	Large1	62,939	3,293	8,533	4,426	2,746
4	Chic	Solid	LA	South	1	1	Large1	55,975	2,822	8,657	3,441	1,849
4	Chic	Solid	LA	Midwest	2	11	Large1	61,988	1,267	8,645	660	2,746
4	Chic	Solid	LA	South	2	17	Large1	54,524	1,213	8,515	545	1,849
4	Chic	Solid	LA	Midwest	3	13	Large1	61,642	972	7,849	0	2,746
4	Chic	Solid	LA	South	3	19	Large1	54,044	972	7,612	0	1,849
4	Chic	Solid	LA	Midwest	1	0	Large1	68,922	16,043	12,207	28,125	2,746

Table 11-13. (Continued)												
Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4	Chic	Solid	LA	South	1	0	Large1	65,141	12,981	14,286	21,728	1,849
4	Chic	Solid	LA	Midwest	2	17	Large1	62,029	1,354	9,780	822	2,746
4	Chic	Solid	LA	South	2	11	Large1	54,588	1,284	10,530	674	1,849
4	Chic	Solid	LA	Midwest	3	19	Large1	61,642	972	7,849	0	2,746
4	Chic	Solid	LA	South	3	13	Large1	54,044	972	7,612	0	1,849
4	Chic	Solid	LA	Midwest	1	0	Large2	270,735	11,191	12,000	19,106	2,746
4	Chic	Solid	LA	South	1	0	Large2	165,299	6,545	11,396	10,143	1,849
4	Chic	Solid	LA	Midwest	2	3	Large2	266,224	1,579	10,660	1,239	2,746
4	Chic	Solid	LA	South	2	5	Large2	160,718	1,468	10,124	1,004	1,849
4	Chic	Solid	LA	Midwest	3	3	Large2	265,732	972	9,040	0	2,746
4	Chic	Solid	LA	South	3	6	Large2	160,008	972	8,288	0	1,849
4	Chic	Solid	LA	Midwest	1	0	Large2	297,074	67,315	28,176	123,431	2,746
4	Chic	Solid	LA	South	1	0	Large2	192,914	37,154	28,356	65,239	1,849
4	Chic	Solid	LA	Midwest	2	4	Large2	266,244	1,622	12,310	1,319	2,746
4	Chic	Solid	LA	South	2	4	Large2	160,749	1,503	13,231	1,067	1,849
4	Chic	Solid	LA	Midwest	3	4	Large2	265,732	972	9,040	0	2,746
4	Chic	Solid	LA	South	3	4	Large2	160,008	972	8,288	0	1,849
4	Chic	Solid	LA	Midwest	1	1	Medium1a	10,154	1,287	7,643	697	2,746
4	Chic	Solid	LA	South	1	1	Medium1a	7,652	1,176	7,459	478	1,849
4	Chic	Solid	LA	Midwest	2	9	Medium1a	10,073	1,114	7,689	376	2,746
4	Chic	Solid	LA	South	2	11	Medium1a	7,573	1,088	7,474	321	1,849
4	Chic	Solid	LA	Midwest	3	5	Medium1a	9,798	972	7,537	0	2,746
4	Chic	Solid	LA	South	3	6	Medium1a	7,205	972	7,326	0	1,849
4	Chic	Solid	LA	Midwest	1	2	Medium1a	10,966	3,018	8,142	3,914	2,746
4	Chic	Solid	LA	South	1	1	Medium1a	8,663	2,297	8,080	2,495	1,849
4	Chic	Solid	LA	Midwest	2	14	Medium1a	10,089	1,149	7,871	439	2,746
4	Chic	Solid	LA	South	2	7	Medium1a	7,598	1,116	7,738	371	1,849
4	Chic	Solid	LA	Midwest	3	8	Medium1a	9,798	972	7,537	0	2,746
4	Chic	Solid	LA	South	3	4	Medium1a	7,205	972	7,326	0	1,849

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4	Chic	Solid	LA	Midwest	1	1	Medium1b	13,364	1,409	7,707	924	2,746
4	Chic	Solid	LA	South	1	1	Medium1b	9,971	1,255	7,506	621	1,849
4	Chic	Solid	LA	Midwest	2	6	Medium1b	13,226	1,114	7,786	376	2,746
4	Chic	Solid	LA	South	2	7	Medium1b	9,821	1,088	7,536	321	1,849
4	Chic	Solid	LA	Midwest	3	3	Medium1b	12,952	972	7,566	0	2,746
4	Chic	Solid	LA	South	3	4	Medium1b	9,453	972	7,330	0	1,849
4	Chic	Solid	LA	Midwest	1	1	Medium1b	14,491	3,810	8,399	5,387	2,746
4	Chic	Solid	LA	South	1	1	Medium1b	11,374	2,809	8,368	3,419	1,849
4	Chic	Solid	LA	Midwest	2	9	Medium1b	13,242	1,149	8,013	439	2,746
4	Chic	Solid	LA	South	2	5	Medium1b	9,846	1,116	7,877	371	1,849
4	Chic	Solid	LA	Midwest	3	5	Medium1b	12,952	972	7,566	0	2,746
4	Chic	Solid	LA	South	3	3	Medium1b	9,453	972	7,330	0	1,849
4	Chic	Solid	LA	Midwest	1	2	Medium2	23,187	1,782	7,851	1,618	2,746
4	Chic	Solid	LA	South	1	3	Medium2	19,687	1,586	7,747	1,216	1,849
4	Chic	Solid	LA	Midwest	2	16	Medium2	22,940	1,257	7,991	641	2,746
4	Chic	Solid	LA	South	2	24	Medium2	19,343	1,205	7,815	530	1,849
4	Chic	Solid	LA	Midwest	3	13	Medium2	22,599	972	7,602	0	2,746
4	Chic	Solid	LA	South	3	19	Medium2	18,871	972	7,387	0	1,849
4	Chic	Solid	LA	Midwest	1	3	Medium2	25,276	6,234	9,134	9,892	2,746
4	Chic	Solid	LA	South	1	2	Medium2	22,729	4,958	9,615	7,285	1,849
4	Chic	Solid	LA	Midwest	2	24	Medium2	22,980	1,341	8,424	797	2,746
4	Chic	Solid	LA	South	2	16	Medium2	19,405	1,273	8,548	654	1,849
4	Chic	Solid	LA	Midwest	3	19	Medium2	22,599	972	7,602	0	2,746
4	Chic	Solid	LA	South	3	13	Medium2	18,871	972	7,387	0	1,849
4	Chic	Liquid	LW	South	1	3	Large1	18,612	1,520	8,411	1,097	1,849
4	Chic	Liquid	LW	South	2	29	Large1	124,846	1,191	31,213	505	1,849
4	Chic	Liquid	LW	South	3	16	Large1	124,386	972	14,997	0	1,849
4	Chic	Liquid	LW	South	1	2	Large1	21,326	4,527	10,077	6,511	1,849
4	Chic	Liquid	LW	South	2	19	Large1	124,884	1,233	28,159	580	1,849

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4	Chic	Liquid	LW	South	3	11	Large1	124,386	972	10,696	0	1,849
4	Chic	Liquid	LW	South	1	13	Medium2	3,095	995	7,396	153	1,849
4	Chic	Liquid	LW	South	2	53	Medium2	12,901	982	8,462	130	1,849
4	Chic	Liquid	LW	South	3	42	Medium2	12,629	972	7,761	0	1,849
4	Chic	Liquid	LW	South	1	9	Medium2	3,209	1,121	7,466	380	1,849
4	Chic	Liquid	LW	South	2	35	Medium2	12,939	1,024	8,356	205	1,849
4	Chic	Liquid	LW	South	3	28	Medium2	12,629	972	7,580	0	1,849
4.1	Chic	Solid	BR	Mid-Atlantic	1	14	Large1	64,538	2,606	8,501	2,391	3,082
4.1	Chic	Solid	BR	South	1	46	Large1	65,498	2,845	8,684	2,740	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	209	Large1	63,405	1,282	8,541	536	3,082
4.1	Chic	Solid	BR	South	2	659	Large1	63,932	1,243	8,410	496	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	102	Large1	62,675	972	7,607	0	3,082
4.1	Chic	Solid	BR	South	3	323	Large1	63,142	972	7,520	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	21	Large1	65,240	3,428	8,932	3,541	3,082
4.1	Chic	Solid	BR	South	1	30	Large1	67,908	5,309	10,164	6,189	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	314	Large1	63,427	1,308	12,579	573	3,082
4.1	Chic	Solid	BR	South	2	440	Large1	63,964	1,276	9,790	543	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	153	Large1	62,675	972	7,607	0	3,082
4.1	Chic	Solid	BR	South	3	215	Large1	63,142	972	7,520	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	2	Large2	168,396	5,270	10,594	6,120	3,082
4.1	Chic	Solid	BR	South	1	10	Large2	155,678	5,456	10,911	6,395	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	40	Large2	165,119	1,439	9,691	756	3,082
4.1	Chic	Solid	BR	South	2	140	Large2	151,693	1,380	9,500	688	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	16	Large2	164,255	972	8,301	0	3,082
4.1	Chic	Solid	BR	South	3	68	Large2	150,769	972	8,179	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	3	Large2	170,244	7,430	11,728	9,144	3,082
4.1	Chic	Solid	BR	South	1	7	Large2	161,445	11,355	14,453	14,653	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	60	Large2	165,162	1,489	16,582	827	3,082
4.1	Chic	Solid	BR	South	2	93	Large2	151,736	1,425	11,538	751	3,082

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4.1	Chic	Solid	BR	Mid-Atlantic	3	24	Large2	164,255	972	8,301	0	3,082
4.1	Chic	Solid	BR	South	3	46	Large2	150,769	972	8,179	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	33	Medium1a	21,127	1,467	7,603	791	3,082
4.1	Chic	Solid	BR	South	1	79	Medium1a	20,967	1,564	7,635	946	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	275	Medium1a	20,831	1,139	7,614	331	3,082
4.1	Chic	Solid	BR	South	2	665	Medium1a	20,547	1,128	7,634	336	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	206	Medium1a	20,239	972	7,295	0	3,082
4.1	Chic	Solid	BR	South	3	499	Medium1a	19,872	972	7,244	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	49	Medium1a	21,351	1,716	7,740	1,139	3,082
4.1	Chic	Solid	BR	South	1	53	Medium1a	21,717	2,342	8,096	2,036	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	413	Medium1a	20,856	1,166	8,733	369	3,082
4.1	Chic	Solid	BR	South	2	444	Medium1a	20,571	1,153	8,101	371	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	309	Medium1a	20,239	972	7,295	0	3,082
4.1	Chic	Solid	BR	South	3	333	Medium1a	19,872	972	7,244	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	15	Medium1b	29,305	1,666	7,791	1,069	3,082
4.1	Chic	Solid	BR	South	1	36	Medium1b	29,076	1,802	7,866	1,279	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	126	Medium1b	28,830	1,139	7,811	331	3,082
4.1	Chic	Solid	BR	South	2	305	Medium1b	28,427	1,128	7,866	336	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	95	Medium1b	28,237	972	7,374	0	3,082
4.1	Chic	Solid	BR	South	3	228	Medium1b	27,751	972	7,335	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	23	Medium1b	29,619	2,015	7,984	1,557	3,082
4.1	Chic	Solid	BR	South	1	24	Medium1b	30,128	2,893	8,513	2,807	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	189	Medium1b	28,854	1,166	9,520	369	3,082
4.1	Chic	Solid	BR	South	2	203	Medium1b	28,451	1,153	8,521	371	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	142	Medium1b	28,237	972	7,374	0	3,082
4.1	Chic	Solid	BR	South	3	152	Medium1b	27,751	972	7,335	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	19	Medium2	41,467	1,962	7,966	1,483	3,082
4.1	Chic	Solid	BR	South	1	57	Medium2	41,417	2,164	8,090	1,786	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	224	Medium2	40,767	1,186	7,996	397	3,082

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4.1	Chic	Solid	BR	South	2	683	Medium2	40,467	1,179	8,024	407	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	148	Medium2	40,132	972	7,385	0	3,082
4.1	Chic	Solid	BR	South	3	450	Medium2	39,743	972	7,344	0	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	1	28	Medium2	41,915	2,459	8,242	2,180	3,082
4.1	Chic	Solid	BR	South	1	38	Medium2	42,929	3,732	9,018	3,982	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	2	336	Medium2	40,791	1,213	10,501	435	3,082
4.1	Chic	Solid	BR	South	2	455	Medium2	40,485	1,197	9,031	432	3,082
4.1	Chic	Solid	BR	Mid-Atlantic	3	222	Medium2	40,132	972	7,385	0	3,082
4.1	Chic	Solid	BR	South	3	300	Medium2	39,743	972	7,344	0	3,082
4.1	Chic	Solid	LA	Midwest	1	1	Large1	59,137	3,293	7,375	4,426	2,746
4.1	Chic	Solid	LA	South	1	2	Large1	52,774	2,822	7,709	3,441	1,849
4.1	Chic	Solid	LA	Midwest	2	30	Large1	58,186	1,267	7,487	660	2,746
4.1	Chic	Solid	LA	South	2	59	Large1	51,323	1,213	7,567	545	1,849
4.1	Chic	Solid	LA	Midwest	3	33	Large1	57,840	972	6,691	0	2,746
4.1	Chic	Solid	LA	South	3	67	Large1	50,843	972	6,664	0	1,849
4.1	Chic	Solid	LA	Midwest	1	1	Large1	65,120	16,043	11,050	28,125	2,746
4.1	Chic	Solid	LA	South	1	1	Large1	61,940	12,981	13,338	21,728	1,849
4.1	Chic	Solid	LA	Midwest	2	44	Large1	58,227	1,354	8,622	822	2,746
4.1	Chic	Solid	LA	South	2	39	Large1	51,387	1,284	9,582	674	1,849
4.1	Chic	Solid	LA	Midwest	3	50	Large1	57,840	972	6,691	0	2,746
4.1	Chic	Solid	LA	South	3	45	Large1	50,843	972	6,664	0	1,849
4.1	Chic	Solid	LA	Midwest	1	0	Large2	259,389	11,191	10,694	19,106	2,746
4.1	Chic	Solid	LA	South	1	0	Large2	158,261	6,545	10,372	10,143	1,849
4.1	Chic	Solid	LA	Midwest	2	7	Large2	254,878	1,579	9,353	1,239	2,746
4.1	Chic	Solid	LA	South	2	19	Large2	153,681	1,468	9,100	1,004	1,849
4.1	Chic	Solid	LA	Midwest	3	8	Large2	254,386	972	7,733	0	2,746
4.1	Chic	Solid	LA	South	3	21	Large2	152,971	972	7,264	0	1,849
4.1	Chic	Solid	LA	Midwest	1	0	Large2	285,727	67,315	26,869	123,431	2,746
4.1	Chic	Solid	LA	South	1	0	Large2	185,877	37,154	27,332	65,239	1,849

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4.1	Chic	Solid	LA	Midwest	2	10	Large2	254,898	1,622	11,003	1,319	2,746
4.1	Chic	Solid	LA	South	2	12	Large2	153,712	1,503	12,207	1,067	1,849
4.1	Chic	Solid	LA	Midwest	3	11	Large2	254,386	972	7,733	0	2,746
4.1	Chic	Solid	LA	South	3	14	Large2	152,971	972	7,264	0	1,849
4.1	Chic	Solid	LA	Midwest	1	3	Medium1a	8,268	1,287	6,524	697	2,746
4.1	Chic	Solid	LA	South	1	4	Medium1a	6,146	1,176	6,544	478	1,849
4.1	Chic	Solid	LA	Midwest	2	24	Medium1a	8,187	1,114	6,569	376	2,746
4.1	Chic	Solid	LA	South	2	36	Medium1a	6,067	1,088	6,559	321	1,849
4.1	Chic	Solid	LA	Midwest	3	13	Medium1a	7,913	972	6,418	0	2,746
4.1	Chic	Solid	LA	South	3	20	Medium1a	5,700	972	6,411	0	1,849
4.1	Chic	Solid	LA	Midwest	1	4	Medium1a	9,081	3,018	7,023	3,914	2,746
4.1	Chic	Solid	LA	South	1	3	Medium1a	7,157	2,297	7,165	2,495	1,849
4.1	Chic	Solid	LA	Midwest	2	37	Medium1a	8,203	1,149	6,751	439	2,746
4.1	Chic	Solid	LA	South	2	24	Medium1a	6,092	1,116	6,823	371	1,849
4.1	Chic	Solid	LA	Midwest	3	20	Medium1a	7,913	972	6,418	0	2,746
4.1	Chic	Solid	LA	South	3	13	Medium1a	5,700	972	6,411	0	1,849
4.1	Chic	Solid	LA	Midwest	1	2	Medium1b	11,362	1,409	6,585	924	2,746
4.1	Chic	Solid	LA	South	1	3	Medium1b	8,384	1,255	6,590	621	1,849
4.1	Chic	Solid	LA	Midwest	2	16	Medium1b	11,224	1,114	6,664	376	2,746
4.1	Chic	Solid	LA	South	2	24	Medium1b	8,234	1,088	6,620	321	1,849
4.1	Chic	Solid	LA	Midwest	3	9	Medium1b	10,950	972	6,444	0	2,746
4.1	Chic	Solid	LA	South	3	13	Medium1b	7,867	972	6,413	0	1,849
4.1	Chic	Solid	LA	Midwest	1	3	Medium1b	12,489	3,810	7,277	5,387	2,746
4.1	Chic	Solid	LA	South	1	2	Medium1b	9,787	2,809	7,451	3,419	1,849
4.1	Chic	Solid	LA	Midwest	2	24	Medium1b	11,240	1,149	6,891	439	2,746
4.1	Chic	Solid	LA	South	2	16	Medium1b	8,259	1,116	6,961	371	1,849
4.1	Chic	Solid	LA	Midwest	3	13	Medium1b	10,950	972	6,444	0	2,746
4.1	Chic	Solid	LA	South	3	9	Medium1b	7,867	972	6,413	0	1,849
4.1	Chic	Solid	LA	Midwest	1	5	Medium2	20,828	1,782	6,722	1,618	2,746

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
4.1	Chic	Solid	LA	South	1	9	Medium2	17,759	1,586	6,824	1,216	1,849
4.1	Chic	Solid	LA	Midwest	2	42	Medium2	20,582	1,257	6,862	641	2,746
4.1	Chic	Solid	LA	South	2	82	Medium2	17,415	1,205	6,892	530	1,849
4.1	Chic	Solid	LA	Midwest	3	34	Medium2	20,240	972	6,473	0	2,746
4.1	Chic	Solid	LA	South	3	66	Medium2	16,943	972	6,464	0	1,849
4.1	Chic	Solid	LA	Midwest	1	8	Medium2	22,917	6,234	8,005	9,892	2,746
4.1	Chic	Solid	LA	South	1	6	Medium2	20,801	4,958	8,692	7,285	1,849
4.1	Chic	Solid	LA	Midwest	2	64	Medium2	20,621	1,341	7,295	797	2,746
4.1	Chic	Solid	LA	South	2	55	Medium2	17,477	1,273	7,625	654	1,849
4.1	Chic	Solid	LA	Midwest	3	51	Medium2	20,240	972	6,473	0	2,746
4.1	Chic	Solid	LA	South	3	44	Medium2	16,943	972	6,464	0	1,849
4.1	Chic	Liquid	LW	South	1	11	Large1	1,053	1,520	6,712	1,097	1,849
4.1	Chic	Liquid	LW	South	2	101	Large1	107,287	1,191	29,514	505	1,849
4.1	Chic	Liquid	LW	South	3	55	Large1	106,827	972	13,298	0	1,849
4.1	Chic	Liquid	LW	South	1	7	Large1	3,767	4,527	8,378	6,511	1,849
4.1	Chic	Liquid	LW	South	2	67	Large1	107,325	1,233	26,461	580	1,849
4.1	Chic	Liquid	LW	South	3	37	Large1	106,827	972	8,997	0	1,849
4.1	Chic	Liquid	LW	South	1	45	Medium2	415	995	6,418	153	1,849
4.1	Chic	Liquid	LW	South	2	183	Medium2	10,221	982	7,484	130	1,849
4.1	Chic	Liquid	LW	South	3	144	Medium2	9,949	972	6,782	0	1,849
4.1	Chic	Liquid	LW	South	1	30	Medium2	529	1,121	6,488	380	1,849
4.1	Chic	Liquid	LW	South	2	122	Medium2	10,259	1,024	7,378	205	1,849
4.1	Chic	Liquid	LW	South	3	96	Medium2	9,949	972	6,602	0	1,849
5	Chic	Solid	BR	Mid-Atlantic	1	19	Large1	64,538	2,214	2,249	2,391	0
5	Chic	Solid	BR	South	1	59	Large1	65,498	2,453	2,432	2,740	0
5	Chic	Solid	BR	Mid-Atlantic	2	275	Large1	63,405	890	2,289	536	0
5	Chic	Solid	BR	South	2	850	Large1	63,932	851	2,158	496	0
5	Chic	Solid	BR	Mid-Atlantic	3	134	Large1	62,675	580	1,355	0	0
5	Chic	Solid	BR	South	3	416	Large1	63,142	580	1,268	0	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5	Chic	Solid	BR	Mid-Atlantic	1	28	Large1	65,240	3,036	2,680	3,541	0
5	Chic	Solid	BR	South	1	39	Large1	67,908	4,917	3,912	6,189	0
5	Chic	Solid	BR	Mid-Atlantic	2	412	Large1	63,427	916	6,327	573	0
5	Chic	Solid	BR	South	2	567	Large1	63,964	884	3,538	543	0
5	Chic	Solid	BR	Mid-Atlantic	3	202	Large1	62,675	580	1,355	0	0
5	Chic	Solid	BR	South	3	278	Large1	63,142	580	1,268	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	3	Large2	168,396	4,878	4,342	6,120	0
5	Chic	Solid	BR	South	1	13	Large2	155,678	5,064	4,659	6,395	0
5	Chic	Solid	BR	Mid-Atlantic	2	53	Large2	165,119	1,047	3,439	756	0
5	Chic	Solid	BR	South	2	181	Large2	151,693	988	3,248	688	0
5	Chic	Solid	BR	Mid-Atlantic	3	21	Large2	164,255	580	2,049	0	0
5	Chic	Solid	BR	South	3	88	Large2	150,769	580	1,927	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	4	Large2	170,244	7,038	5,476	9,144	0
5	Chic	Solid	BR	South	1	8	Large2	161,445	10,963	8,201	14,653	0
5	Chic	Solid	BR	Mid-Atlantic	2	79	Large2	165,162	1,097	10,330	827	0
5	Chic	Solid	BR	South	2	120	Large2	151,736	1,033	5,286	751	0
5	Chic	Solid	BR	Mid-Atlantic	3	32	Large2	164,255	580	2,049	0	0
5	Chic	Solid	BR	South	3	59	Large2	150,769	580	1,927	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	43	Medium1a	21,127	1,075	1,351	791	0
5	Chic	Solid	BR	South	1	102	Medium1a	20,967	1,172	1,383	946	0
5	Chic	Solid	BR	Mid-Atlantic	2	362	Medium1a	20,831	747	1,362	331	0
5	Chic	Solid	BR	South	2	858	Medium1a	20,547	736	1,382	336	0
5	Chic	Solid	BR	Mid-Atlantic	3	271	Medium1a	20,239	580	1,043	0	0
5	Chic	Solid	BR	South	3	643	Medium1a	19,872	580	992	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	65	Medium1a	21,351	1,324	1,488	1,139	0
5	Chic	Solid	BR	South	1	68	Medium1a	21,717	1,950	1,844	2,036	0
5	Chic	Solid	BR	Mid-Atlantic	2	542	Medium1a	20,856	774	2,481	369	0
5	Chic	Solid	BR	South	2	572	Medium1a	20,571	761	1,849	371	0
5	Chic	Solid	BR	Mid-Atlantic	3	406	Medium1a	20,239	580	1,043	0	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5	Chic	Solid	BR	South	3	429	Medium1a	19,872	580	992	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	20	Medium1b	29,305	1,274	1,539	1,069	0
5	Chic	Solid	BR	South	1	47	Medium1b	29,076	1,410	1,614	1,279	0
5	Chic	Solid	BR	Mid-Atlantic	2	166	Medium1b	28,830	747	1,559	331	0
5	Chic	Solid	BR	South	2	394	Medium1b	28,427	736	1,614	336	0
5	Chic	Solid	BR	Mid-Atlantic	3	124	Medium1b	28,237	580	1,122	0	0
5	Chic	Solid	BR	South	3	295	Medium1b	27,751	580	1,083	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	30	Medium1b	29,619	1,623	1,732	1,557	0
5	Chic	Solid	BR	South	1	31	Medium1b	30,128	2,501	2,261	2,807	0
5	Chic	Solid	BR	Mid-Atlantic	2	249	Medium1b	28,854	774	3,268	369	0
5	Chic	Solid	BR	South	2	262	Medium1b	28,451	761	2,269	371	0
5	Chic	Solid	BR	Mid-Atlantic	3	187	Medium1b	28,237	580	1,122	0	0
5	Chic	Solid	BR	South	3	196	Medium1b	27,751	580	1,083	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	24	Medium2	41,467	1,570	1,714	1,483	0
5	Chic	Solid	BR	South	1	73	Medium2	41,417	1,772	1,838	1,786	0
5	Chic	Solid	BR	Mid-Atlantic	2	295	Medium2	40,767	794	1,744	397	0
5	Chic	Solid	BR	South	2	880	Medium2	40,467	787	1,772	407	0
5	Chic	Solid	BR	Mid-Atlantic	3	194	Medium2	40,132	580	1,133	0	0
5	Chic	Solid	BR	South	3	580	Medium2	39,743	580	1,092	0	0
5	Chic	Solid	BR	Mid-Atlantic	1	37	Medium2	41,915	2,067	1,990	2,180	0
5	Chic	Solid	BR	South	1	49	Medium2	42,929	3,340	2,766	3,982	0
5	Chic	Solid	BR	Mid-Atlantic	2	442	Medium2	40,791	821	4,249	435	0
5	Chic	Solid	BR	South	2	587	Medium2	40,485	805	2,779	432	0
5	Chic	Solid	BR	Mid-Atlantic	3	292	Medium2	40,132	580	1,133	0	0
5	Chic	Solid	BR	South	3	387	Medium2	39,743	580	1,092	0	0
5	Chic	Solid	LA	Midwest	1	1	Large1	59,137	2,901	1,123	4,426	0
5	Chic	Solid	LA	South	1	2	Large1	52,774	2,430	1,457	3,441	0
5	Chic	Solid	LA	Midwest	2	41	Large1	58,186	875	1,235	660	0
5	Chic	Solid	LA	South	2	76	Large1	51,323	821	1,315	545	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5	Chic	Solid	LA	Midwest	3	46	Large1	57,840	580	439	0	0
5	Chic	Solid	LA	South	3	86	Large1	50,843	580	412	0	0
5	Chic	Solid	LA	Midwest	1	1	Large1	65,120	15,651	4,798	28,125	0
5	Chic	Solid	LA	South	1	2	Large1	61,940	12,589	7,086	21,728	0
5	Chic	Solid	LA	Midwest	2	61	Large1	58,227	962	2,370	822	0
5	Chic	Solid	LA	South	2	51	Large1	51,387	892	3,330	674	0
5	Chic	Solid	LA	Midwest	3	69	Large1	57,840	580	439	0	0
5	Chic	Solid	LA	South	3	58	Large1	50,843	580	412	0	0
5	Chic	Solid	LA	Midwest	1	0	Large2	259,389	10,799	4,442	19,106	0
5	Chic	Solid	LA	South	1	0	Large2	158,261	6,153	4,120	10,143	0
5	Chic	Solid	LA	Midwest	2	9	Large2	254,878	1,187	3,101	1,239	0
5	Chic	Solid	LA	South	2	24	Large2	153,681	1,076	2,848	1,004	0
5	Chic	Solid	LA	Midwest	3	10	Large2	254,386	580	1,481	0	0
5	Chic	Solid	LA	South	3	27	Large2	152,971	580	1,012	0	0
5	Chic	Solid	LA	Midwest	1	0	Large2	285,727	66,923	20,617	123,431	0
5	Chic	Solid	LA	South	1	0	Large2	185,877	36,762	21,080	65,239	0
5	Chic	Solid	LA	Midwest	2	14	Large2	254,898	1,230	4,751	1,319	0
5	Chic	Solid	LA	South	2	16	Large2	153,712	1,111	5,955	1,067	0
5	Chic	Solid	LA	Midwest	3	16	Large2	254,386	580	1,481	0	0
5	Chic	Solid	LA	South	3	18	Large2	152,971	580	1,012	0	0
5	Chic	Solid	LA	Midwest	1	4	Medium1a	8,268	895	272	697	0
5	Chic	Solid	LA	South	1	5	Medium1a	6,146	784	292	478	0
5	Chic	Solid	LA	Midwest	2	34	Medium1a	8,187	722	317	376	0
5	Chic	Solid	LA	South	2	47	Medium1a	6,067	696	307	321	0
5	Chic	Solid	LA	Midwest	3	18	Medium1a	7,913	580	166	0	0
5	Chic	Solid	LA	South	3	26	Medium1a	5,700	580	159	0	0
5	Chic	Solid	LA	Midwest	1	6	Medium1a	9,081	2,626	771	3,914	0
5	Chic	Solid	LA	South	1	4	Medium1a	7,157	1,905	913	2,495	0
5	Chic	Solid	LA	Midwest	2	50	Medium1a	8,203	757	499	439	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5	Chic	Solid	LA	South	2	31	Medium1a	6,092	724	571	371	0
5	Chic	Solid	LA	Midwest	3	28	Medium1a	7,913	580	166	0	0
5	Chic	Solid	LA	South	3	17	Medium1a	5,700	580	159	0	0
5	Chic	Solid	LA	Midwest	1	2	Medium1b	11,362	1,017	333	924	0
5	Chic	Solid	LA	South	1	4	Medium1b	8,384	863	338	621	0
5	Chic	Solid	LA	Midwest	2	22	Medium1b	11,224	722	412	376	0
5	Chic	Solid	LA	South	2	31	Medium1b	8,234	696	368	321	0
5	Chic	Solid	LA	Midwest	3	12	Medium1b	10,950	580	192	0	0
5	Chic	Solid	LA	South	3	17	Medium1b	7,867	580	161	0	0
5	Chic	Solid	LA	Midwest	1	4	Medium1b	12,489	3,418	1,025	5,387	0
5	Chic	Solid	LA	South	1	2	Medium1b	9,787	2,417	1,199	3,419	0
5	Chic	Solid	LA	Midwest	2	33	Medium1b	11,240	757	639	439	0
5	Chic	Solid	LA	South	2	21	Medium1b	8,259	724	709	371	0
5	Chic	Solid	LA	Midwest	3	18	Medium1b	10,950	580	192	0	0
5	Chic	Solid	LA	South	3	12	Medium1b	7,867	580	161	0	0
5	Chic	Solid	LA	Midwest	1	7	Medium2	20,828	1,390	470	1,618	0
5	Chic	Solid	LA	South	1	12	Medium2	17,759	1,194	572	1,216	0
5	Chic	Solid	LA	Midwest	2	58	Medium2	20,582	865	610	641	0
5	Chic	Solid	LA	South	2	106	Medium2	17,415	813	640	530	0
5	Chic	Solid	LA	Midwest	3	47	Medium2	20,240	580	221	0	0
5	Chic	Solid	LA	South	3	85	Medium2	16,943	580	212	0	0
5	Chic	Solid	LA	Midwest	1	11	Medium2	22,917	5,842	1,753	9,892	0
5	Chic	Solid	LA	South	1	8	Medium2	20,801	4,566	2,440	7,285	0
5	Chic	Solid	LA	Midwest	2	88	Medium2	20,621	949	1,043	797	0
5	Chic	Solid	LA	South	2	70	Medium2	17,477	881	1,373	654	0
5	Chic	Solid	LA	Midwest	3	70	Medium2	20,240	580	221	0	0
5	Chic	Solid	LA	South	3	57	Medium2	16,943	580	212	0	0
5	Chic	Liquid	LW	South	1	14	Large1	107,584	1,128	2,590	1,097	0
5	Chic	Liquid	LW	South	2	130	Large1	107,287	799	23,262	505	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5	Chic	Liquid	LW	South	3	71	Large1	106,827	580	7,046	0	0
5	Chic	Liquid	LW	South	1	10	Large1	110,298	4,135	4,257	6,511	0
5	Chic	Liquid	LW	South	2	87	Large1	107,325	841	20,209	580	0
5	Chic	Liquid	LW	South	3	48	Large1	106,827	580	2,745	0	0
5	Chic	Liquid	LW	South	1	58	Medium2	10,233	603	362	153	0
5	Chic	Liquid	LW	South	2	236	Medium2	10,221	590	1,232	130	0
5	Chic	Liquid	LW	South	3	186	Medium2	9,949	580	530	0	0
5	Chic	Liquid	LW	South	1	39	Medium2	10,347	729	432	380	0
5	Chic	Liquid	LW	South	2	157	Medium2	10,259	632	1,126	205	0
5	Chic	Liquid	LW	South	3	124	Medium2	9,949	580	350	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	19	Large1	64,538	2,214	2,249	2,391	0
5a	Chic	Solid	BR	South	1	59	Large1	65,498	2,453	2,432	2,740	0
5a	Chic	Solid	BR	Mid-Atlantic	2	275	Large1	63,405	890	2,289	536	0
5a	Chic	Solid	BR	South	2	850	Large1	63,932	851	2,158	496	0
5a	Chic	Solid	BR	Mid-Atlantic	3	134	Large1	62,675	580	1,355	0	0
5a	Chic	Solid	BR	South	3	416	Large1	63,142	580	1,268	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	28	Large1	65,240	3,036	2,680	3,541	0
5a	Chic	Solid	BR	South	1	39	Large1	67,908	4,917	3,912	6,189	0
5a	Chic	Solid	BR	Mid-Atlantic	2	412	Large1	63,427	916	6,327	573	0
5a	Chic	Solid	BR	South	2	567	Large1	63,964	884	3,538	543	0
5a	Chic	Solid	BR	Mid-Atlantic	3	202	Large1	62,675	580	1,355	0	0
5a	Chic	Solid	BR	South	3	278	Large1	63,142	580	1,268	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	3	Large2	168,396	4,878	4,342	6,120	0
5a	Chic	Solid	BR	South	1	13	Large2	155,678	5,064	4,659	6,395	0
5a	Chic	Solid	BR	Mid-Atlantic	2	53	Large2	165,119	1,047	3,439	756	0
5a	Chic	Solid	BR	South	2	181	Large2	151,693	988	3,248	688	0
5a	Chic	Solid	BR	Mid-Atlantic	3	21	Large2	164,255	580	2,049	0	0
5a	Chic	Solid	BR	South	3	88	Large2	150,769	580	1,927	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	4	Large2	170,244	7,038	5,476	9,144	0

Table 11-13. (Continued)												
Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5a	Chic	Solid	BR	South	1	8	Large2	161,445	10,963	8,201	14,653	0
5a	Chic	Solid	BR	Mid-Atlantic	2	79	Large2	165,162	1,097	10,330	827	0
5a	Chic	Solid	BR	South	2	120	Large2	151,736	1,033	5,286	751	0
5a	Chic	Solid	BR	Mid-Atlantic	3	32	Large2	164,255	580	2,049	0	0
5a	Chic	Solid	BR	South	3	59	Large2	150,769	580	1,927	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	43	Medium1a	21,127	1,075	1,351	791	0
5a	Chic	Solid	BR	South	1	102	Medium1a	20,967	1,172	1,383	946	0
5a	Chic	Solid	BR	Mid-Atlantic	2	362	Medium1a	20,831	747	1,362	331	0
5a	Chic	Solid	BR	South	2	858	Medium1a	20,547	736	1,382	336	0
5a	Chic	Solid	BR	Mid-Atlantic	3	271	Medium1a	20,239	580	1,043	0	0
5a	Chic	Solid	BR	South	3	643	Medium1a	19,872	580	992	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	65	Medium1a	21,351	1,324	1,488	1,139	0
5a	Chic	Solid	BR	South	1	68	Medium1a	21,717	1,950	1,844	2,036	0
5a	Chic	Solid	BR	Mid-Atlantic	2	542	Medium1a	20,856	774	2,481	369	0
5a	Chic	Solid	BR	South	2	572	Medium1a	20,571	761	1,849	371	0
5a	Chic	Solid	BR	Mid-Atlantic	3	406	Medium1a	20,239	580	1,043	0	0
5a	Chic	Solid	BR	South	3	429	Medium1a	19,872	580	992	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	20	Medium1b	29,305	1,274	1,539	1,069	0
5a	Chic	Solid	BR	South	1	47	Medium1b	29,076	1,410	1,614	1,279	0
5a	Chic	Solid	BR	Mid-Atlantic	2	166	Medium1b	28,830	747	1,559	331	0
5a	Chic	Solid	BR	South	2	394	Medium1b	28,427	736	1,614	336	0
5a	Chic	Solid	BR	Mid-Atlantic	3	124	Medium1b	28,237	580	1,122	0	0
5a	Chic	Solid	BR	South	3	295	Medium1b	27,751	580	1,083	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	30	Medium1b	29,619	1,623	1,732	1,557	0
5a	Chic	Solid	BR	South	1	31	Medium1b	30,128	2,501	2,261	2,807	0
5a	Chic	Solid	BR	Mid-Atlantic	2	249	Medium1b	28,854	774	3,268	369	0
5a	Chic	Solid	BR	South	2	262	Medium1b	28,451	761	2,269	371	0
5a	Chic	Solid	BR	Mid-Atlantic	3	187	Medium1b	28,237	580	1,122	0	0
5a	Chic	Solid	BR	South	3	196	Medium1b	27,751	580	1,083	0	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5a	Chic	Solid	BR	Mid-Atlantic	1	24	Medium2	41,467	1,570	1,714	1,483	0
5a	Chic	Solid	BR	South	1	73	Medium2	41,417	1,772	1,838	1,786	0
5a	Chic	Solid	BR	Mid-Atlantic	2	295	Medium2	40,767	794	1,744	397	0
5a	Chic	Solid	BR	South	2	880	Medium2	40,467	787	1,772	407	0
5a	Chic	Solid	BR	Mid-Atlantic	3	194	Medium2	40,132	580	1,133	0	0
5a	Chic	Solid	BR	South	3	580	Medium2	39,743	580	1,092	0	0
5a	Chic	Solid	BR	Mid-Atlantic	1	37	Medium2	41,915	2,067	1,990	2,180	0
5a	Chic	Solid	BR	South	1	49	Medium2	42,929	3,340	2,766	3,982	0
5a	Chic	Solid	BR	Mid-Atlantic	2	442	Medium2	40,791	821	4,249	435	0
5a	Chic	Solid	BR	South	2	587	Medium2	40,485	805	2,779	432	0
5a	Chic	Solid	BR	Mid-Atlantic	3	292	Medium2	40,132	580	1,133	0	0
5a	Chic	Solid	BR	South	3	387	Medium2	39,743	580	1,092	0	0
5a	Chic	Solid	LA	Midwest	1	1	Large1	59,137	2,901	1,123	4,426	0
5a	Chic	Solid	LA	South	1	2	Large1	52,774	2,430	1,457	3,441	0
5a	Chic	Solid	LA	Midwest	2	41	Large1	58,186	875	1,235	660	0
5a	Chic	Solid	LA	South	2	76	Large1	51,323	821	1,315	545	0
5a	Chic	Solid	LA	Midwest	3	46	Large1	57,840	580	439	0	0
5a	Chic	Solid	LA	South	3	86	Large1	50,843	580	412	0	0
5a	Chic	Solid	LA	Midwest	1	1	Large1	65,120	15,651	4,798	28,125	0
5a	Chic	Solid	LA	South	1	2	Large1	61,940	12,589	7,086	21,728	0
5a	Chic	Solid	LA	Midwest	2	61	Large1	58,227	962	2,370	822	0
5a	Chic	Solid	LA	South	2	51	Large1	51,387	892	3,330	674	0
5a	Chic	Solid	LA	Midwest	3	69	Large1	57,840	580	439	0	0
5a	Chic	Solid	LA	South	3	58	Large1	50,843	580	412	0	0
5a	Chic	Solid	LA	Midwest	1	0	Large2	259,389	10,799	4,442	19,106	0
5a	Chic	Solid	LA	South	1	0	Large2	158,261	6,153	4,120	10,143	0
5a	Chic	Solid	LA	Midwest	2	9	Large2	254,878	1,187	3,101	1,239	0
5a	Chic	Solid	LA	South	2	24	Large2	153,681	1,076	2,848	1,004	0
5a	Chic	Solid	LA	Midwest	3	10	Large2	254,386	580	1,481	0	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5a	Chic	Solid	LA	South	3	27	Large2	152,971	580	1,012	0	0
5a	Chic	Solid	LA	Midwest	1	0	Large2	285,727	66,923	20,617	123,431	0
5a	Chic	Solid	LA	South	1	0	Large2	185,877	36,762	21,080	65,239	0
5a	Chic	Solid	LA	Midwest	2	14	Large2	254,898	1,230	4,751	1,319	0
5a	Chic	Solid	LA	South	2	16	Large2	153,712	1,111	5,955	1,067	0
5a	Chic	Solid	LA	Midwest	3	16	Large2	254,386	580	1,481	0	0
5a	Chic	Solid	LA	South	3	18	Large2	152,971	580	1,012	0	0
5a	Chic	Solid	LA	Midwest	1	4	Medium1a	8,268	895	272	697	0
5a	Chic	Solid	LA	South	1	5	Medium1a	6,146	784	292	478	0
5a	Chic	Solid	LA	Midwest	2	34	Medium1a	8,187	722	317	376	0
5a	Chic	Solid	LA	South	2	47	Medium1a	6,067	696	307	321	0
5a	Chic	Solid	LA	Midwest	3	18	Medium1a	7,913	580	166	0	0
5a	Chic	Solid	LA	South	3	26	Medium1a	5,700	580	159	0	0
5a	Chic	Solid	LA	Midwest	1	6	Medium1a	9,081	2,626	771	3,914	0
5a	Chic	Solid	LA	South	1	4	Medium1a	7,157	1,905	913	2,495	0
5a	Chic	Solid	LA	Midwest	2	50	Medium1a	8,203	757	499	439	0
5a	Chic	Solid	LA	South	2	31	Medium1a	6,092	724	571	371	0
5a	Chic	Solid	LA	Midwest	3	28	Medium1a	7,913	580	166	0	0
5a	Chic	Solid	LA	South	3	17	Medium1a	5,700	580	159	0	0
5a	Chic	Solid	LA	Midwest	1	2	Medium1b	11,362	1,017	333	924	0
5a	Chic	Solid	LA	South	1	4	Medium1b	8,384	863	338	621	0
5a	Chic	Solid	LA	Midwest	2	22	Medium1b	11,224	722	412	376	0
5a	Chic	Solid	LA	South	2	31	Medium1b	8,234	696	368	321	0
5a	Chic	Solid	LA	Midwest	3	12	Medium1b	10,950	580	192	0	0
5a	Chic	Solid	LA	South	3	17	Medium1b	7,867	580	161	0	0
5a	Chic	Solid	LA	Midwest	1	4	Medium1b	12,489	3,418	1,025	5,387	0
5a	Chic	Solid	LA	South	1	2	Medium1b	9,787	2,417	1,199	3,419	0
5a	Chic	Solid	LA	Midwest	2	33	Medium1b	11,240	757	639	439	0
5a	Chic	Solid	LA	South	2	21	Medium1b	8,259	724	709	371	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
5a	Chic	Solid	LA	Midwest	3	18	Medium1b	10,950	580	192	0	0
5a	Chic	Solid	LA	South	3	12	Medium1b	7,867	580	161	0	0
5a	Chic	Solid	LA	Midwest	1	7	Medium2	20,828	1,390	470	1,618	0
5a	Chic	Solid	LA	South	1	12	Medium2	17,759	1,194	572	1,216	0
5a	Chic	Solid	LA	Midwest	2	58	Medium2	20,582	865	610	641	0
5a	Chic	Solid	LA	South	2	106	Medium2	17,415	813	640	530	0
5a	Chic	Solid	LA	Midwest	3	47	Medium2	20,240	580	221	0	0
5a	Chic	Solid	LA	South	3	85	Medium2	16,943	580	212	0	0
5a	Chic	Solid	LA	Midwest	1	11	Medium2	22,917	5,842	1,753	9,892	0
5a	Chic	Solid	LA	South	1	8	Medium2	20,801	4,566	2,440	7,285	0
5a	Chic	Solid	LA	Midwest	2	88	Medium2	20,621	949	1,043	797	0
5a	Chic	Solid	LA	South	2	70	Medium2	17,477	881	1,373	654	0
5a	Chic	Solid	LA	Midwest	3	70	Medium2	20,240	580	221	0	0
5a	Chic	Solid	LA	South	3	57	Medium2	16,943	580	212	0	0
5a	Chic	Liquid	LW	South	1	14	Large1	1,053	1,128	460	1,097	0
5a	Chic	Liquid	LW	South	2	130	Large1	107,287	799	23,262	505	0
5a	Chic	Liquid	LW	South	3	71	Large1	106,827	580	136	0	0
5a	Chic	Liquid	LW	South	1	10	Large1	3,767	4,135	2,126	6,511	0
5a	Chic	Liquid	LW	South	2	87	Large1	107,325	841	20,209	580	0
5a	Chic	Liquid	LW	South	3	48	Large1	106,827	580	136	0	0
5a	Chic	Liquid	LW	South	1	58	Medium2	415	603	166	153	0
5a	Chic	Liquid	LW	South	2	236	Medium2	10,221	590	1,232	130	0
5a	Chic	Liquid	LW	South	3	186	Medium2	9,949	580	133	0	0
5a	Chic	Liquid	LW	South	1	39	Medium2	529	729	236	380	0
5a	Chic	Liquid	LW	South	2	157	Medium2	10,259	632	1,126	205	0
5a	Chic	Liquid	LW	South	3	124	Medium2	9,949	580	133	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	19	Large1	64,538	2,214	2,249	2,391	0
7	Chic	Solid	BR	South	1	59	Large1	65,498	2,453	2,432	2,740	0
7	Chic	Solid	BR	Mid-Atlantic	2	275	Large1	63,405	890	2,289	536	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
7	Chic	Solid	BR	South	2	850	Large1	63,932	851	2,158	496	0
7	Chic	Solid	BR	Mid-Atlantic	3	134	Large1	62,675	580	1,355	0	0
7	Chic	Solid	BR	South	3	416	Large1	63,142	580	1,268	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	28	Large1	65,240	3,036	2,680	3,541	0
7	Chic	Solid	BR	South	1	39	Large1	67,908	4,917	3,912	6,189	0
7	Chic	Solid	BR	Mid-Atlantic	2	412	Large1	63,427	916	6,327	573	0
7	Chic	Solid	BR	South	2	567	Large1	63,964	884	3,538	543	0
7	Chic	Solid	BR	Mid-Atlantic	3	202	Large1	62,675	580	1,355	0	0
7	Chic	Solid	BR	South	3	278	Large1	63,142	580	1,268	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	3	Large2	168,396	4,878	4,342	6,120	0
7	Chic	Solid	BR	South	1	13	Large2	155,678	5,064	4,659	6,395	0
7	Chic	Solid	BR	Mid-Atlantic	2	53	Large2	165,119	1,047	3,439	756	0
7	Chic	Solid	BR	South	2	181	Large2	151,693	988	3,248	688	0
7	Chic	Solid	BR	Mid-Atlantic	3	21	Large2	164,255	580	2,049	0	0
7	Chic	Solid	BR	South	3	88	Large2	150,769	580	1,927	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	4	Large2	170,244	7,038	5,476	9,144	0
7	Chic	Solid	BR	South	1	8	Large2	161,445	10,963	8,201	14,653	0
7	Chic	Solid	BR	Mid-Atlantic	2	79	Large2	165,162	1,097	10,330	827	0
7	Chic	Solid	BR	South	2	120	Large2	151,736	1,033	5,286	751	0
7	Chic	Solid	BR	Mid-Atlantic	3	32	Large2	164,255	580	2,049	0	0
7	Chic	Solid	BR	South	3	59	Large2	150,769	580	1,927	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	43	Medium1a	21,127	1,075	1,351	791	0
7	Chic	Solid	BR	South	1	102	Medium1a	20,967	1,172	1,383	946	0
7	Chic	Solid	BR	Mid-Atlantic	2	362	Medium1a	20,831	747	1,362	331	0
7	Chic	Solid	BR	South	2	858	Medium1a	20,547	736	1,382	336	0
7	Chic	Solid	BR	Mid-Atlantic	3	271	Medium1a	20,239	580	1,043	0	0
7	Chic	Solid	BR	South	3	643	Medium1a	19,872	580	992	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	65	Medium1a	21,351	1,324	1,488	1,139	0
7	Chic	Solid	BR	South	1	68	Medium1a	21,717	1,950	1,844	2,036	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
7	Chic	Solid	BR	Mid-Atlantic	2	542	Medium1a	20,856	774	2,481	369	0
7	Chic	Solid	BR	South	2	572	Medium1a	20,571	761	1,849	371	0
7	Chic	Solid	BR	Mid-Atlantic	3	406	Medium1a	20,239	580	1,043	0	0
7	Chic	Solid	BR	South	3	429	Medium1a	19,872	580	992	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	20	Medium1b	29,305	1,274	1,539	1,069	0
7	Chic	Solid	BR	South	1	47	Medium1b	29,076	1,410	1,614	1,279	0
7	Chic	Solid	BR	Mid-Atlantic	2	166	Medium1b	28,830	747	1,559	331	0
7	Chic	Solid	BR	South	2	394	Medium1b	28,427	736	1,614	336	0
7	Chic	Solid	BR	Mid-Atlantic	3	124	Medium1b	28,237	580	1,122	0	0
7	Chic	Solid	BR	South	3	295	Medium1b	27,751	580	1,083	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	30	Medium1b	29,619	1,623	1,732	1,557	0
7	Chic	Solid	BR	South	1	31	Medium1b	30,128	2,501	2,261	2,807	0
7	Chic	Solid	BR	Mid-Atlantic	2	249	Medium1b	28,854	774	3,268	369	0
7	Chic	Solid	BR	South	2	262	Medium1b	28,451	761	2,269	371	0
7	Chic	Solid	BR	Mid-Atlantic	3	187	Medium1b	28,237	580	1,122	0	0
7	Chic	Solid	BR	South	3	196	Medium1b	27,751	580	1,083	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	24	Medium2	41,467	1,570	1,714	1,483	0
7	Chic	Solid	BR	South	1	73	Medium2	41,417	1,772	1,838	1,786	0
7	Chic	Solid	BR	Mid-Atlantic	2	295	Medium2	40,767	794	1,744	397	0
7	Chic	Solid	BR	South	2	880	Medium2	40,467	787	1,772	407	0
7	Chic	Solid	BR	Mid-Atlantic	3	194	Medium2	40,132	580	1,133	0	0
7	Chic	Solid	BR	South	3	580	Medium2	39,743	580	1,092	0	0
7	Chic	Solid	BR	Mid-Atlantic	1	37	Medium2	41,915	2,067	1,990	2,180	0
7	Chic	Solid	BR	South	1	49	Medium2	42,929	3,340	2,766	3,982	0
7	Chic	Solid	BR	Mid-Atlantic	2	442	Medium2	40,791	821	4,249	435	0
7	Chic	Solid	BR	South	2	587	Medium2	40,485	805	2,779	432	0
7	Chic	Solid	BR	Mid-Atlantic	3	292	Medium2	40,132	580	1,133	0	0
7	Chic	Solid	BR	South	3	387	Medium2	39,743	580	1,092	0	0
7	Chic	Solid	LA	Midwest	1	1	Large1	59,137	2,901	1,123	4,426	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
7	Chic	Solid	LA	South	1	2	Large1	52,774	2,430	1,457	3,441	0
7	Chic	Solid	LA	Midwest	2	41	Large1	58,186	875	1,235	660	0
7	Chic	Solid	LA	South	2	76	Large1	51,323	821	1,315	545	0
7	Chic	Solid	LA	Midwest	3	46	Large1	57,840	580	439	0	0
7	Chic	Solid	LA	South	3	86	Large1	50,843	580	412	0	0
7	Chic	Solid	LA	Midwest	1	1	Large1	65,120	15,651	4,798	28,125	0
7	Chic	Solid	LA	South	1	2	Large1	61,940	12,589	7,086	21,728	0
7	Chic	Solid	LA	Midwest	2	61	Large1	58,227	962	2,370	822	0
7	Chic	Solid	LA	South	2	51	Large1	51,387	892	3,330	674	0
7	Chic	Solid	LA	Midwest	3	69	Large1	57,840	580	439	0	0
7	Chic	Solid	LA	South	3	58	Large1	50,843	580	412	0	0
7	Chic	Solid	LA	Midwest	1	0	Large2	259,389	10,799	4,442	19,106	0
7	Chic	Solid	LA	South	1	0	Large2	158,261	6,153	4,120	10,143	0
7	Chic	Solid	LA	Midwest	2	9	Large2	254,878	1,187	3,101	1,239	0
7	Chic	Solid	LA	South	2	24	Large2	153,681	1,076	2,848	1,004	0
7	Chic	Solid	LA	Midwest	3	10	Large2	254,386	580	1,481	0	0
7	Chic	Solid	LA	South	3	27	Large2	152,971	580	1,012	0	0
7	Chic	Solid	LA	Midwest	1	0	Large2	285,727	66,923	20,617	123,431	0
7	Chic	Solid	LA	South	1	0	Large2	185,877	36,762	21,080	65,239	0
7	Chic	Solid	LA	Midwest	2	14	Large2	254,898	1,230	4,751	1,319	0
7	Chic	Solid	LA	South	2	16	Large2	153,712	1,111	5,955	1,067	0
7	Chic	Solid	LA	Midwest	3	16	Large2	254,386	580	1,481	0	0
7	Chic	Solid	LA	South	3	18	Large2	152,971	580	1,012	0	0
7	Chic	Solid	LA	Midwest	1	4	Medium1a	8,268	895	272	697	0
7	Chic	Solid	LA	South	1	5	Medium1a	6,146	784	292	478	0
7	Chic	Solid	LA	Midwest	2	34	Medium1a	8,187	722	317	376	0
7	Chic	Solid	LA	South	2	47	Medium1a	6,067	696	307	321	0
7	Chic	Solid	LA	Midwest	3	18	Medium1a	7,913	580	166	0	0
7	Chic	Solid	LA	South	3	26	Medium1a	5,700	580	159	0	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
7	Chic	Solid	LA	Midwest	1	6	Medium1a	9,081	2,626	771	3,914	0
7	Chic	Solid	LA	South	1	4	Medium1a	7,157	1,905	913	2,495	0
7	Chic	Solid	LA	Midwest	2	50	Medium1a	8,203	757	499	439	0
7	Chic	Solid	LA	South	2	31	Medium1a	6,092	724	571	371	0
7	Chic	Solid	LA	Midwest	3	28	Medium1a	7,913	580	166	0	0
7	Chic	Solid	LA	South	3	17	Medium1a	5,700	580	159	0	0
7	Chic	Solid	LA	Midwest	1	2	Medium1b	11,362	1,017	333	924	0
7	Chic	Solid	LA	South	1	4	Medium1b	8,384	863	338	621	0
7	Chic	Solid	LA	Midwest	2	22	Medium1b	11,224	722	412	376	0
7	Chic	Solid	LA	South	2	31	Medium1b	8,234	696	368	321	0
7	Chic	Solid	LA	Midwest	3	12	Medium1b	10,950	580	192	0	0
7	Chic	Solid	LA	South	3	17	Medium1b	7,867	580	161	0	0
7	Chic	Solid	LA	Midwest	1	4	Medium1b	12,489	3,418	1,025	5,387	0
7	Chic	Solid	LA	South	1	2	Medium1b	9,787	2,417	1,199	3,419	0
7	Chic	Solid	LA	Midwest	2	33	Medium1b	11,240	757	639	439	0
7	Chic	Solid	LA	South	2	21	Medium1b	8,259	724	709	371	0
7	Chic	Solid	LA	Midwest	3	18	Medium1b	10,950	580	192	0	0
7	Chic	Solid	LA	South	3	12	Medium1b	7,867	580	161	0	0
7	Chic	Solid	LA	Midwest	1	7	Medium2	20,828	1,390	470	1,618	0
7	Chic	Solid	LA	South	1	12	Medium2	17,759	1,194	572	1,216	0
7	Chic	Solid	LA	Midwest	2	58	Medium2	20,582	865	610	641	0
7	Chic	Solid	LA	South	2	106	Medium2	17,415	813	640	530	0
7	Chic	Solid	LA	Midwest	3	47	Medium2	20,240	580	221	0	0
7	Chic	Solid	LA	South	3	85	Medium2	16,943	580	212	0	0
7	Chic	Solid	LA	Midwest	1	11	Medium2	22,917	5,842	1,753	9,892	0
7	Chic	Solid	LA	South	1	8	Medium2	20,801	4,566	2,440	7,285	0
7	Chic	Solid	LA	Midwest	2	88	Medium2	20,621	949	1,043	797	0
7	Chic	Solid	LA	South	2	70	Medium2	17,477	881	1,373	654	0
7	Chic	Solid	LA	Midwest	3	70	Medium2	20,240	580	221	0	0

Table 11-13. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yr. rec.	5yr. rec.
7	Chic	Solid	LA	South	3	57	Medium2	16,943	580	212	0	0
7	Chic	Liquid	LW	South	1	14	Large1	1,053	1,128	460	1,097	0
7	Chic	Liquid	LW	South	2	130	Large1	107,287	799	23,262	505	0
7	Chic	Liquid	LW	South	3	71	Large1	106,827	580	7,046	0	0
7	Chic	Liquid	LW	South	1	10	Large1	3,767	4,135	2,126	6,511	0
7	Chic	Liquid	LW	South	2	87	Large1	107,325	841	20,209	580	0
7	Chic	Liquid	LW	South	3	48	Large1	106,827	580	2,745	0	0
7	Chic	Liquid	LW	South	1	58	Medium2	415	603	166	153	0
7	Chic	Liquid	LW	South	2	236	Medium2	10,221	590	1,232	130	0
7	Chic	Liquid	LW	South	3	186	Medium2	9,949	580	530	0	0
7	Chic	Liquid	LW	South	1	39	Medium2	529	729	236	380	0
7	Chic	Liquid	LW	South	2	157	Medium2	10,259	632	1,126	205	0
7	Chic	Liquid	LW	South	3	124	Medium2	9,949	580	350	0	0

Table 11-14. Regulatory Compliance Costs for the Turkey (SL, slaughter) Operations

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
1	Turk	Solid	SL	Mid-Atlantic	1	30	Medium1a	7,842	1,483	1,755	1,380	0
1	Turk	Solid	SL	Mid-Atlantic	1	20	Medium1b	12,627	2,103	2,307	2,248	0
1	Turk	Solid	SL	Mid-Atlantic	1	8	Medium2	17,863	2,781	2,802	3,197	0
1	Turk	Solid	SL	Mid-Atlantic	1	5	Large1	37,378	5,266	4,674	6,676	0
1	Turk	Solid	SL	Midwest	1	26	Medium1a	18,125	1,314	1,224	1,032	0
1	Turk	Solid	SL	Midwest	1	17	Medium1b	30,109	1,818	1,572	1,660	0
1	Turk	Solid	SL	Midwest	1	7	Medium2	44,537	2,424	2,022	2,416	0
1	Turk	Solid	SL	Midwest	1	7	Large1	153,603	7,003	6,060	8,850	0
1	Turk	Solid	SL	Mid-Atlantic	2	288	Medium1a	7,780	1,401	1,762	1,266	0
1	Turk	Solid	SL	Mid-Atlantic	2	192	Medium1b	12,098	1,401	2,416	1,266	0
1	Turk	Solid	SL	Mid-Atlantic	2	127	Medium2	16,986	1,619	2,986	1,571	0
1	Turk	Solid	SL	Mid-Atlantic	2	90	Large1	35,073	2,239	5,167	2,439	0
1	Turk	Solid	SL	Midwest	2	247	Medium1a	18,215	1,434	1,280	1,182	0
1	Turk	Solid	SL	Midwest	2	165	Medium1b	29,798	1,404	1,748	1,145	0
1	Turk	Solid	SL	Midwest	2	113	Medium2	43,935	1,623	2,367	1,418	0
1	Turk	Solid	SL	Midwest	2	124	Large1	150,038	2,261	8,147	2,403	0
1	Turk	Solid	SL	Mid-Atlantic	3	123	Medium1a	6,637	580	1,297	0	0
1	Turk	Solid	SL	Mid-Atlantic	3	82	Medium1b	10,955	580	1,562	0	0
1	Turk	Solid	SL	Mid-Atlantic	3	59	Medium2	15,679	580	1,742	0	0
1	Turk	Solid	SL	Mid-Atlantic	3	60	Large1	33,290	580	2,442	0	0
1	Turk	Solid	SL	Midwest	3	106	Medium1a	17,240	580	861	0	0
1	Turk	Solid	SL	Midwest	3	70	Medium1b	28,845	580	976	0	0
1	Turk	Solid	SL	Midwest	3	52	Medium2	42,817	580	1,146	0	0
1	Turk	Solid	SL	Midwest	3	83	Large1	148,300	580	3,058	0	0
2	Turk	Solid	SL	Mid-Atlantic	1	18	Medium1a	11,037	5,716	3,718	7,306	0
2	Turk	Solid	SL	Mid-Atlantic	1	12	Medium1b	18,016	9,242	5,617	12,243	0
2	Turk	Solid	SL	Mid-Atlantic	1	5	Medium2	25,653	13,100	7,586	17,644	0
2	Turk	Solid	SL	Mid-Atlantic	1	3	Large1	54,117	27,239	14,953	37,438	0

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
2	Turk	Solid	SL	Midwest	1	16	Medium1a	22,410	7,013	3,856	8,137	0
2	Turk	Solid	SL	Midwest	1	10	Medium1b	37,336	11,429	6,010	13,644	0
2	Turk	Solid	SL	Midwest	1	4	Medium2	55,305	16,747	8,635	20,273	0
2	Turk	Solid	SL	Midwest	1	4	Large1	191,109	56,888	29,093	76,673	0
2	Turk	Solid	SL	Mid-Atlantic	2	173	Medium1a	7,929	1,599	4,331	1,543	0
2	Turk	Solid	SL	Mid-Atlantic	2	115	Medium1b	12,220	1,563	7,131	1,493	0
2	Turk	Solid	SL	Mid-Atlantic	2	76	Medium2	17,116	1,790	9,830	1,811	0
2	Turk	Solid	SL	Mid-Atlantic	2	54	Large1	35,423	2,699	19,871	3,082	0
2	Turk	Solid	SL	Midwest	2	148	Medium1a	18,342	1,603	2,287	1,392	0
2	Turk	Solid	SL	Midwest	2	99	Medium1b	29,921	1,567	3,152	1,347	0
2	Turk	Solid	SL	Midwest	2	68	Medium2	44,064	1,795	4,303	1,632	0
2	Turk	Solid	SL	Midwest	2	74	Large1	150,389	2,727	13,404	3,036	0
2	Turk	Solid	SL	Mid-Atlantic	3	74	Medium1a	6,637	580	1,297	0	0
2	Turk	Solid	SL	Mid-Atlantic	3	49	Medium1b	10,955	580	1,562	0	0
2	Turk	Solid	SL	Mid-Atlantic	3	35	Medium2	15,679	580	1,742	0	0
2	Turk	Solid	SL	Mid-Atlantic	3	36	Large1	33,290	580	2,442	0	0
2	Turk	Solid	SL	Midwest	3	64	Medium1a	17,240	580	861	0	0
2	Turk	Solid	SL	Midwest	3	42	Medium1b	28,845	580	976	0	0
2	Turk	Solid	SL	Midwest	3	31	Medium2	42,817	580	1,146	0	0
2	Turk	Solid	SL	Midwest	3	50	Large1	148,300	580	3,058	0	0
3	Turk	Solid	SL	Mid-Atlantic	1	3	Medium1a	10,925	1,483	2,759	1,380	3,082
3	Turk	Solid	SL	Mid-Atlantic	1	2	Medium1b	16,881	2,103	3,334	2,248	3,082
3	Turk	Solid	SL	Mid-Atlantic	1	1	Medium2	23,397	2,781	3,854	3,197	3,082
3	Turk	Solid	SL	Mid-Atlantic	1	0	Large1	47,685	5,266	5,820	6,676	3,082
3	Turk	Solid	SL	Midwest	1	3	Medium1a	21,619	1,314	2,376	1,032	3,082
3	Turk	Solid	SL	Midwest	1	2	Medium1b	34,915	1,818	2,749	1,660	3,082
3	Turk	Solid	SL	Midwest	1	1	Medium2	50,922	2,424	3,230	2,416	3,082
3	Turk	Solid	SL	Midwest	1	1	Large1	171,906	7,003	7,505	8,850	3,082
3	Turk	Solid	SL	Mid-Atlantic	2	28	Medium1a	10,864	1,401	2,766	1,266	3,082

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
3	Turk	Solid	SL	Mid-Atlantic	2	18	Medium1b	16,351	1,401	3,443	1,266	3,082
3	Turk	Solid	SL	Mid-Atlantic	2	12	Medium2	22,520	1,619	4,038	1,571	3,082
3	Turk	Solid	SL	Mid-Atlantic	2	9	Large1	45,379	2,239	6,313	2,439	3,082
3	Turk	Solid	SL	Midwest	2	27	Medium1a	21,710	1,434	2,431	1,182	3,082
3	Turk	Solid	SL	Midwest	2	18	Medium1b	34,604	1,404	2,925	1,145	3,082
3	Turk	Solid	SL	Midwest	2	12	Medium2	50,319	1,623	3,576	1,418	3,082
3	Turk	Solid	SL	Midwest	2	14	Large1	168,341	2,261	9,592	2,403	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	12	Medium1a	9,721	580	2,300	0	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	8	Medium1b	15,209	580	2,588	0	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	6	Medium2	21,213	580	2,794	0	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	6	Large1	43,597	580	3,589	0	3,082
3	Turk	Solid	SL	Midwest	3	12	Medium1a	20,734	580	2,012	0	3,082
3	Turk	Solid	SL	Midwest	3	8	Medium1b	33,651	580	2,153	0	3,082
3	Turk	Solid	SL	Midwest	3	6	Medium2	49,202	580	2,354	0	3,082
3	Turk	Solid	SL	Midwest	3	9	Large1	166,603	580	4,503	0	3,082
3	Turk	Solid	SL	Mid-Atlantic	1	4	Medium1a	14,121	5,716	4,721	7,306	3,082
3	Turk	Solid	SL	Mid-Atlantic	1	3	Medium1b	22,270	9,242	6,643	12,243	3,082
3	Turk	Solid	SL	Mid-Atlantic	1	1	Medium2	31,186	13,100	8,638	17,644	3,082
3	Turk	Solid	SL	Mid-Atlantic	1	1	Large1	64,423	27,239	16,099	37,438	3,082
3	Turk	Solid	SL	Midwest	1	4	Medium1a	25,904	7,013	5,007	8,137	3,082
3	Turk	Solid	SL	Midwest	1	3	Medium1b	42,142	11,429	7,187	13,644	3,082
3	Turk	Solid	SL	Midwest	1	1	Medium2	61,690	16,747	9,843	20,273	3,082
3	Turk	Solid	SL	Midwest	1	1	Large1	209,412	56,888	30,538	76,673	3,082
3	Turk	Solid	SL	Mid-Atlantic	2	41	Medium1a	11,013	1,599	5,334	1,543	3,082
3	Turk	Solid	SL	Mid-Atlantic	2	28	Medium1b	16,474	1,563	8,157	1,493	3,082
3	Turk	Solid	SL	Mid-Atlantic	2	18	Medium2	22,649	1,790	10,882	1,811	3,082
3	Turk	Solid	SL	Mid-Atlantic	2	13	Large1	45,729	2,699	21,017	3,082	3,082
3	Turk	Solid	SL	Midwest	2	41	Medium1a	21,837	1,603	3,439	1,392	3,082
3	Turk	Solid	SL	Midwest	2	27	Medium1b	34,726	1,567	4,330	1,347	3,082

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
3	Turk	Solid	SL	Midwest	2	19	Medium2	50,449	1,795	5,511	1,632	3,082
3	Turk	Solid	SL	Midwest	2	20	Large1	168,691	2,727	14,849	3,036	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	18	Medium1a	9,721	580	2,300	0	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	12	Medium1b	15,209	580	2,588	0	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	8	Medium2	21,213	580	2,794	0	3,082
3	Turk	Solid	SL	Mid-Atlantic	3	9	Large1	43,597	580	3,589	0	3,082
3	Turk	Solid	SL	Midwest	3	17	Medium1a	20,734	580	2,012	0	3,082
3	Turk	Solid	SL	Midwest	3	12	Medium1b	33,651	580	2,153	0	3,082
3	Turk	Solid	SL	Midwest	3	9	Medium2	49,202	580	2,354	0	3,082
3	Turk	Solid	SL	Midwest	3	14	Large1	166,603	580	4,503	0	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	9	Medium1a	7,842	1,483	1,755	1,380	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	6	Medium1b	12,627	2,103	2,307	2,248	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	2	Medium2	17,863	2,781	2,802	3,197	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	2	Large1	37,378	5,266	4,674	6,676	3,082
3.1	Turk	Solid	SL	Midwest	1	8	Medium1a	18,125	1,314	1,224	1,032	3,082
3.1	Turk	Solid	SL	Midwest	1	5	Medium1b	30,109	1,818	1,572	1,660	3,082
3.1	Turk	Solid	SL	Midwest	1	2	Medium2	44,537	2,424	2,022	2,416	3,082
3.1	Turk	Solid	SL	Midwest	1	2	Large1	153,603	7,003	6,060	8,850	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	88	Medium1a	7,780	1,401	1,762	1,266	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	58	Medium1b	12,098	1,401	2,416	1,266	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	39	Medium2	16,986	1,619	2,986	1,571	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	27	Large1	35,073	2,239	5,167	2,439	3,082
3.1	Turk	Solid	SL	Midwest	2	72	Medium1a	18,215	1,434	1,280	1,182	3,082
3.1	Turk	Solid	SL	Midwest	2	48	Medium1b	29,798	1,404	1,748	1,145	3,082
3.1	Turk	Solid	SL	Midwest	2	33	Medium2	43,935	1,623	2,367	1,418	3,082
3.1	Turk	Solid	SL	Midwest	2	36	Large1	150,038	2,261	8,147	2,403	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	3	37	Medium1a	6,637	580	1,297	0	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	3	25	Medium1b	10,955	580	1,562	0	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	3	18	Medium2	15,679	580	1,742	0	3,082

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
3.1	Turk	Solid	SL	Mid-Atlantic	3	18	Large1	33,290	580	2,442	0	3,082
3.1	Turk	Solid	SL	Midwest	3	31	Medium1a	17,240	580	861	0	3,082
3.1	Turk	Solid	SL	Midwest	3	20	Medium1b	28,845	580	976	0	3,082
3.1	Turk	Solid	SL	Midwest	3	15	Medium2	42,817	580	1,146	0	3,082
3.1	Turk	Solid	SL	Midwest	3	24	Large1	148,300	580	3,058	0	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	14	Medium1a	11,037	5,716	3,718	7,306	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	9	Medium1b	18,016	9,242	5,617	12,243	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	4	Medium2	25,653	13,100	7,586	17,644	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	1	2	Large1	54,117	27,239	14,953	37,438	3,082
3.1	Turk	Solid	SL	Midwest	1	11	Medium1a	22,410	7,013	3,856	8,137	3,082
3.1	Turk	Solid	SL	Midwest	1	7	Medium1b	37,336	11,429	6,010	13,644	3,082
3.1	Turk	Solid	SL	Midwest	1	3	Medium2	55,305	16,747	8,635	20,273	3,082
3.1	Turk	Solid	SL	Midwest	1	3	Large1	191,109	56,888	29,093	76,673	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	131	Medium1a	7,929	1,599	4,331	1,543	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	88	Medium1b	12,220	1,563	7,131	1,493	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	58	Medium2	17,116	1,790	9,830	1,811	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	2	41	Large1	35,423	2,699	19,871	3,082	3,082
3.1	Turk	Solid	SL	Midwest	2	108	Medium1a	18,342	1,603	2,287	1,392	3,082
3.1	Turk	Solid	SL	Midwest	2	72	Medium1b	29,921	1,567	3,152	1,347	3,082
3.1	Turk	Solid	SL	Midwest	2	49	Medium2	44,064	1,795	4,303	1,632	3,082
3.1	Turk	Solid	SL	Midwest	2	54	Large1	150,389	2,727	13,404	3,036	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	3	56	Medium1a	6,637	580	1,297	0	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	3	37	Medium1b	10,955	580	1,562	0	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	3	27	Medium2	15,679	580	1,742	0	3,082
3.1	Turk	Solid	SL	Mid-Atlantic	3	27	Large1	33,290	580	2,442	0	3,082
3.1	Turk	Solid	SL	Midwest	3	46	Medium1a	17,240	580	861	0	3,082
3.1	Turk	Solid	SL	Midwest	3	30	Medium1b	28,845	580	976	0	3,082
3.1	Turk	Solid	SL	Midwest	3	23	Medium2	42,817	580	1,146	0	3,082
3.1	Turk	Solid	SL	Midwest	3	36	Large1	148,300	580	3,058	0	3,082

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
4	Turk	Solid	SL	Mid-Atlantic	1	3	Medium1a	10,925	1,875	9,011	1,380	3,082
4	Turk	Solid	SL	Mid-Atlantic	1	2	Medium1b	16,881	2,495	9,586	2,248	3,082
4	Turk	Solid	SL	Mid-Atlantic	1	1	Medium2	23,397	3,173	10,106	3,197	3,082
4	Turk	Solid	SL	Mid-Atlantic	1	0	Large1	47,685	5,658	12,072	6,676	3,082
4	Turk	Solid	SL	Midwest	1	3	Medium1a	21,619	1,706	8,628	1,032	3,082
4	Turk	Solid	SL	Midwest	1	2	Medium1b	34,915	2,210	9,001	1,660	3,082
4	Turk	Solid	SL	Midwest	1	1	Medium2	50,922	2,816	9,482	2,416	3,082
4	Turk	Solid	SL	Midwest	1	1	Large1	171,906	7,395	13,757	8,850	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	28	Medium1a	10,864	1,793	9,018	1,266	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	18	Medium1b	16,351	1,793	9,695	1,266	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	12	Medium2	22,520	2,011	10,290	1,571	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	9	Large1	45,379	2,631	12,565	2,439	3,082
4	Turk	Solid	SL	Midwest	2	27	Medium1a	21,710	1,826	8,683	1,182	3,082
4	Turk	Solid	SL	Midwest	2	18	Medium1b	34,604	1,796	9,177	1,145	3,082
4	Turk	Solid	SL	Midwest	2	12	Medium2	50,319	2,015	9,828	1,418	3,082
4	Turk	Solid	SL	Midwest	2	14	Large1	168,341	2,653	15,844	2,403	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	12	Medium1a	9,721	972	8,552	0	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	8	Medium1b	15,209	972	8,840	0	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	6	Medium2	21,213	972	9,046	0	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	6	Large1	43,597	972	9,841	0	3,082
4	Turk	Solid	SL	Midwest	3	12	Medium1a	20,734	972	8,264	0	3,082
4	Turk	Solid	SL	Midwest	3	8	Medium1b	33,651	972	8,405	0	3,082
4	Turk	Solid	SL	Midwest	3	6	Medium2	49,202	972	8,606	0	3,082
4	Turk	Solid	SL	Midwest	3	9	Large1	166,603	972	10,755	0	3,082
4	Turk	Solid	SL	Mid-Atlantic	1	4	Medium1a	14,121	6,108	10,973	7,306	3,082
4	Turk	Solid	SL	Mid-Atlantic	1	3	Medium1b	22,270	9,634	12,895	12,243	3,082
4	Turk	Solid	SL	Mid-Atlantic	1	1	Medium2	31,186	13,492	14,890	17,644	3,082
4	Turk	Solid	SL	Mid-Atlantic	1	1	Large1	64,423	27,631	22,351	37,438	3,082
4	Turk	Solid	SL	Midwest	1	4	Medium1a	25,904	7,405	11,259	8,137	3,082

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
4	Turk	Solid	SL	Midwest	1	3	Medium1b	42,142	11,821	13,439	13,644	3,082
4	Turk	Solid	SL	Midwest	1	1	Medium2	61,690	17,139	16,095	20,273	3,082
4	Turk	Solid	SL	Midwest	1	1	Large1	209,412	57,280	36,790	76,673	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	41	Medium1a	11,013	1,991	11,586	1,543	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	28	Medium1b	16,474	1,955	14,409	1,493	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	18	Medium2	22,649	2,182	17,134	1,811	3,082
4	Turk	Solid	SL	Mid-Atlantic	2	13	Large1	45,729	3,091	27,269	3,082	3,082
4	Turk	Solid	SL	Midwest	2	41	Medium1a	21,837	1,995	9,691	1,392	3,082
4	Turk	Solid	SL	Midwest	2	27	Medium1b	34,726	1,959	10,582	1,347	3,082
4	Turk	Solid	SL	Midwest	2	19	Medium2	50,449	2,187	11,763	1,632	3,082
4	Turk	Solid	SL	Midwest	2	20	Large1	168,691	3,119	21,101	3,036	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	18	Medium1a	9,721	972	8,552	0	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	12	Medium1b	15,209	972	8,840	0	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	8	Medium2	21,213	972	9,046	0	3,082
4	Turk	Solid	SL	Mid-Atlantic	3	9	Large1	43,597	972	9,841	0	3,082
4	Turk	Solid	SL	Midwest	3	17	Medium1a	20,734	972	8,264	0	3,082
4	Turk	Solid	SL	Midwest	3	12	Medium1b	33,651	972	8,405	0	3,082
4	Turk	Solid	SL	Midwest	3	9	Medium2	49,202	972	8,606	0	3,082
4	Turk	Solid	SL	Midwest	3	14	Large1	166,603	972	10,755	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	9	Medium1a	7,842	1,875	8,007	1,380	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	6	Medium1b	12,627	2,495	8,559	2,248	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	2	Medium2	17,863	3,173	9,054	3,197	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	2	Large1	37,378	5,658	10,926	6,676	3,082
4.1	Turk	Solid	SL	Midwest	1	8	Medium1a	18,125	1,706	7,476	1,032	3,082
4.1	Turk	Solid	SL	Midwest	1	5	Medium1b	30,109	2,210	7,824	1,660	3,082
4.1	Turk	Solid	SL	Midwest	1	2	Medium2	44,537	2,816	8,274	2,416	3,082
4.1	Turk	Solid	SL	Midwest	1	2	Large1	153,603	7,395	12,312	8,850	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	2	88	Medium1a	7,780	1,793	8,014	1,266	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	2	58	Medium1b	12,098	1,793	8,668	1,266	3,082

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
4.1	Turk	Solid	SL	Mid-Atlantic	2	39	Medium2	16,986	2,011	9,238	1,571	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	2	27	Large1	35,073	2,631	11,419	2,439	3,082
4.1	Turk	Solid	SL	Midwest	2	72	Medium1a	18,215	1,826	7,532	1,182	3,082
4.1	Turk	Solid	SL	Midwest	2	48	Medium1b	29,798	1,796	8,000	1,145	3,082
4.1	Turk	Solid	SL	Midwest	2	33	Medium2	43,935	2,015	8,619	1,418	3,082
4.1	Turk	Solid	SL	Midwest	2	36	Large1	150,038	2,653	14,399	2,403	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	37	Medium1a	6,637	972	7,549	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	25	Medium1b	10,955	972	7,814	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	18	Medium2	15,679	972	7,994	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	18	Large1	33,290	972	8,694	0	3,082
4.1	Turk	Solid	SL	Midwest	3	31	Medium1a	17,240	972	7,113	0	3,082
4.1	Turk	Solid	SL	Midwest	3	20	Medium1b	28,845	972	7,228	0	3,082
4.1	Turk	Solid	SL	Midwest	3	15	Medium2	42,817	972	7,398	0	3,082
4.1	Turk	Solid	SL	Midwest	3	24	Large1	148,300	972	9,310	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	14	Medium1a	11,037	6,108	9,970	7,306	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	9	Medium1b	18,016	9,634	11,869	12,243	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	4	Medium2	25,653	13,492	13,838	17,644	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	1	2	Large1	54,117	27,631	21,205	37,438	3,082
4.1	Turk	Solid	SL	Midwest	1	11	Medium1a	22,410	7,405	10,108	8,137	3,082
4.1	Turk	Solid	SL	Midwest	1	7	Medium1b	37,336	11,821	12,262	13,644	3,082
4.1	Turk	Solid	SL	Midwest	1	3	Medium2	55,305	17,139	14,887	20,273	3,082
4.1	Turk	Solid	SL	Midwest	1	3	Large1	191,109	57,280	35,345	76,673	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	2	131	Medium1a	7,929	1,991	10,583	1,543	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	2	88	Medium1b	12,220	1,955	13,383	1,493	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	2	58	Medium2	17,116	2,182	16,082	1,811	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	2	41	Large1	35,423	3,091	26,123	3,082	3,082
4.1	Turk	Solid	SL	Midwest	2	108	Medium1a	18,342	1,995	8,539	1,392	3,082
4.1	Turk	Solid	SL	Midwest	2	72	Medium1b	29,921	1,959	9,404	1,347	3,082
4.1	Turk	Solid	SL	Midwest	2	49	Medium2	44,064	2,187	10,555	1,632	3,082

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
4.1	Turk	Solid	SL	Midwest	2	54	Large1	150,389	3,119	19,656	3,036	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	56	Medium1a	6,637	972	7,549	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	37	Medium1b	10,955	972	7,814	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	27	Medium2	15,679	972	7,994	0	3,082
4.1	Turk	Solid	SL	Mid-Atlantic	3	27	Large1	33,290	972	8,694	0	3,082
4.1	Turk	Solid	SL	Midwest	3	46	Medium1a	17,240	972	7,113	0	3,082
4.1	Turk	Solid	SL	Midwest	3	30	Medium1b	28,845	972	7,228	0	3,082
4.1	Turk	Solid	SL	Midwest	3	23	Medium2	42,817	972	7,398	0	3,082
4.1	Turk	Solid	SL	Midwest	3	36	Large1	148,300	972	9,310	0	3,082
5	Turk	Solid	SL	Mid-Atlantic	1	12	Medium1a	7,842	1,483	1,755	1,380	0
5	Turk	Solid	SL	Mid-Atlantic	1	8	Medium1b	12,627	2,103	2,307	2,248	0
5	Turk	Solid	SL	Mid-Atlantic	1	3	Medium2	17,863	2,781	2,802	3,197	0
5	Turk	Solid	SL	Mid-Atlantic	1	2	Large1	37,378	5,266	4,674	6,676	0
5	Turk	Solid	SL	Midwest	1	10	Medium1a	18,125	1,314	1,224	1,032	0
5	Turk	Solid	SL	Midwest	1	7	Medium1b	30,109	1,818	1,572	1,660	0
5	Turk	Solid	SL	Midwest	1	3	Medium2	44,537	2,424	2,022	2,416	0
5	Turk	Solid	SL	Midwest	1	3	Large1	153,603	7,003	6,060	8,850	0
5	Turk	Solid	SL	Mid-Atlantic	2	115	Medium1a	7,780	1,401	1,762	1,266	0
5	Turk	Solid	SL	Mid-Atlantic	2	77	Medium1b	12,098	1,401	2,416	1,266	0
5	Turk	Solid	SL	Mid-Atlantic	2	51	Medium2	16,986	1,619	2,986	1,571	0
5	Turk	Solid	SL	Mid-Atlantic	2	36	Large1	35,073	2,239	5,167	2,439	0
5	Turk	Solid	SL	Midwest	2	99	Medium1a	18,215	1,434	1,280	1,182	0
5	Turk	Solid	SL	Midwest	2	66	Medium1b	29,798	1,404	1,748	1,145	0
5	Turk	Solid	SL	Midwest	2	45	Medium2	43,935	1,623	2,367	1,418	0
5	Turk	Solid	SL	Midwest	2	50	Large1	150,038	2,261	8,147	2,403	0
5	Turk	Solid	SL	Mid-Atlantic	3	49	Medium1a	6,637	580	1,297	0	0
5	Turk	Solid	SL	Mid-Atlantic	3	33	Medium1b	10,955	580	1,562	0	0
5	Turk	Solid	SL	Mid-Atlantic	3	24	Medium2	15,679	580	1,742	0	0
5	Turk	Solid	SL	Mid-Atlantic	3	24	Large1	33,290	580	2,442	0	0

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
5	Turk	Solid	SL	Midwest	3	42	Medium1a	17,240	580	861	0	0
5	Turk	Solid	SL	Midwest	3	28	Medium1b	28,845	580	976	0	0
5	Turk	Solid	SL	Midwest	3	21	Medium2	42,817	580	1,146	0	0
5	Turk	Solid	SL	Midwest	3	33	Large1	148,300	580	3,058	0	0
5	Turk	Solid	SL	Mid-Atlantic	1	18	Medium1a	11,037	5,716	3,718	7,306	0
5	Turk	Solid	SL	Mid-Atlantic	1	12	Medium1b	18,016	9,242	5,617	12,243	0
5	Turk	Solid	SL	Mid-Atlantic	1	5	Medium2	25,653	13,100	7,586	17,644	0
5	Turk	Solid	SL	Mid-Atlantic	1	3	Large1	54,117	27,239	14,953	37,438	0
5	Turk	Solid	SL	Midwest	1	16	Medium1a	22,410	7,013	3,856	8,137	0
5	Turk	Solid	SL	Midwest	1	10	Medium1b	37,336	11,429	6,010	13,644	0
5	Turk	Solid	SL	Midwest	1	4	Medium2	55,305	16,747	8,635	20,273	0
5	Turk	Solid	SL	Midwest	1	4	Large1	191,109	56,888	29,093	76,673	0
5	Turk	Solid	SL	Mid-Atlantic	2	173	Medium1a	7,929	1,599	4,331	1,543	0
5	Turk	Solid	SL	Mid-Atlantic	2	115	Medium1b	12,220	1,563	7,131	1,493	0
5	Turk	Solid	SL	Mid-Atlantic	2	76	Medium2	17,116	1,790	9,830	1,811	0
5	Turk	Solid	SL	Mid-Atlantic	2	54	Large1	35,423	2,699	19,871	3,082	0
5	Turk	Solid	SL	Midwest	2	148	Medium1a	18,342	1,603	2,287	1,392	0
5	Turk	Solid	SL	Midwest	2	99	Medium1b	29,921	1,567	3,152	1,347	0
5	Turk	Solid	SL	Midwest	2	68	Medium2	44,064	1,795	4,303	1,632	0
5	Turk	Solid	SL	Midwest	2	74	Large1	150,389	2,727	13,404	3,036	0
5	Turk	Solid	SL	Mid-Atlantic	3	74	Medium1a	6,637	580	1,297	0	0
5	Turk	Solid	SL	Mid-Atlantic	3	49	Medium1b	10,955	580	1,562	0	0
5	Turk	Solid	SL	Mid-Atlantic	3	35	Medium2	15,679	580	1,742	0	0
5	Turk	Solid	SL	Mid-Atlantic	3	36	Large1	33,290	580	2,442	0	0
5	Turk	Solid	SL	Midwest	3	64	Medium1a	17,240	580	861	0	0
5	Turk	Solid	SL	Midwest	3	42	Medium1b	28,845	580	976	0	0
5	Turk	Solid	SL	Midwest	3	31	Medium2	42,817	580	1,146	0	0
5	Turk	Solid	SL	Midwest	3	50	Large1	148,300	580	3,058	0	0
5a	Turk	Solid	SL	Mid-Atlantic	1	12	Medium1a	7,842	1,483	1,755	1,380	0

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
5a	Turk	Solid	SL	Mid-Atlantic	1	8	Medium1b	12,627	2,103	2,307	2,248	0
5a	Turk	Solid	SL	Mid-Atlantic	1	3	Medium2	17,863	2,781	2,802	3,197	0
5a	Turk	Solid	SL	Mid-Atlantic	1	2	Large1	37,378	5,266	4,674	6,676	0
5a	Turk	Solid	SL	Midwest	1	10	Medium1a	18,125	1,314	1,224	1,032	0
5a	Turk	Solid	SL	Midwest	1	7	Medium1b	30,109	1,818	1,572	1,660	0
5a	Turk	Solid	SL	Midwest	1	3	Medium2	44,537	2,424	2,022	2,416	0
5a	Turk	Solid	SL	Midwest	1	3	Large1	153,603	7,003	6,060	8,850	0
5a	Turk	Solid	SL	Mid-Atlantic	2	115	Medium1a	7,780	1,401	1,762	1,266	0
5a	Turk	Solid	SL	Mid-Atlantic	2	77	Medium1b	12,098	1,401	2,416	1,266	0
5a	Turk	Solid	SL	Mid-Atlantic	2	51	Medium2	16,986	1,619	2,986	1,571	0
5a	Turk	Solid	SL	Mid-Atlantic	2	36	Large1	35,073	2,239	5,167	2,439	0
5a	Turk	Solid	SL	Midwest	2	99	Medium1a	18,215	1,434	1,280	1,182	0
5a	Turk	Solid	SL	Midwest	2	66	Medium1b	29,798	1,404	1,748	1,145	0
5a	Turk	Solid	SL	Midwest	2	45	Medium2	43,935	1,623	2,367	1,418	0
5a	Turk	Solid	SL	Midwest	2	50	Large1	150,038	2,261	8,147	2,403	0
5a	Turk	Solid	SL	Mid-Atlantic	3	49	Medium1a	6,637	580	1,297	0	0
5a	Turk	Solid	SL	Mid-Atlantic	3	33	Medium1b	10,955	580	1,562	0	0
5a	Turk	Solid	SL	Mid-Atlantic	3	24	Medium2	15,679	580	1,742	0	0
5a	Turk	Solid	SL	Mid-Atlantic	3	24	Large1	33,290	580	2,442	0	0
5a	Turk	Solid	SL	Midwest	3	42	Medium1a	17,240	580	861	0	0
5a	Turk	Solid	SL	Midwest	3	28	Medium1b	28,845	580	976	0	0
5a	Turk	Solid	SL	Midwest	3	21	Medium2	42,817	580	1,146	0	0
5a	Turk	Solid	SL	Midwest	3	33	Large1	148,300	580	3,058	0	0
5a	Turk	Solid	SL	Mid-Atlantic	1	18	Medium1a	11,037	5,716	3,718	7,306	0
5a	Turk	Solid	SL	Mid-Atlantic	1	12	Medium1b	18,016	9,242	5,617	12,243	0
5a	Turk	Solid	SL	Mid-Atlantic	1	5	Medium2	25,653	13,100	7,586	17,644	0
5a	Turk	Solid	SL	Mid-Atlantic	1	3	Large1	54,117	27,239	14,953	37,438	0
5a	Turk	Solid	SL	Midwest	1	16	Medium1a	22,410	7,013	3,856	8,137	0
5a	Turk	Solid	SL	Midwest	1	10	Medium1b	37,336	11,429	6,010	13,644	0

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
5a	Turk	Solid	SL	Midwest	1	4	Medium2	55,305	16,747	8,635	20,273	0
5a	Turk	Solid	SL	Midwest	1	4	Large1	191,109	56,888	29,093	76,673	0
5a	Turk	Solid	SL	Mid-Atlantic	2	173	Medium1a	7,929	1,599	4,331	1,543	0
5a	Turk	Solid	SL	Mid-Atlantic	2	115	Medium1b	12,220	1,563	7,131	1,493	0
5a	Turk	Solid	SL	Mid-Atlantic	2	76	Medium2	17,116	1,790	9,830	1,811	0
5a	Turk	Solid	SL	Mid-Atlantic	2	54	Large1	35,423	2,699	19,871	3,082	0
5a	Turk	Solid	SL	Midwest	2	148	Medium1a	18,342	1,603	2,287	1,392	0
5a	Turk	Solid	SL	Midwest	2	99	Medium1b	29,921	1,567	3,152	1,347	0
5a	Turk	Solid	SL	Midwest	2	68	Medium2	44,064	1,795	4,303	1,632	0
5a	Turk	Solid	SL	Midwest	2	74	Large1	150,389	2,727	13,404	3,036	0
5a	Turk	Solid	SL	Mid-Atlantic	3	74	Medium1a	6,637	580	1,297	0	0
5a	Turk	Solid	SL	Mid-Atlantic	3	49	Medium1b	10,955	580	1,562	0	0
5a	Turk	Solid	SL	Mid-Atlantic	3	35	Medium2	15,679	580	1,742	0	0
5a	Turk	Solid	SL	Mid-Atlantic	3	36	Large1	33,290	580	2,442	0	0
5a	Turk	Solid	SL	Midwest	3	64	Medium1a	17,240	580	861	0	0
5a	Turk	Solid	SL	Midwest	3	42	Medium1b	28,845	580	976	0	0
5a	Turk	Solid	SL	Midwest	3	31	Medium2	42,817	580	1,146	0	0
5a	Turk	Solid	SL	Midwest	3	50	Large1	148,300	580	3,058	0	0
7	Turk	Solid	SL	Mid-Atlantic	1	12	Medium1a	7,842	1,483	1,755	1,380	0
7	Turk	Solid	SL	Mid-Atlantic	1	8	Medium1b	12,627	2,103	2,307	2,248	0
7	Turk	Solid	SL	Mid-Atlantic	1	3	Medium2	17,863	2,781	2,802	3,197	0
7	Turk	Solid	SL	Mid-Atlantic	1	2	Large1	37,378	5,266	4,674	6,676	0
7	Turk	Solid	SL	Midwest	1	10	Medium1a	18,125	1,314	1,224	1,032	0
7	Turk	Solid	SL	Midwest	1	7	Medium1b	30,109	1,818	1,572	1,660	0
7	Turk	Solid	SL	Midwest	1	3	Medium2	44,537	2,424	2,022	2,416	0
7	Turk	Solid	SL	Midwest	1	3	Large1	153,603	7,003	6,060	8,850	0
7	Turk	Solid	SL	Mid-Atlantic	2	115	Medium1a	7,780	1,401	1,762	1,266	0
7	Turk	Solid	SL	Mid-Atlantic	2	77	Medium1b	12,098	1,401	2,416	1,266	0
7	Turk	Solid	SL	Mid-Atlantic	2	51	Medium2	16,986	1,619	2,986	1,571	0

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
7	Turk	Solid	SL	Mid-Atlantic	2	36	Large1	35,073	2,239	5,167	2,439	0
7	Turk	Solid	SL	Midwest	2	99	Medium1a	18,215	1,434	1,280	1,182	0
7	Turk	Solid	SL	Midwest	2	66	Medium1b	29,798	1,404	1,748	1,145	0
7	Turk	Solid	SL	Midwest	2	45	Medium2	43,935	1,623	2,367	1,418	0
7	Turk	Solid	SL	Midwest	2	50	Large1	150,038	2,261	8,147	2,403	0
7	Turk	Solid	SL	Mid-Atlantic	3	49	Medium1a	6,637	580	1,297	0	0
7	Turk	Solid	SL	Mid-Atlantic	3	33	Medium1b	10,955	580	1,562	0	0
7	Turk	Solid	SL	Mid-Atlantic	3	24	Medium2	15,679	580	1,742	0	0
7	Turk	Solid	SL	Mid-Atlantic	3	24	Large1	33,290	580	2,442	0	0
7	Turk	Solid	SL	Midwest	3	42	Medium1a	17,240	580	861	0	0
7	Turk	Solid	SL	Midwest	3	28	Medium1b	28,845	580	976	0	0
7	Turk	Solid	SL	Midwest	3	21	Medium2	42,817	580	1,146	0	0
7	Turk	Solid	SL	Midwest	3	33	Large1	148,300	580	3,058	0	0
7	Turk	Solid	SL	Mid-Atlantic	1	18	Medium1a	11,037	5,716	3,718	7,306	0
7	Turk	Solid	SL	Mid-Atlantic	1	12	Medium1b	18,016	9,242	5,617	12,243	0
7	Turk	Solid	SL	Mid-Atlantic	1	5	Medium2	25,653	13,100	7,586	17,644	0
7	Turk	Solid	SL	Mid-Atlantic	1	3	Large1	54,117	27,239	14,953	37,438	0
7	Turk	Solid	SL	Midwest	1	16	Medium1a	22,410	7,013	3,856	8,137	0
7	Turk	Solid	SL	Midwest	1	10	Medium1b	37,336	11,429	6,010	13,644	0
7	Turk	Solid	SL	Midwest	1	4	Medium2	55,305	16,747	8,635	20,273	0
7	Turk	Solid	SL	Midwest	1	4	Large1	191,109	56,888	29,093	76,673	0
7	Turk	Solid	SL	Mid-Atlantic	2	173	Medium1a	7,929	1,599	4,331	1,543	0
7	Turk	Solid	SL	Mid-Atlantic	2	115	Medium1b	12,220	1,563	7,131	1,493	0
7	Turk	Solid	SL	Mid-Atlantic	2	76	Medium2	17,116	1,790	9,830	1,811	0
7	Turk	Solid	SL	Mid-Atlantic	2	54	Large1	35,423	2,699	19,871	3,082	0
7	Turk	Solid	SL	Midwest	2	148	Medium1a	18,342	1,603	2,287	1,392	0
7	Turk	Solid	SL	Midwest	2	99	Medium1b	29,921	1,567	3,152	1,347	0
7	Turk	Solid	SL	Midwest	2	68	Medium2	44,064	1,795	4,303	1,632	0
7	Turk	Solid	SL	Midwest	2	74	Large1	150,389	2,727	13,404	3,036	0

Table 11-14. (Continued)

Option	Animal	Type	Operation	Region	Category	# Facilities	Size ID	Capital	Fixed	O&M	3yrrec	5yrrec
7	Turk	Solid	SL	Mid-Atlantic	3	74	Medium1a	6,637	580	1,297	0	0
7	Turk	Solid	SL	Mid-Atlantic	3	49	Medium1b	10,955	580	1,562	0	0
7	Turk	Solid	SL	Mid-Atlantic	3	35	Medium2	15,679	580	1,742	0	0
7	Turk	Solid	SL	Mid-Atlantic	3	36	Large1	33,290	580	2,442	0	0
7	Turk	Solid	SL	Midwest	3	64	Medium1a	17,240	580	861	0	0
7	Turk	Solid	SL	Midwest	3	42	Medium1b	28,845	580	976	0	0
7	Turk	Solid	SL	Midwest	3	31	Medium2	42,817	580	1,146	0	0
7	Turk	Solid	SL	Midwest	3	50	Large1	148,300	580	3,058	0	0

Table 11-15. Regulatory Compliance Costs for the Dairy Industry

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Dairy	0	0	Central	1	Large1	66,157	1,980	3,364	3,034
1	Dairy	0	0	Central	2	Large1	439,469	1,006	34,150	1,184
1	Dairy	0	0	Central	3	Large1	66,157	190	2,533	600
1	Dairy	0	0	Mid-Atlantic	1	Large1	45,347	2,334	3,153	3,690
1	Dairy	0	0	Mid-Atlantic	2	Large1	45,347	1,006	46,898	1,184
1	Dairy	0	0	Mid-Atlantic	3	Large1	45,347	190	2,117	600
1	Dairy	0	0	Midwest	1	Large1	45,347	2,492	3,245	3,982
1	Dairy	0	0	Midwest	2	Large1	45,347	1,164	55,084	1,497
1	Dairy	0	0	Midwest	3	Large1	45,347	190	2,117	600
1	Dairy	0	0	Pacific	1	Large1	66,157	2,234	3,511	3,495
1	Dairy	0	0	Pacific	2	Large1	439,469	986	37,270	1,158
1	Dairy	0	0	Pacific	3	Large1	66,157	190	2,533	600
1	Dairy	0	0	South	1	Large1	66,157	2,111	3,440	3,270
1	Dairy	0	0	South	2	Large1	66,157	782	54,494	764
1	Dairy	0	0	South	3	Large1	66,157	190	2,533	600
1	Dairy	0	0	Central	1	Medium2	31,721	1,106	2,560	1,379
1	Dairy	0	0	Central	2	Medium2	31,426	829	27,117	866
1	Dairy	0	0	Central	3	Medium2	28,581	190	1,964	600
1	Dairy	0	0	Mid-Atlantic	1	Medium2	26,056	1,225	2,732	1,599
1	Dairy	0	0	Mid-Atlantic	2	Medium2	25,400	840	13,629	882
1	Dairy	0	0	Mid-Atlantic	3	Medium2	21,117	190	1,854	600
1	Dairy	0	0	Midwest	1	Medium2	25,046	1,275	2,734	1,707
1	Dairy	0	0	Midwest	2	Medium2	24,363	894	15,789	974
1	Dairy	0	0	Midwest	3	Medium2	20,003	190	1,801	600
1	Dairy	0	0	Pacific	1	Medium2	34,281	1,191	2,769	1,533
1	Dairy	0	0	Pacific	2	Medium2	33,882	832	30,648	871
1	Dairy	0	0	Pacific	3	Medium2	31,034	190	2,087	6000

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Dairy	0	0	South	1	Medium2	33,730	1,152	2,706	1,461
1	Dairy	0	0	South	2	Medium2	33,357	767	15,809	744
1	Dairy	0	0	South	3	Medium2	30,533	190	2,062	600
1	Dairy	0	0	Central	1	Medium1	20,442	902	2,024	1,005
1	Dairy	0	0	Central	2	Medium1	20,394	852	4,499	897
1	Dairy	0	0	Central	3	Medium1	17,528	190	1,681	600
1	Dairy	0	0	Mid-Atlantic	1	Medium1	17,832	963	2,142	1,107
1	Dairy	0	0	Mid-Atlantic	2	Medium1	17,726	894	2,798	974
1	Dairy	0	0	Mid-Atlantic	3	Medium1	13,367	190	1,616	600
1	Dairy	0	0	Midwest	1	Medium1	17,220	990	2,154	1,164
1	Dairy	0	0	Midwest	2	Medium1	17,110	921	2,961	1,031
1	Dairy	0	0	Midwest	3	Medium1	12,711	190	1,585	600
1	Dairy	0	0	Pacific	1	Medium1	21,924	944	2,157	1,082
1	Dairy	0	0	Pacific	2	Medium1	21,863	883	4,972	959
1	Dairy	0	0	Pacific	3	Medium1	18,968	190	1,753	600
1	Dairy	0	0	South	1	Medium1	21,593	925	2,115	1,036
1	Dairy	0	0	South	2	Medium1	21,526	856	3,400	903
1	Dairy	0	0	South	3	Medium1	18,656	190	1,737	600
1	Dairy	0	0	Central	1	Large1	273,999	2,458	14,034	3,933
1	Dairy	0	0	Mid-Atlantic	1	Large1	349,278	2,759	18,597	4,491
1	Dairy	0	0	Midwest	1	Large1	280,372	2,795	15,173	4,554
1	Dairy	0	0	Pacific	1	Large1	290,359	2,530	14,893	4,057
1	Dairy	0	0	South	1	Large1	168,524	2,382	8,716	3,783
1	Dairy	0	0	Central	1	Medium2	109,228	1,422	6,665	1,972
1	Dairy	0	0	Mid-Atlantic	1	Medium2	136,137	1,368	8,359	1,872
1	Dairy	0	0	Midwest	1	Medium2	108,918	1,411	7,039	1,959
1	Dairy	0	0	Pacific	1	Medium2	119,249	1,306	7,112	1,757
1	Dairy	0	0	South	1	Medium2	74,211	1,209	4,776	1,569
1	Dairy	0	0	Central	1	Medium1	20,653	1,064	2,193	1,310

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Dairy	0	0	Mid-Atlantic	1	Medium1	17,964	1,037	2,241	1,249
1	Dairy	0	0	Midwest	1	Medium1	17,349	1,060	2,244	1,294
1	Dairy	0	0	Pacific	1	Medium1	21,991	1,004	2,229	1,187
1	Dairy	0	0	South	1	Medium1	21,627	955	2,150	1,093
1	Dairy	0	0	Central	2	Large1	273,999	1,228	78,162	1,603
1	Dairy	0	0	Mid-Atlantic	2	Large1	349,278	1,075	57,990	1,314
1	Dairy	0	0	Midwest	2	Large1	280,372	1,281	45,242	1,709
1	Dairy	0	0	Pacific	2	Large1	290,359	1,010	76,755	1,203
1	Dairy	0	0	South	2	Large1	168,524	742	40,386	690
1	Dairy	0	0	Central	2	Medium2	108,613	1,057	21,077	1,289
1	Dairy	0	0	Mid-Atlantic	2	Medium2	135,282	937	18,846	1,060
1	Dairy	0	0	Midwest	2	Medium2	108,074	1,006	14,994	1,192
1	Dairy	0	0	Pacific	2	Medium2	118,748	902	21,607	993
1	Dairy	0	0	South	2	Medium2	73,771	802	15,323	812
1	Dairy	0	0	Central	2	Medium1	20,717	1,122	3,741	1,412
1	Dairy	0	0	Mid-Atlantic	2	Medium1	17,932	1,019	3,035	1,214
1	Dairy	0	0	Midwest	2	Medium1	17,328	1,048	2,824	1,268
1	Dairy	0	0	Pacific	2	Medium1	21,954	971	3,676	1,121
1	Dairy	0	0	South	2	Medium1	21,592	919	3,212	1,025
1	Dairy	0	0	Central	3	Large1	273,999	190	12,925	600
1	Dairy	0	0	Mid-Atlantic	3	Large1	349,278	190	17,313	600
1	Dairy	0	0	Midwest	3	Large1	280,372	190	13,868	600
1	Dairy	0	0	Pacific	3	Large1	290,359	190	13,743	600
1	Dairy	0	0	South	3	Large1	168,524	190	7,652	600
1	Dairy	0	0	Central	3	Medium2	105,511	190	5,811	600
1	Dairy	0	0	Mid-Atlantic	3	Medium2	130,852	190	7,341	600
1	Dairy	0	0	Midwest	3	Medium2	103,530	190	5,978	600
1	Dairy	0	0	Pacific	3	Medium2	115,834	190	6,327	600
1	Dairy	0	0	South	3	Medium2	70,929	190	4,081	600

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Dairy	0	0	Central	3	Medium1	17,528	190	1,681	600
1	Dairy	0	0	Mid-Atlantic	3	Medium1	13,367	190	1,616	600
1	Dairy	0	0	Midwest	3	Medium1	12,711	190	1,585	600
1	Dairy	0	0	Pacific	3	Medium1	18,968	190	1,753	600
1	Dairy	0	0	South	3	Medium1	18,656	190	1,737	600
2	Dairy	0	0	Central	1	Large1	66,157	2,458	3,642	3,933
2	Dairy	0	0	Mid-Atlantic	1	Large1	45,347	2,759	3,401	4,491
2	Dairy	0	0	Midwest	1	Large1	45,347	2,795	3,422	4,554
2	Dairy	0	0	Pacific	1	Large1	66,157	2,530	3,683	4,057
2	Dairy	0	0	South	1	Large1	66,157	2,382	3,598	3,783
2	Dairy	0	0	Central	2	Large1	66,157	1,228	67,770	1,603
2	Dairy	0	0	Mid-Atlantic	2	Large1	45,347	1,075	42,794	1,314
2	Dairy	0	0	Midwest	2	Large1	45,347	1,281	33,491	1,709
2	Dairy	0	0	Pacific	2	Large1	66,157	1,010	65,545	1,203
2	Dairy	0	0	South	2	Large1	66,157	742	35,267	690
2	Dairy	0	0	Central	3	Large1	66,157	190	2,533	600
2	Dairy	0	0	Mid-Atlantic	3	Large1	45,347	190	2,117	600
2	Dairy	0	0	Midwest	3	Large1	45,347	190	2,117	600
2	Dairy	0	0	Pacific	3	Large1	66,157	190	2,533	600
2	Dairy	0	0	South	3	Large1	66,157	190	2,533	600
2	Dairy	0	0	Central	1	Medium1	20,653	1,064	2,193	1,310
2	Dairy	0	0	Mid-Atlantic	1	Medium1	17,964	1,037	2,241	1,249
2	Dairy	0	0	Midwest	1	Medium1	17,349	1,060	2,244	1,294
2	Dairy	0	0	Pacific	1	Medium1	21,991	1,004	2,229	1,187
2	Dairy	0	0	South	1	Medium1	21,627	955	2,150	1,093
2	Dairy	0	0	Central	2	Medium1	20,717	1,122	3,741	1,412
2	Dairy	0	0	Mid-Atlantic	2	Medium1	17,932	1,019	3,035	1,214
2	Dairy	0	0	Midwest	2	Medium1	17,328	1,048	2,824	1,268
2	Dairy	0	0	Pacific	2	Medium1	21,954	971	3,676	1,121

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
2	Dairy	0	0	South	2	Medium1	21,592	919	3,212	1,025
2	Dairy	0	0	Central	3	Medium1	17,528	190	1,681	600
2	Dairy	0	0	Mid-Atlantic	3	Medium1	13,367	190	1,616	600
2	Dairy	0	0	Midwest	3	Medium1	12,711	190	1,585	600
2	Dairy	0	0	Pacific	3	Medium1	18,968	190	1,753	600
2	Dairy	0	0	South	3	Medium1	18,656	190	1,737	600
2	Dairy	0	0	Central	1	Medium2	32,299	1,422	2,818	1,972
2	Dairy	0	0	Mid-Atlantic	1	Medium2	26,402	1,368	2,872	1,872
2	Dairy	0	0	Midwest	1	Medium2	25,392	1,411	2,863	1,959
2	Dairy	0	0	Pacific	1	Medium2	34,450	1,306	2,873	1,757
2	Dairy	0	0	South	1	Medium2	33,815	1,209	2,756	1,569
2	Dairy	0	0	Central	2	Medium2	31,683	1,057	17,230	1,289
2	Dairy	0	0	Mid-Atlantic	2	Medium2	25,547	937	13,359	1,060
2	Dairy	0	0	Midwest	2	Medium2	24,548	1,006	10,818	1,192
2	Dairy	0	0	Pacific	2	Medium2	33,949	902	17,367	993
2	Dairy	0	0	South	2	Medium2	33,376	802	13,303	812
2	Dairy	0	0	Central	3	Medium2	28,581	190	1,964	600
2	Dairy	0	0	Mid-Atlantic	3	Medium2	21,117	190	1,854	600
2	Dairy	0	0	Midwest	3	Medium2	20,003	190	1,801	600
2	Dairy	0	0	Pacific	3	Medium2	31,034	190	2,087	600
2	Dairy	0	0	South	3	Medium2	30,533	190	2,062	600
3	Dairy	0	0	Central	1	Large1	205,246	5,140	10,396	3,933
3	Dairy	0	0	Mid-Atlantic	1	Large1	296,252	4,966	15,660	4,491
3	Dairy	0	0	Midwest	1	Large1	322,071	5,324	16,925	4,554
3	Dairy	0	0	Pacific	1	Large1	212,269	4,540	10,808	4,057
3	Dairy	0	0	South	1	Large1	321,901	4,827	16,037	3,783
3	Dairy	0	0	Central	2	Large1	205,246	1,228	74,524	1,603
3	Dairy	0	0	Mid-Atlantic	2	Large1	296,252	1,075	55,052	1,314
3	Dairy	0	0	Midwest	2	Large1	322,071	1,281	46,995	1,709

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
3	Dairy	0	0	Pacific	2	Large1	212,269	1,010	72,669	1,203
3	Dairy	0	0	South	2	Large1	321,901	742	47,706	690
3	Dairy	0	0	Central	3	Large1	205,246	190	9,287	600
3	Dairy	0	0	Mid-Atlantic	3	Large1	296,252	190	14,376	600
3	Dairy	0	0	Midwest	3	Large1	322,071	190	15,621	600
3	Dairy	0	0	Pacific	3	Large1	212,269	190	9,657	600
3	Dairy	0	0	South	3	Large1	321,901	190	14,972	600
3	Dairy	0	0	Central	1	Medium1	58,077	3,284	4,014	1,310
3	Dairy	0	0	Mid-Atlantic	1	Medium1	87,351	3,204	5,634	1,249
3	Dairy	0	0	Midwest	1	Medium1	91,593	3,356	5,868	1,294
3	Dairy	0	0	Pacific	1	Medium1	62,841	2,791	4,225	1,187
3	Dairy	0	0	South	1	Medium1	98,010	3,636	5,882	1,093
3	Dairy	0	0	Central	2	Medium1	58,142	1,122	5,562	1,412
3	Dairy	0	0	Mid-Atlantic	2	Medium1	87,319	1,019	6,428	1,214
3	Dairy	0	0	Midwest	2	Medium1	91,573	1,048	6,448	1,268
3	Dairy	0	0	Pacific	2	Medium1	62,804	971	5,673	1,121
3	Dairy	0	0	South	2	Medium1	97,975	919	6,944	1,025
3	Dairy	0	0	Central	3	Medium1	54,953	190	3,501	600
3	Dairy	0	0	Mid-Atlantic	3	Medium1	82,754	190	5,009	600
3	Dairy	0	0	Midwest	3	Medium1	86,955	190	5,209	600
3	Dairy	0	0	Pacific	3	Medium1	59,818	190	3,749	600
3	Dairy	0	0	South	3	Medium1	95,039	190	5,469	600
3	Dairy	0	0	Central	1	Medium2	86,664	3,642	5,515	1,972
3	Dairy	0	0	Mid-Atlantic	1	Medium2	126,691	3,535	7,877	1,872
3	Dairy	0	0	Midwest	1	Medium2	135,126	3,708	8,336	1,959
3	Dairy	0	0	Pacific	1	Medium2	92,200	3,093	5,742	1,757
3	Dairy	0	0	South	1	Medium2	141,772	3,890	8,116	1,569
3	Dairy	0	0	Central	2	Medium2	86,048	1,057	19,928	1,289
3	Dairy	0	0	Mid-Atlantic	2	Medium2	125,836	937	18,365	1,060

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
3	Dairy	0	0	Midwest	2	Medium2	134,282	1,006	16,291	1,192
3	Dairy	0	0	Pacific	2	Medium2	91,699	902	20,237	993
3	Dairy	0	0	South	2	Medium2	141,332	802	18,662	812
3	Dairy	0	0	Central	3	Medium2	82,947	190	4,662	600
3	Dairy	0	0	Mid-Atlantic	3	Medium2	121,406	190	6,860	600
3	Dairy	0	0	Midwest	3	Medium2	129,738	190	7,274	600
3	Dairy	0	0	Pacific	3	Medium2	88,784	190	4,956	600
3	Dairy	0	0	South	3	Medium2	138,490	190	7,421	600
4	Dairy	0	0	Central	1	Large1	205,638	5,140	16,648	3,933
4	Dairy	0	0	Mid-Atlantic	1	Large1	296,644	4,966	21,912	4,491
4	Dairy	0	0	Midwest	1	Large1	322,463	5,324	23,177	4,554
4	Dairy	0	0	Pacific	1	Large1	212,661	4,540	17,060	4,057
4	Dairy	0	0	South	1	Large1	322,293	4,827	22,289	3,783
4	Dairy	0	0	Central	2	Large1	205,638	1,228	80,776	1,603
4	Dairy	0	0	Mid-Atlantic	2	Large1	296,644	1,075	61,304	1,314
4	Dairy	0	0	Midwest	2	Large1	322,463	1,281	53,247	1,709
4	Dairy	0	0	Pacific	2	Large1	212,661	1,010	78,921	1,203
4	Dairy	0	0	South	2	Large1	322,293	742	53,958	690
4	Dairy	0	0	Central	3	Large1	205,638	190	15,539	600
4	Dairy	0	0	Mid-Atlantic	3	Large1	296,644	190	20,628	600
4	Dairy	0	0	Midwest	3	Large1	322,463	190	21,873	600
4	Dairy	0	0	Pacific	3	Large1	212,661	190	15,909	600
4	Dairy	0	0	South	3	Large1	322,293	190	21,224	600
4	Dairy	0	0	Central	1	Medium1	58,469	3,284	10,266	1,310
4	Dairy	0	0	Mid-Atlantic	1	Medium1	87,743	3,204	11,886	1,249
4	Dairy	0	0	Midwest	1	Medium1	91,985	3,356	12,120	1,294
4	Dairy	0	0	Pacific	1	Medium1	63,233	2,791	10,477	1,187
4	Dairy	0	0	South	1	Medium1	98,402	3,636	12,134	1,093
4	Dairy	0	0	Central	2	Medium1	58,534	1,122	11,814	1,412

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
4	Dairy	0	0	Mid-Atlantic	2	Medium1	87,711	1,019	12,680	1,214
4	Dairy	0	0	Midwest	2	Medium1	91,965	1,048	12,700	1,268
4	Dairy	0	0	Pacific	2	Medium1	63,196	971	11,925	1,121
4	Dairy	0	0	South	2	Medium1	98,367	919	13,196	1,025
4	Dairy	0	0	Central	3	Medium1	55,345	190	9,753	600
4	Dairy	0	0	Mid-Atlantic	3	Medium1	83,146	190	11,261	600
4	Dairy	0	0	Midwest	3	Medium1	87,347	190	11,461	600
4	Dairy	0	0	Pacific	3	Medium1	60,210	190	10,001	600
4	Dairy	0	0	South	3	Medium1	95,431	190	11,721	600
4	Dairy	0	0	Central	1	Medium2	87,056	3,642	11,767	1,972
4	Dairy	0	0	Mid-Atlantic	1	Medium2	127,083	3,535	14,129	1,872
4	Dairy	0	0	Midwest	1	Medium2	135,518	3,708	14,588	1,959
4	Dairy	0	0	Pacific	1	Medium2	92,592	3,093	11,994	1,757
4	Dairy	0	0	South	1	Medium2	142,164	3,890	14,368	1,569
4	Dairy	0	0	Central	2	Medium2	86,440	1,057	26,180	1,289
4	Dairy	0	0	Mid-Atlantic	2	Medium2	126,228	937	24,617	1,060
4	Dairy	0	0	Midwest	2	Medium2	134,674	1,006	22,543	1,192
4	Dairy	0	0	Pacific	2	Medium2	92,091	902	26,489	993
4	Dairy	0	0	South	2	Medium2	141,724	802	24,914	812
4	Dairy	0	0	Central	3	Medium2	83,339	190	10,914	600
4	Dairy	0	0	Mid-Atlantic	3	Medium2	121,798	190	13,112	600
4	Dairy	0	0	Midwest	3	Medium2	130,130	190	13,526	600
4	Dairy	0	0	Pacific	3	Medium2	89,176	190	11,208	600
4	Dairy	0	0	South	3	Medium2	138,882	190	13,673	600
5	Dairy	0	0	Central	1	Large1	75,314	2,458	31,227	3,933
5	Dairy	0	0	Mid-Atlantic	1	Large1	54,504	2,759	43,339	4,491
5	Dairy	0	0	Midwest	1	Large1	54,504	2,795	44,823	4,554
5	Dairy	0	0	Pacific	1	Large1	75,314	2,530	27,480	4,057
5	Dairy	0	0	South	1	Large1	75,314	2,382	26,422	3,783

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
5	Dairy	0	0	Central	2	Large1	75,314	1,228	101,067	1,603
5	Dairy	0	0	Mid-Atlantic	2	Large1	54,504	1,075	82,623	1,314
5	Dairy	0	0	Midwest	2	Large1	54,504	1,281	70,773	1,709
5	Dairy	0	0	Pacific	2	Large1	75,314	1,010	82,352	1,203
5	Dairy	0	0	South	2	Large1	75,314	742	52,255	690
5	Dairy	0	0	Central	3	Large1	75,314	190	30,119	600
5	Dairy	0	0	Mid-Atlantic	3	Large1	54,504	190	42,055	600
5	Dairy	0	0	Midwest	3	Large1	54,504	190	43,518	600
5	Dairy	0	0	Pacific	3	Large1	75,314	190	26,329	600
5	Dairy	0	0	South	3	Large1	75,314	190	25,358	600
5	Dairy	0	0	Central	1	Medium1	29,810	1,064	9,121	1,310
5	Dairy	0	0	Mid-Atlantic	1	Medium1	27,120	1,037	11,362	1,249
5	Dairy	0	0	Midwest	1	Medium1	26,505	1,060	11,488	1,294
5	Dairy	0	0	Pacific	1	Medium1	31,147	1,004	8,737	1,187
5	Dairy	0	0	South	1	Medium1	30,784	955	8,546	1,093
5	Dairy	0	0	Central	2	Medium1	29,874	1,122	11,680	1,412
5	Dairy	0	0	Mid-Atlantic	2	Medium1	27,089	1,019	12,131	1,214
5	Dairy	0	0	Midwest	2	Medium1	26,485	1,048	11,734	1,268
5	Dairy	0	0	Pacific	2	Medium1	31,111	971	9,214	1,121
5	Dairy	0	0	South	2	Medium1	30,749	919	10,397	1,025
5	Dairy	0	0	Central	3	Medium1	26,685	190	8,608	600
5	Dairy	0	0	Mid-Atlantic	3	Medium1	22,524	190	10,736	600
5	Dairy	0	0	Midwest	3	Medium1	21,867	190	10,829	600
5	Dairy	0	0	Pacific	3	Medium1	28,124	190	8,261	600
5	Dairy	0	0	South	3	Medium1	27,813	190	8,133	600
5	Dairy	0	0	Central	1	Medium2	41,456	1,422	16,367	1,972
5	Dairy	0	0	Mid-Atlantic	1	Medium2	35,559	1,368	20,721	1,872
5	Dairy	0	0	Midwest	1	Medium2	34,549	1,411	20,955	1,959
5	Dairy	0	0	Pacific	1	Medium2	43,606	1,306	15,601	1,757

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
5	Dairy	0	0	South	1	Medium2	42,972	1,209	15,270	1,569
5	Dairy	0	0	Central	2	Medium2	40,840	1,057	30,979	1,289
5	Dairy	0	0	Mid-Atlantic	2	Medium2	34,704	937	31,154	1,060
5	Dairy	0	0	Midwest	2	Medium2	33,704	1,006	30,870	1,192
5	Dairy	0	0	Pacific	2	Medium2	43,106	902	30,278	993
5	Dairy	0	0	South	2	Medium2	42,533	802	25,792	812
5	Dairy	0	0	Central	3	Medium2	37,738	190	15,513	600
5	Dairy	0	0	Mid-Atlantic	3	Medium2	30,274	190	19,703	600
5	Dairy	0	0	Midwest	3	Medium2	29,160	190	19,893	600
5	Dairy	0	0	Pacific	3	Medium2	40,191	190	14,815	600
5	Dairy	0	0	South	3	Medium2	39,690	190	14,576	600
6	Dairy	0	0	Central	1	Large1	321,284	2,458	-39,295	3,933
6	Dairy	0	0	Mid-Atlantic	1	Large1	341,247	2,759	-40,410	4,491
6	Dairy	0	0	Midwest	1	Large1	341,247	2,795	-40,389	4,554
6	Dairy	0	0	Pacific	1	Large1	321,284	2,530	-39,253	4,057
6	Dairy	0	0	South	1	Large1	321,284	2,382	-39,339	3,783
6	Dairy	0	0	Central	2	Large1	321,284	1,228	30,562	1,603
6	Dairy	0	0	Mid-Atlantic	2	Large1	341,247	1,075	4,346	1,314
6	Dairy	0	0	Midwest	2	Large1	341,247	1,281	-5,383	1,709
6	Dairy	0	0	Pacific	2	Large1	321,284	1,010	27,515	1,203
6	Dairy	0	0	South	2	Large1	321,284	742	-4,907	690
6	Dairy	0	0	Central	3	Large1	321,284	190	-40,403	600
6	Dairy	0	0	Mid-Atlantic	3	Large1	341,247	190	-41,694	600
6	Dairy	0	0	Midwest	3	Large1	341,247	190	-41,694	600
6	Dairy	0	0	Pacific	3	Large1	321,284	190	-40,403	600
6	Dairy	0	0	South	3	Large1	321,284	190	-40,403	600
6	Dairy	0	0	Central	1	Medium1	20,653	1,064	2,193	1,310
6	Dairy	0	0	Central	3	Medium1	17,528	190	1,681	600
6	Dairy	0	0	Mid-Atlantic	3	Medium1	13,367	190	1,616	600

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
6	Dairy	0	0	Midwest	3	Medium1	12,711	190	1,585	600
6	Dairy	0	0	Pacific	3	Medium1	18,968	190	1,753	600
6	Dairy	0	0	South	3	Medium1	18,656	190	1,737	600
6	Dairy	0	0	Mid-Atlantic	1	Medium1	17,964	1,037	2,241	1,249
6	Dairy	0	0	Midwest	1	Medium1	17,349	1,060	2,244	1,294
6	Dairy	0	0	Pacific	1	Medium1	21,991	1,004	2,229	1,187
6	Dairy	0	0	South	1	Medium1	21,627	955	2,150	1,093
6	Dairy	0	0	Central	2	Medium1	20,717	1,122	4,998	1,412
6	Dairy	0	0	Mid-Atlantic	2	Medium1	17,932	1,019	4,249	1,214
6	Dairy	0	0	Midwest	2	Medium1	17,328	1,048	3,922	1,268
6	Dairy	0	0	Pacific	2	Medium1	21,954	971	4,843	1,121
6	Dairy	0	0	South	2	Medium1	21,592	919	4,188	1,025
6	Dairy	0	0	Central	1	Medium2	180,161	1,422	-6,133	1,972
6	Dairy	0	0	Mid-Atlantic	1	Medium2	188,664	1,368	-7,555	1,872
6	Dairy	0	0	Midwest	1	Medium2	187,653	1,411	-7,564	1,959
6	Dairy	0	0	Pacific	1	Medium2	182,312	1,306	-6,078	1,757
6	Dairy	0	0	South	1	Medium2	181,678	1,209	-6,195	1,569
6	Dairy	0	0	Central	2	Medium2	179,546	1,057	10,865	1,289
6	Dairy	0	0	Mid-Atlantic	2	Medium2	187,808	937	5,610	1,060
6	Dairy	0	0	Midwest	2	Medium2	186,809	1,006	2,649	1,192
6	Dairy	0	0	Pacific	2	Medium2	181,811	902	10,904	993
6	Dairy	0	0	South	2	Medium2	181,238	802	6,331	812
6	Dairy	0	0	Central	3	Medium2	176,444	190	-6,987	600
6	Dairy	0	0	Mid-Atlantic	3	Medium2	183,378	190	-8,572	600
6	Dairy	0	0	Midwest	3	Medium2	182,265	190	-8,625	600
6	Dairy	0	0	Pacific	3	Medium2	178,897	190	-6,864	600
6	Dairy	0	0	South	3	Medium2	178,395	190	-6,889	600
7	Dairy	0	0	Central	1	Large1	273,999	2,458	14,034	3,933
7	Dairy	0	0	Central	2	Large1	273,999	1,228	78,162	1,603

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
7	Dairy	0	0	Central	3	Large1	273,999	190	12,925	600
7	Dairy	0	0	Mid-Atlantic	1	Large1	349,278	2,759	18,597	4,491
7	Dairy	0	0	Mid-Atlantic	2	Large1	349,278	1,075	57,990	1,314
7	Dairy	0	0	Mid-Atlantic	3	Large1	349,278	190	17,313	600
7	Dairy	0	0	Midwest	1	Large1	280,372	2,795	15,173	4,554
7	Dairy	0	0	Midwest	2	Large1	280,372	1,281	45,242	1,709
7	Dairy	0	0	Midwest	3	Large1	280,372	190	13,868	600
7	Dairy	0	0	Pacific	1	Large1	290,359	2,530	14,893	4,057
7	Dairy	0	0	Pacific	2	Large1	290,359	1,010	76,755	1,203
7	Dairy	0	0	Pacific	3	Large1	290,359	190	13,743	600
7	Dairy	0	0	South	1	Large1	168,524	2,382	8,716	3,783
7	Dairy	0	0	South	2	Large1	168,524	742	40,386	690
7	Dairy	0	0	South	3	Large1	168,524	190	7,652	600
7	Dairy	0	0	Central	1	Medium1	20,653	1,064	2,193	1,310
7	Dairy	0	0	Central	2	Medium1	20,717	1,122	3,741	1,412
7	Dairy	0	0	Central	3	Medium1	17,528	190	1,681	600
7	Dairy	0	0	Mid-Atlantic	1	Medium1	17,964	1,037	2,241	1,249
7	Dairy	0	0	Mid-Atlantic	2	Medium1	17,932	1,019	3,035	1,214
7	Dairy	0	0	Mid-Atlantic	3	Medium1	13,367	190	1,616	600
7	Dairy	0	0	Midwest	1	Medium1	17,349	1,060	2,244	1,294
7	Dairy	0	0	Midwest	2	Medium1	17,328	1,048	2,824	1,268
7	Dairy	0	0	Midwest	3	Medium1	12,711	190	1,585	600
7	Dairy	0	0	Pacific	1	Medium1	21,991	1,004	2,229	1,187
7	Dairy	0	0	Pacific	2	Medium1	21,954	971	3,676	1,121
7	Dairy	0	0	Pacific	3	Medium1	18,968	190	1,753	600
7	Dairy	0	0	South	1	Medium1	21,627	955	2,150	1,093
7	Dairy	0	0	South	2	Medium1	21,592	919	3,212	1,025
7	Dairy	0	0	South	3	Medium1	18,656	190	1,737	600
7	Dairy	0	0	Central	1	Medium2	109,228	1,422	6,665	1,972

Table 11-15. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
7	Dairy	0	0	Central	2	Medium2	108,613	1,057	21,077	1,289
7	Dairy	0	0	Central	3	Medium2	105,511	190	5,811	600
7	Dairy	0	0	Mid-Atlantic	1	Medium2	136,137	1,368	8,359	1,872
7	Dairy	0	0	Mid-Atlantic	2	Medium2	135,282	937	18,846	1,060
7	Dairy	0	0	Mid-Atlantic	3	Medium2	130,852	190	7,341	600
7	Dairy	0	0	Midwest	1	Medium2	108,918	1,411	7,039	1,959
7	Dairy	0	0	Midwest	2	Medium2	108,074	1,006	14,994	1,192
7	Dairy	0	0	Midwest	3	Medium2	103,530	190	5,978	600
7	Dairy	0	0	Pacific	1	Medium2	119,249	1,306	7,112	1,757
7	Dairy	0	0	Pacific	2	Medium2	118,748	902	21,607	993
7	Dairy	0	0	Pacific	3	Medium2	115,834	190	6,327	600
7	Dairy	0	0	South	1	Medium2	74,211	1,209	4,776	1,569
7	Dairy	0	0	South	2	Medium2	73,771	802	15,323	812
7	Dairy	0	0	South	3	Medium2	70,929	190	4,081	600

Table 11-16. Regulatory Compliance Costs for the Beef Industry

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Beef	0	0	Central	1	Large1	869	1,941	2,061	2,962
1	Beef	0	0	Central	2	Large1	869	1,283	47,302	1,717
1	Beef	0	0	Central	3	Large1	869	190	1,253	600
1	Beef	0	0	Mid-Atlantic	1	Large1	2,464	2,014	2,184	3,100
1	Beef	0	0	Mid-Atlantic	2	Large1	2,464	1,264	24,559	1,671
1	Beef	0	0	Mid-Atlantic	3	Large1	2,464	190	1,333	600
1	Beef	0	0	Midwest	1	Large1	2,321	2,476	2,445	3,961
1	Beef	0	0	Midwest	2	Large1	2,321	1,464	28,815	2,060
1	Beef	0	0	Midwest	3	Large1	2,321	190	1,326	600
1	Beef	0	0	Pacific	1	Large1	1,741	2,330	2,331	3,685
1	Beef	0	0	Pacific	2	Large1	1,741	1,487	53,685	2,091
1	Beef	0	0	Pacific	3	Large1	1,741	190	1,297	600
1	Beef	0	0	South	1	Large1	3,771	2,272	2,399	3,567
1	Beef	0	0	South	2	Large1	3,771	1,375	26,763	1,881
1	Beef	0	0	South	3	Large1	3,771	190	1,399	600
1	Beef	0	0	Central	1	Large2	12,238	21,531	14,027	39,812
1	Beef	0	0	Central	2	Large2	664,614	13,927	145,574	25,512
1	Beef	0	0	Central	3	Large2	12,238	190	1,822	600
1	Beef	0	0	Mid-Atlantic	1	Large2	38,849	22,767	16,077	42,133
1	Beef	0	0	Mid-Atlantic	2	Large2	687,347	14,089	105,111	25,809
1	Beef	0	0	Mid-Atlantic	3	Large2	38,849	190	3,152	600
1	Beef	0	0	Midwest	1	Large2	36,430	30,494	20,451	56,680
1	Beef	0	0	Midwest	2	Large2	622,064	18,774	108,476	34,627
1	Beef	0	0	Midwest	3	Large2	36,430	190	3,032	600
1	Beef	0	0	Pacific	1	Large2	26,754	28,019	18,527	52,032
1	Beef	0	0	Pacific	2	Large2	701,378	18,285	162,592	33,710
1	Beef	0	0	Pacific	3	Large2	26,754	190	2,548	600
1	Beef	0	0	South	1	Large2	60,622	27,068	19,667	50,234

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Beef	0	0	South	2	Large2	638,840	16,695	103,905	30,712
1	Beef	0	0	South	3	Large2	60,622	190	4,241	600
1	Beef	0	0	Central	1	Medium2	40,168	1,206	5,024	1,573
1	Beef	0	0	Central	2	Medium2	38,706	1,090	6,719	1,358
1	Beef	0	0	Central	3	Medium2	7,501	190	1,477	600
1	Beef	0	0	Mid-Atlantic	1	Medium2	46,348	1,237	5,445	1,635
1	Beef	0	0	Mid-Atlantic	2	Medium2	44,611	1,102	5,939	1,374
1	Beef	0	0	Mid-Atlantic	3	Medium2	13,266	190	1,766	600
1	Beef	0	0	Midwest	1	Medium2	45,620	1,429	5,981	1,994
1	Beef	0	0	Midwest	2	Medium2	42,943	1,248	6,658	1,650
1	Beef	0	0	Midwest	3	Medium2	9,702	190	1,593	600
1	Beef	0	0	Pacific	1	Medium2	49,009	1,368	5,984	1,871
1	Beef	0	0	Pacific	2	Medium2	46,865	1,217	7,974	1,589
1	Beef	0	0	Pacific	3	Medium2	14,043	190	1,804	600
1	Beef	0	0	South	1	Medium2	49,496	1,345	5,944	1,820
1	Beef	0	0	South	2	Medium2	47,240	1,183	6,524	1,522
1	Beef	0	0	South	3	Medium2	14,877	190	1,846	600
1	Beef	0	0	Central	1	Medium1	37,279	879	2,930	954
1	Beef	0	0	Central	2	Medium1	37,095	859	2,897	908
1	Beef	0	0	Central	3	Medium1	8,366	190	1,563	600
1	Beef	0	0	Mid-Atlantic	1	Medium1	40,380	890	3,204	969
1	Beef	0	0	Mid-Atlantic	2	Medium1	40,195	871	3,088	943
1	Beef	0	0	Mid-Atlantic	3	Medium1	11,355	190	1,712	600
1	Beef	0	0	Midwest	1	Medium1	39,249	963	3,772	1,107
1	Beef	0	0	Midwest	2	Medium1	38,928	933	3,630	1,046
1	Beef	0	0	Midwest	3	Medium1	9,479	190	1,622	600
1	Beef	0	0	Pacific	1	Medium1	41,387	940	3,699	1,076
1	Beef	0	0	Pacific	2	Medium1	41,113	913	3,675	1,020
1	Beef	0	0	Pacific	3	Medium1	11,859	190	1,738	600

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Beef	0	0	South	1	Medium1	41,550	933	3,646	1,046
1	Beef	0	0	South	2	Medium1	41,278	906	3,501	1,010
1	Beef	0	0	South	3	Medium1	12,101	190	1,750	600
1	Beef	0	0	Central	1	Large1	20,155	3,352	3,846	5,612
1	Beef	0	0	Mid-Atlantic	1	Large1	47,073	2,420	4,650	3,862
1	Beef	0	0	Midwest	1	Large1	14,357	2,548	3,089	4,096
1	Beef	0	0	Pacific	1	Large1	45,036	3,144	4,970	5,216
1	Beef	0	0	South	1	Large1	3,771	2,778	2,693	4,521
1	Beef	0	0	Central	1	Large2	128,183	32,110	25,979	59,719
1	Beef	0	0	Mid-Atlantic	1	Large2	297,158	25,630	30,658	47,522
1	Beef	0	0	Midwest	1	Large2	105,992	30,960	24,200	57,556
1	Beef	0	0	Pacific	1	Large2	287,781	34,574	35,392	64,367
1	Beef	0	0	South	1	Large2	60,622	30,666	21,761	57,004
1	Beef	0	0	Central	1	Medium2	78,618	1,974	7,400	3,018
1	Beef	0	0	Mid-Atlantic	1	Medium2	66,676	1,510	6,870	2,145
1	Beef	0	0	Midwest	1	Medium2	55,271	1,543	6,578	2,206
1	Beef	0	0	Pacific	1	Medium2	74,817	1,910	7,985	2,894
1	Beef	0	0	South	1	Medium2	62,761	1,935	7,253	2,935
1	Beef	0	0	Central	1	Medium1	41,488	1,162	4,162	1,485
1	Beef	0	0	Mid-Atlantic	1	Medium1	41,610	991	3,791	1,160
1	Beef	0	0	Midwest	1	Medium1	39,795	1,005	3,973	1,185
1	Beef	0	0	Pacific	1	Medium1	43,854	1,139	4,770	1,448
1	Beef	0	0	South	1	Medium1	44,360	1,148	4,728	1,458
1	Beef	0	0	Central	2	Large1	20,155	3,985	16,993	6,797
1	Beef	0	0	Mid-Atlantic	2	Large1	47,073	2,298	15,699	3,621
1	Beef	0	0	Midwest	2	Large1	14,357	1,811	24,514	2,713
1	Beef	0	0	Pacific	2	Large1	45,036	2,812	25,420	4,583
1	Beef	0	0	South	2	Large1	3,771	2,614	17,620	4,214
1	Beef	0	0	Central	2	Large2	503,452	46,972	115,571	87,690

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Beef	0	0	Mid-Atlantic	2	Large2	297,158	24,601	174,430	45,589
1	Beef	0	0	Midwest	2	Large2	650,147	21,138	106,790	39,075
1	Beef	0	0	Pacific	2	Large2	287,781	35,006	318,176	65,170
1	Beef	0	0	South	2	Large2	60,622	29,544	201,385	54,892
1	Beef	0	0	Central	2	Medium2	90,190	2,518	10,055	4,040
1	Beef	0	0	Mid-Atlantic	2	Medium2	69,691	1,683	8,685	2,470
1	Beef	0	0	Midwest	2	Medium2	56,652	1,585	7,658	2,283
1	Beef	0	0	Pacific	2	Medium2	75,218	1,969	9,792	3,001
1	Beef	0	0	South	2	Medium2	64,706	2,080	8,673	3,213
1	Beef	0	0	Central	2	Medium1	45,174	1,429	5,584	1,981
1	Beef	0	0	Mid-Atlantic	2	Medium1	42,861	1,098	4,628	1,366
1	Beef	0	0	Midwest	2	Medium1	40,581	1,064	4,329	1,293
1	Beef	0	0	Pacific	2	Medium1	44,588	1,204	5,390	1,561
1	Beef	0	0	South	2	Medium1	45,668	1,258	5,479	1,671
1	Beef	0	0	Central	3	Large1	20,155	190	2,217	600
1	Beef	0	0	Mid-Atlantic	3	Large1	47,073	190	3,563	600
1	Beef	0	0	Midwest	3	Large1	14,357	190	1,928	600
1	Beef	0	0	Pacific	3	Large1	45,036	190	3,462	600
1	Beef	0	0	South	3	Large1	3,771	190	1,399	600
1	Beef	0	0	Central	3	Large2	128,183	190	7,619	600
1	Beef	0	0	Mid-Atlantic	3	Large2	297,158	190	16,067	600
1	Beef	0	0	Midwest	3	Large2	105,992	190	6,510	600
1	Beef	0	0	Pacific	3	Large2	287,781	190	15,599	600
1	Beef	0	0	South	3	Large2	60,622	190	4,241	600
1	Beef	0	0	Central	3	Medium2	24,794	190	2,342	600
1	Beef	0	0	Mid-Atlantic	3	Medium2	28,068	190	2,506	600
1	Beef	0	0	Midwest	3	Medium2	16,774	190	1,947	600
1	Beef	0	0	Pacific	3	Medium2	28,524	190	2,528	600
1	Beef	0	0	South	3	Medium2	14,877	190	1,846	600

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Beef	0	0	Central	3	Medium1	8,366	190	1,563	600
1	Beef	0	0	Mid-Atlantic	3	Medium1	11,355	190	1,712	600
1	Beef	0	0	Midwest	3	Medium1	9,479	190	1,622	600
1	Beef	0	0	Pacific	3	Medium1	11,859	190	1,738	600
1	Beef	0	0	South	3	Medium1	12,101	190	1,750	600
2	Beef	0	0	Central	1	Large1	869	3,352	2,882	5,612
2	Beef	0	0	Mid-Atlantic	1	Large1	2,464	2,420	2,420	3,862
2	Beef	0	0	Midwest	1	Large1	2,321	2,548	2,487	4,096
2	Beef	0	0	Pacific	1	Large1	1,741	3,144	2,805	5,216
2	Beef	0	0	South	1	Large1	3,771	2,778	2,693	4,521
2	Beef	0	0	Central	2	Large1	869	3,985	16,029	6,797
2	Beef	0	0	Mid-Atlantic	2	Large1	2,464	2,298	13,469	3,621
2	Beef	0	0	Midwest	2	Large1	2,321	1,811	23,912	2,713
2	Beef	0	0	Pacific	2	Large1	1,741	2,812	23,255	4,583
2	Beef	0	0	South	2	Large1	3,771	2,614	17,620	4,214
2	Beef	0	0	Central	3	Large1	869	190	1,253	600
2	Beef	0	0	Mid-Atlantic	3	Large1	2,464	190	1,333	600
2	Beef	0	0	Midwest	3	Large1	2,321	190	1,326	600
2	Beef	0	0	Pacific	3	Large1	1,741	190	1,297	600
2	Beef	0	0	South	3	Large1	3,771	190	1,399	600
2	Beef	0	0	Central	1	Large2	12,238	32,110	20,182	59,719
2	Beef	0	0	Mid-Atlantic	1	Large2	38,849	25,630	17,743	47,522
2	Beef	0	0	Midwest	1	Large2	36,430	30,960	20,722	57,556
2	Beef	0	0	Pacific	1	Large2	26,754	34,574	22,341	64,367
2	Beef	0	0	South	1	Large2	60,622	30,666	21,761	57,004
2	Beef	0	0	Central	2	Large2	387,507	46,972	109,774	87,690
2	Beef	0	0	Mid-Atlantic	2	Large2	38,849	24,601	161,515	45,589
2	Beef	0	0	Midwest	2	Large2	580,585	21,138	103,312	39,075
2	Beef	0	0	Pacific	2	Large2	26,754	35,006	305,125	65,170

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
2	Beef	0	0	South	2	Large2	60,622	29,544	201,385	54,892
2	Beef	0	0	Central	3	Large2	12,238	190	1,822	600
2	Beef	0	0	Mid-Atlantic	3	Large2	38,849	190	3,152	600
2	Beef	0	0	Midwest	3	Large2	36,430	190	3,032	600
2	Beef	0	0	Pacific	3	Large2	26,754	190	2,548	600
2	Beef	0	0	South	3	Large2	60,622	190	4,241	600
2	Beef	0	0	Central	1	Medium1	41,488	1,162	4,162	1,485
2	Beef	0	0	Mid-Atlantic	1	Medium1	41,610	991	3,791	1,160
2	Beef	0	0	Midwest	1	Medium1	39,795	1,005	3,973	1,185
2	Beef	0	0	Pacific	1	Medium1	43,854	1,139	4,770	1,448
2	Beef	0	0	South	1	Medium1	44,360	1,148	4,728	1,458
2	Beef	0	0	Central	2	Medium1	45,174	1,429	5,584	1,981
2	Beef	0	0	Mid-Atlantic	2	Medium1	42,861	1,098	4,628	1,366
2	Beef	0	0	Midwest	2	Medium1	40,581	1,064	4,329	1,293
2	Beef	0	0	Pacific	2	Medium1	44,588	1,204	5,390	1,561
2	Beef	0	0	South	2	Medium1	45,668	1,258	5,479	1,671
2	Beef	0	0	Central	3	Medium1	8,366	190	1,563	600
2	Beef	0	0	Mid-Atlantic	3	Medium1	11,355	190	1,712	600
2	Beef	0	0	Midwest	3	Medium1	9,479	190	1,622	600
2	Beef	0	0	Pacific	3	Medium1	11,859	190	1,738	600
2	Beef	0	0	South	3	Medium1	12,101	190	1,750	600
2	Beef	0	0	Central	1	Medium2	61,325	1,974	6,535	3,018
2	Beef	0	0	Mid-Atlantic	1	Medium2	51,874	1,510	6,130	2,145
2	Beef	0	0	Midwest	1	Medium2	48,199	1,543	6,225	2,206
2	Beef	0	0	Pacific	1	Medium2	60,336	1,910	7,261	2,894
2	Beef	0	0	South	1	Medium2	62,761	1,935	7,253	2,935
2	Beef	0	0	Central	2	Medium2	72,897	2,518	9,190	4,040
2	Beef	0	0	Mid-Atlantic	2	Medium2	54,889	1,683	7,945	2,470
2	Beef	0	0	Midwest	2	Medium2	49,580	1,585	7,304	2,283

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
2	Beef	0	0	Pacific	2	Medium2	60,737	1,969	9,068	3,001
2	Beef	0	0	South	2	Medium2	64,706	2,080	8,673	3,213
2	Beef	0	0	Central	3	Medium2	7,501	190	1,477	600
2	Beef	0	0	Mid-Atlantic	3	Medium2	13,266	190	1,766	600
2	Beef	0	0	Midwest	3	Medium2	9,702	190	1,593	600
2	Beef	0	0	Pacific	3	Medium2	14,043	190	1,804	600
2	Beef	0	0	South	3	Medium2	14,877	190	1,846	600
3	Beef	0	0	Central	1	Large1	43,694	5,760	4,466	5,612
3	Beef	0	0	Mid-Atlantic	1	Large1	126,820	5,101	7,645	3,862
3	Beef	0	0	Midwest	1	Large1	109,638	5,601	6,693	4,096
3	Beef	0	0	Pacific	1	Large1	67,590	5,250	5,602	5,216
3	Beef	0	0	South	1	Large1	127,811	5,424	7,953	4,521
3	Beef	0	0	Central	2	Large1	43,694	3,985	17,613	6,797
3	Beef	0	0	Mid-Atlantic	2	Large1	126,820	2,298	18,694	3,621
3	Beef	0	0	Midwest	2	Large1	109,638	1,811	28,118	2,713
3	Beef	0	0	Pacific	2	Large1	67,590	2,812	26,053	4,583
3	Beef	0	0	South	2	Large1	127,811	2,614	22,880	4,214
3	Beef	0	0	Central	3	Large1	43,694	190	2,837	600
3	Beef	0	0	Mid-Atlantic	3	Large1	126,820	190	6,558	600
3	Beef	0	0	Midwest	3	Large1	109,638	190	5,532	600
3	Beef	0	0	Pacific	3	Large1	67,590	190	4,094	600
3	Beef	0	0	South	3	Large1	127,811	190	6,659	600
3	Beef	0	0	Central	1	Large2	460,625	34,915	33,080	59,719
3	Beef	0	0	Mid-Atlantic	1	Large2	1,249,800	28,569	61,283	47,522
3	Beef	0	0	Midwest	1	Large2	1,116,166	34,059	54,907	57,556
3	Beef	0	0	Pacific	1	Large2	658,940	37,208	45,465	64,367
3	Beef	0	0	South	1	Large2	1,276,807	33,588	66,488	57,004
3	Beef	0	0	Central	2	Large2	835,894	46,972	122,672	87,690
3	Beef	0	0	Mid-Atlantic	2	Large2	1,249,800	24,601	205,056	45,589

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
3	Beef	0	0	Midwest	2	Large2	1,660,321	21,138	137,496	39,075
3	Beef	0	0	Pacific	2	Large2	658,940	35,006	328,249	65,170
3	Beef	0	0	South	2	Large2	1,276,807	29,544	246,112	54,892
3	Beef	0	0	Central	3	Large2	460,625	190	14,720	600
3	Beef	0	0	Mid-Atlantic	3	Large2	1,249,800	190	46,693	600
3	Beef	0	0	Midwest	3	Large2	1,116,166	190	37,216	600
3	Beef	0	0	Pacific	3	Large2	658,940	190	25,671	600
3	Beef	0	0	South	3	Large2	1,276,807	190	48,969	600
3	Beef	0	0	Central	1	Medium1	53,321	3,344	4,643	1,485
3	Beef	0	0	Mid-Atlantic	1	Medium1	76,294	3,394	5,328	1,160
3	Beef	0	0	Midwest	1	Medium1	70,522	3,847	5,280	1,185
3	Beef	0	0	Pacific	1	Medium1	62,755	2,623	5,616	1,448
3	Beef	0	0	South	1	Medium1	79,171	2,917	6,282	1,458
3	Beef	0	0	Central	2	Medium1	57,007	1,429	6,065	1,981
3	Beef	0	0	Mid-Atlantic	2	Medium1	77,544	1,098	6,164	1,366
3	Beef	0	0	Midwest	2	Medium1	71,308	1,064	5,636	1,293
3	Beef	0	0	Pacific	2	Medium1	63,489	1,204	6,237	1,561
3	Beef	0	0	South	2	Medium1	80,479	1,258	7,032	1,671
3	Beef	0	0	Central	3	Medium1	20,199	190	2,044	600
3	Beef	0	0	Mid-Atlantic	3	Medium1	46,039	190	3,249	600
3	Beef	0	0	Midwest	3	Medium1	40,207	190	2,929	600
3	Beef	0	0	Pacific	3	Medium1	30,760	190	2,584	600
3	Beef	0	0	South	3	Medium1	46,912	190	3,304	600
3	Beef	0	0	Central	1	Medium2	84,414	4,156	7,481	3,018
3	Beef	0	0	Mid-Atlantic	1	Medium2	117,418	3,913	9,039	2,145
3	Beef	0	0	Midwest	1	Medium2	106,151	4,385	8,690	2,206
3	Beef	0	0	Pacific	1	Medium2	95,342	3,394	8,828	2,894
3	Beef	0	0	South	1	Medium2	128,175	3,704	10,172	2,935
3	Beef	0	0	Central	2	Medium2	95,986	2,518	10,137	4,040

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
3	Beef	0	0	Mid-Atlantic	2	Medium2	120,433	1,683	10,855	2,470
3	Beef	0	0	Midwest	2	Medium2	107,532	1,585	9,770	2,283
3	Beef	0	0	Pacific	2	Medium2	95,744	1,969	10,635	3,001
3	Beef	0	0	South	2	Medium2	130,120	2,080	11,592	3,213
3	Beef	0	0	Central	3	Medium2	30,590	190	2,424	600
3	Beef	0	0	Mid-Atlantic	3	Medium2	78,810	190	4,675	600
3	Beef	0	0	Midwest	3	Medium2	67,654	190	4,059	600
3	Beef	0	0	Pacific	3	Medium2	49,050	190	3,371	600
3	Beef	0	0	South	3	Medium2	80,290	190	4,766	600
4	Beef	0	0	Central	1	Large1	44,086	5,760	10,718	5,612
4	Beef	0	0	Mid-Atlantic	1	Large1	127,212	5,101	13,897	3,862
4	Beef	0	0	Midwest	1	Large1	110,030	5,601	12,945	4,096
4	Beef	0	0	Pacific	1	Large1	67,982	5,250	11,854	5,216
4	Beef	0	0	South	1	Large1	128,203	5,424	14,205	4,521
4	Beef	0	0	Central	2	Large1	44,086	3,985	23,865	6,797
4	Beef	0	0	Mid-Atlantic	2	Large1	127,212	2,298	24,946	3,621
4	Beef	0	0	Midwest	2	Large1	110,030	1,811	34,370	2,713
4	Beef	0	0	Pacific	2	Large1	67,982	2,812	32,305	4,583
4	Beef	0	0	South	2	Large1	128,203	2,614	29,132	4,214
4	Beef	0	0	Central	3	Large1	44,086	190	9,089	600
4	Beef	0	0	Mid-Atlantic	3	Large1	127,212	190	12,810	600
4	Beef	0	0	Midwest	3	Large1	110,030	190	11,784	600
4	Beef	0	0	Pacific	3	Large1	67,982	190	10,346	600
4	Beef	0	0	South	3	Large1	128,203	190	12,911	600
4	Beef	0	0	Central	1	Large2	461,017	34,915	39,332	59,719
4	Beef	0	0	Mid-Atlantic	1	Large2	1,250,192	28,569	67,535	47,522
4	Beef	0	0	Midwest	1	Large2	1,116,558	34,059	61,159	57,556
4	Beef	0	0	Pacific	1	Large2	659,332	37,208	51,717	64,367
4	Beef	0	0	South	1	Large2	1,277,199	33,588	72,740	57,004

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
4	Beef	0	0	Central	2	Large2	836,286	46,972	128,924	87,690
4	Beef	0	0	Mid-Atlantic	2	Large2	1,250,192	24,601	211,308	45,589
4	Beef	0	0	Midwest	2	Large2	1,660,713	21,138	143,748	39,075
4	Beef	0	0	Pacific	2	Large2	659,332	35,006	334,501	65,170
4	Beef	0	0	South	2	Large2	1,277,199	29,544	252,364	54,892
4	Beef	0	0	Central	3	Large2	461,017	190	20,972	600
4	Beef	0	0	Mid-Atlantic	3	Large2	1,250,192	190	52,945	600
4	Beef	0	0	Midwest	3	Large2	1,116,558	190	43,468	600
4	Beef	0	0	Pacific	3	Large2	659,332	190	31,923	600
4	Beef	0	0	South	3	Large2	1,277,199	190	55,221	600
4	Beef	0	0	Central	1	Medium1	53,713	3,344	10,895	1,485
4	Beef	0	0	Mid-Atlantic	1	Medium1	76,686	3,394	11,580	1,160
4	Beef	0	0	Midwest	1	Medium1	70,914	3,847	11,532	1,185
4	Beef	0	0	Pacific	1	Medium1	63,147	2,623	11,868	1,448
4	Beef	0	0	South	1	Medium1	79,563	2,917	12,534	1,458
4	Beef	0	0	Central	2	Medium1	57,399	1,429	12,317	1,981
4	Beef	0	0	Mid-Atlantic	2	Medium1	77,936	1,098	12,416	1,366
4	Beef	0	0	Midwest	2	Medium1	71,700	1,064	11,888	1,293
4	Beef	0	0	Pacific	2	Medium1	63,881	1,204	12,489	1,561
4	Beef	0	0	South	2	Medium1	80,871	1,258	13,284	1,671
4	Beef	0	0	Central	3	Medium1	20,591	190	8,296	600
4	Beef	0	0	Mid-Atlantic	3	Medium1	46,431	190	9,501	600
4	Beef	0	0	Midwest	3	Medium1	40,599	190	9,181	600
4	Beef	0	0	Pacific	3	Medium1	31,152	190	8,836	600
4	Beef	0	0	South	3	Medium1	47,304	190	9,556	600
4	Beef	0	0	Central	1	Medium2	84,806	4,156	13,733	3,018
4	Beef	0	0	Mid-Atlantic	1	Medium2	117,810	3,913	15,291	2,145
4	Beef	0	0	Midwest	1	Medium2	106,543	4,385	14,942	2,206
4	Beef	0	0	Pacific	1	Medium2	95,734	3,394	15,080	2,894

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
4	Beef	0	0	South	1	Medium2	128,567	3,704	16,424	2,935
4	Beef	0	0	Central	2	Medium2	96,378	2,518	16,389	4,040
4	Beef	0	0	Mid-Atlantic	2	Medium2	120,825	1,683	17,107	2,470
4	Beef	0	0	Midwest	2	Medium2	107,924	1,585	16,022	2,283
4	Beef	0	0	Pacific	2	Medium2	96,136	1,969	16,887	3,001
4	Beef	0	0	South	2	Medium2	130,512	2,080	17,844	3,213
4	Beef	0	0	Central	3	Medium2	30,982	190	8,676	600
4	Beef	0	0	Mid-Atlantic	3	Medium2	79,202	190	10,927	600
4	Beef	0	0	Midwest	3	Medium2	68,046	190	10,311	600
4	Beef	0	0	Pacific	3	Medium2	49,442	190	9,623	600
4	Beef	0	0	South	3	Medium2	80,682	190	11,018	600
5	Beef	0	0	Central	1	Large1	10,026	3,352	100,067	5,612
5	Beef	0	0	Mid-Atlantic	1	Large1	11,621	2,420	86,435	3,862
5	Beef	0	0	Midwest	1	Large1	11,478	2,548	89,251	4,096
5	Beef	0	0	Pacific	1	Large1	10,897	3,144	86,829	5,216
5	Beef	0	0	South	1	Large1	12,927	2,778	86,609	4,521
5	Beef	0	0	Central	2	Large1	10,026	3,985	113,155	6,797
5	Beef	0	0	Mid-Atlantic	2	Large1	11,621	2,298	97,417	3,621
5	Beef	0	0	Midwest	2	Large1	11,478	1,811	110,595	2,713
5	Beef	0	0	Pacific	2	Large1	10,897	2,812	107,079	4,583
5	Beef	0	0	South	2	Large1	12,927	2,614	101,415	4,214
5	Beef	0	0	Central	3	Large1	10,026	190	98,439	600
5	Beef	0	0	Mid-Atlantic	3	Large1	11,621	190	85,349	600
5	Beef	0	0	Midwest	3	Large1	11,478	190	88,090	600
5	Beef	0	0	Pacific	3	Large1	10,897	190	85,321	600
5	Beef	0	0	South	3	Large1	12,927	190	85,314	600
5	Beef	0	0	Central	1	Large2	21,395	32,110	1,639,971	59,719
5	Beef	0	0	Mid-Atlantic	1	Large2	48,006	25,630	1,418,158	47,522
5	Beef	0	0	Midwest	1	Large2	45,587	30,960	1,466,719	57,556

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
5	Beef	0	0	Pacific	1	Large2	35,911	34,574	1,422,903	64,367
5	Beef	0	0	South	1	Large2	69,779	30,666	1,420,514	57,004
5	Beef	0	0	Central	2	Large2	382,306	46,972	1,728,577	87,690
5	Beef	0	0	Mid-Atlantic	2	Large2	48,006	24,601	1,560,703	45,589
5	Beef	0	0	Midwest	2	Large2	647,503	21,138	1,556,128	39,075
5	Beef	0	0	Pacific	2	Large2	35,911	35,006	1,702,393	65,170
5	Beef	0	0	South	2	Large2	69,779	29,544	1,598,328	54,892
5	Beef	0	0	Central	3	Large2	21,395	190	1,621,611	600
5	Beef	0	0	Mid-Atlantic	3	Large2	48,006	190	1,403,567	600
5	Beef	0	0	Midwest	3	Large2	45,587	190	1,449,029	600
5	Beef	0	0	Pacific	3	Large2	35,911	190	1,403,110	600
5	Beef	0	0	South	3	Large2	69,779	190	1,402,994	600
5	Beef	0	0	Central	1	Medium1	50,645	1,162	18,957	1,485
5	Beef	0	0	Mid-Atlantic	1	Medium1	50,767	991	16,579	1,160
5	Beef	0	0	Midwest	1	Medium1	48,951	1,005	17,186	1,185
5	Beef	0	0	Pacific	1	Medium1	53,011	1,139	17,559	1,448
5	Beef	0	0	South	1	Medium1	53,517	1,148	17,501	1,458
5	Beef	0	0	Central	2	Medium1	54,331	1,429	20,368	1,981
5	Beef	0	0	Mid-Atlantic	2	Medium1	52,018	1,098	17,404	1,366
5	Beef	0	0	Midwest	2	Medium1	49,737	1,064	17,535	1,293
5	Beef	0	0	Pacific	2	Medium1	53,744	1,204	18,165	1,561
5	Beef	0	0	South	2	Medium1	54,824	1,258	18,243	1,671
5	Beef	0	0	Central	3	Medium1	17,522	190	16,358	600
5	Beef	0	0	Mid-Atlantic	3	Medium1	20,512	190	14,500	600
5	Beef	0	0	Midwest	3	Medium1	18,636	190	14,835	600
5	Beef	0	0	Pacific	3	Medium1	21,016	190	14,527	600
5	Beef	0	0	South	3	Medium1	21,257	190	14,522	600
5	Beef	0	0	Central	1	Medium2	70,481	1,974	46,776	3,018
5	Beef	0	0	Mid-Atlantic	1	Medium2	61,030	1,510	40,912	2,145

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
5	Beef	0	0	Midwest	1	Medium2	57,355	1,543	42,149	2,206
5	Beef	0	0	Pacific	1	Medium2	69,492	1,910	42,047	2,894
5	Beef	0	0	South	1	Medium2	71,918	1,935	41,994	2,935
5	Beef	0	0	Central	2	Medium2	82,054	2,518	49,374	4,040
5	Beef	0	0	Mid-Atlantic	2	Medium2	64,046	1,683	42,667	2,470
5	Beef	0	0	Midwest	2	Medium2	58,737	1,585	43,191	2,283
5	Beef	0	0	Pacific	2	Medium2	69,894	1,969	43,783	3,001
5	Beef	0	0	South	2	Medium2	73,863	2,080	43,369	3,213
5	Beef	0	0	Central	3	Medium2	16,658	190	41,719	600
5	Beef	0	0	Mid-Atlantic	3	Medium2	22,423	190	36,548	600
5	Beef	0	0	Midwest	3	Medium2	18,859	190	37,518	600
5	Beef	0	0	Pacific	3	Medium2	23,200	190	36,591	600
5	Beef	0	0	South	3	Medium2	24,033	190	36,588	600
6	Beef	0	0	Central	1	Large1	869	3,352	2,882	5,612
6	Beef	0	0	Mid-Atlantic	1	Large1	2,464	2,420	2,420	3,862
6	Beef	0	0	Midwest	1	Large1	2,321	2,548	2,487	4,096
6	Beef	0	0	Pacific	1	Large1	1,741	3,144	2,805	5,216
6	Beef	0	0	South	1	Large1	3,771	2,778	2,693	4,521
6	Beef	0	0	Central	2	Large1	869	3,985	16,029	6,797
6	Beef	0	0	Mid-Atlantic	2	Large1	2,464	2,298	13,469	3,621
6	Beef	0	0	Midwest	2	Large1	2,321	1,811	23,912	2,713
6	Beef	0	0	Pacific	2	Large1	1,741	2,812	23,255	4,583
6	Beef	0	0	South	2	Large1	3,771	2,614	17,620	4,214
6	Beef	0	0	Central	3	Large1	869	190	1,253	600
6	Beef	0	0	Mid-Atlantic	3	Large1	2,464	190	1,333	600
6	Beef	0	0	Midwest	3	Large1	2,321	190	1,326	600
6	Beef	0	0	Pacific	3	Large1	1,741	190	1,297	600
6	Beef	0	0	South	3	Large1	3,771	190	1,399	600
6	Beef	0	0	Central	1	Large2	12,238	32,110	20,182	59,719

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
6	Beef	0	0	Mid-Atlantic	1	Large2	38,849	25,630	17,743	47,522
6	Beef	0	0	Midwest	1	Large2	36,430	30,960	20,722	57,556
6	Beef	0	0	Pacific	1	Large2	26,754	34,574	22,341	64,367
6	Beef	0	0	South	1	Large2	60,622	30,666	21,761	57,004
6	Beef	0	0	Central	2	Large2	387,507	46,972	109,774	87,690
6	Beef	0	0	Mid-Atlantic	2	Large2	38,849	24,601	161,515	45,589
6	Beef	0	0	Midwest	2	Large2	580,585	21,138	103,312	39,075
6	Beef	0	0	Pacific	2	Large2	26,754	35,006	305,125	65,170
6	Beef	0	0	South	2	Large2	60,622	29,544	201,385	54,892
6	Beef	0	0	Central	3	Large2	12,238	190	1,822	600
6	Beef	0	0	Mid-Atlantic	3	Large2	38,849	190	3,152	600
6	Beef	0	0	Midwest	3	Large2	36,430	190	3,032	600
6	Beef	0	0	Pacific	3	Large2	26,754	190	2,548	600
6	Beef	0	0	South	3	Large2	60,622	190	4,241	600
6	Beef	0	0	Central	1	Medium1	41,488	1,162	4,162	1,485
6	Beef	0	0	Mid-Atlantic	1	Medium1	41,610	991	3,791	1,160
6	Beef	0	0	Midwest	1	Medium1	39,795	1,005	3,973	1,185
6	Beef	0	0	Pacific	1	Medium1	43,854	1,139	4,770	1,448
6	Beef	0	0	South	1	Medium1	44,360	1,148	4,728	1,458
6	Beef	0	0	Mid-Atlantic	3	Medium1	11,355	190	1,712	600
6	Beef	0	0	Midwest	3	Medium1	9,479	190	1,622	600
6	Beef	0	0	Pacific	3	Medium1	11,859	190	1,738	600
6	Beef	0	0	South	3	Medium1	12,101	190	1,750	600
6	Beef	0	0	Central	2	Medium1	45,174	1,429	5,584	1,981
6	Beef	0	0	Mid-Atlantic	2	Medium1	42,861	1,098	4,628	1,366
6	Beef	0	0	Midwest	2	Medium1	40,581	1,064	4,329	1,293
6	Beef	0	0	Pacific	2	Medium1	44,588	1,204	5,390	1,561
6	Beef	0	0	South	2	Medium1	45,668	1,258	5,479	1,671
6	Beef	0	0	Central	3	Medium1	8,366	190	1,563	600

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
6	Beef	0	0	Central	1	Medium2	61,325	1,974	6,535	3,018
6	Beef	0	0	Mid-Atlantic	1	Medium2	51,874	1,510	6,130	2,145
6	Beef	0	0	Midwest	1	Medium2	48,199	1,543	6,225	2,206
6	Beef	0	0	Pacific	1	Medium2	60,336	1,910	7,261	2,894
6	Beef	0	0	South	1	Medium2	62,761	1,935	7,253	2,935
6	Beef	0	0	Central	2	Medium2	72,897	2,518	9,190	4,040
6	Beef	0	0	Mid-Atlantic	2	Medium2	54,889	1,683	7,945	2,470
6	Beef	0	0	Midwest	2	Medium2	49,580	1,585	7,304	2,283
6	Beef	0	0	Pacific	2	Medium2	60,737	1,969	9,068	3,001
6	Beef	0	0	South	2	Medium2	64,706	2,080	8,673	3,213
6	Beef	0	0	Central	3	Medium2	7,501	190	1,477	600
6	Beef	0	0	Mid-Atlantic	3	Medium2	13,266	190	1,766	600
6	Beef	0	0	Midwest	3	Medium2	9,702	190	1,593	600
6	Beef	0	0	Pacific	3	Medium2	14,043	190	1,804	600
6	Beef	0	0	South	3	Medium2	14,877	190	1,846	600
7	Beef	0	0	Central	1	Large1	20,155	3,352	3,846	5,612
7	Beef	0	0	Central	2	Large1	20,155	3,985	16,993	6,797
7	Beef	0	0	Central	3	Large1	20,155	190	2,217	600
7	Beef	0	0	Mid-Atlantic	1	Large1	47,073	2,420	4,650	3,862
7	Beef	0	0	Mid-Atlantic	2	Large1	47,073	2,298	15,699	3,621
7	Beef	0	0	Mid-Atlantic	3	Large1	47,073	190	3,563	600
7	Beef	0	0	Midwest	1	Large1	14,357	2,548	3,089	4,096
7	Beef	0	0	Midwest	2	Large1	14,357	1,811	24,514	2,713
7	Beef	0	0	Midwest	3	Large1	14,357	190	1,928	600
7	Beef	0	0	Pacific	1	Large1	45,036	3,144	4,970	5,216
7	Beef	0	0	Pacific	2	Large1	45,036	2,812	25,420	4,583
7	Beef	0	0	Pacific	3	Large1	45,036	190	3,462	600
7	Beef	0	0	South	1	Large1	3,771	2,778	2,693	4,521
7	Beef	0	0	South	2	Large1	3,771	2,614	17,620	4,214

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
7	Beef	0	0	South	3	Large1	3,771	190	1,399	600
7	Beef	0	0	Central	1	Large2	128,183	32,110	25,979	59,719
7	Beef	0	0	Central	2	Large2	503,452	46,972	115,571	87,690
7	Beef	0	0	Central	3	Large2	128,183	190	7,619	600
7	Beef	0	0	Mid-Atlantic	1	Large2	297,158	25,630	30,658	47,522
7	Beef	0	0	Mid-Atlantic	2	Large2	297,158	24,601	174,430	45,589
7	Beef	0	0	Mid-Atlantic	3	Large2	297,158	190	16,067	600
7	Beef	0	0	Midwest	1	Large2	105,992	30,960	24,200	57,556
7	Beef	0	0	Midwest	2	Large2	650,147	21,138	106,790	39,075
7	Beef	0	0	Midwest	3	Large2	105,992	190	6,510	600
7	Beef	0	0	Pacific	1	Large2	287,781	34,574	35,392	64,367
7	Beef	0	0	Pacific	2	Large2	287,781	35,006	318,176	65,170
7	Beef	0	0	Pacific	3	Large2	287,781	190	15,599	600
7	Beef	0	0	South	1	Large2	60,622	30,666	21,761	57,004
7	Beef	0	0	South	2	Large2	60,622	29,544	201,385	54,892
7	Beef	0	0	South	3	Large2	60,622	190	4,241	600
7	Beef	0	0	Central	1	Medium1	41,488	1,162	4,162	1,485
7	Beef	0	0	Central	2	Medium1	45,174	1,429	5,584	1,981
7	Beef	0	0	Central	3	Medium1	8,366	190	1,563	600
7	Beef	0	0	Mid-Atlantic	1	Medium1	41,610	991	3,791	1,160
7	Beef	0	0	Mid-Atlantic	2	Medium1	42,861	1,098	4,628	1,366
7	Beef	0	0	Mid-Atlantic	3	Medium1	11,355	190	1,712	600
7	Beef	0	0	Midwest	1	Medium1	39,795	1,005	3,973	1,185
7	Beef	0	0	Midwest	2	Medium1	40,581	1,064	4,329	1,293
7	Beef	0	0	Midwest	3	Medium1	9,479	190	1,622	600
7	Beef	0	0	Pacific	1	Medium1	43,854	1,139	4,770	1,448
7	Beef	0	0	Pacific	2	Medium1	44,588	1,204	5,390	1,561
7	Beef	0	0	Pacific	3	Medium1	11,859	190	1,738	600
7	Beef	0	0	South	1	Medium1	44,360	1,148	4,728	1,458

Table 11-16. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
7	Beef	0	0	South	2	Medium1	45,668	1,258	5,479	1,671
7	Beef	0	0	South	3	Medium1	12,101	190	1,750	600
7	Beef	0	0	Central	1	Medium2	78,618	1,974	7,400	3,018
7	Beef	0	0	Central	2	Medium2	90,190	2,518	10,055	4,040
7	Beef	0	0	Central	3	Medium2	24,794	190	2,342	600
7	Beef	0	0	Mid-Atlantic	1	Medium2	66,676	1,510	6,870	2,145
7	Beef	0	0	Mid-Atlantic	2	Medium2	69,691	1,683	8,685	2,470
7	Beef	0	0	Mid-Atlantic	3	Medium2	28,068	190	2,506	600
7	Beef	0	0	Midwest	1	Medium2	55,271	1,543	6,578	2,206
7	Beef	0	0	Midwest	2	Medium2	56,652	1,585	7,658	2,283
7	Beef	0	0	Midwest	3	Medium2	16,774	190	1,947	600
7	Beef	0	0	Pacific	1	Medium2	74,817	1,910	7,985	2,894
7	Beef	0	0	Pacific	2	Medium2	75,218	1,969	9,792	3,001
7	Beef	0	0	Pacific	3	Medium2	28,524	190	2,528	600
7	Beef	0	0	South	1	Medium2	62,761	1,935	7,253	2,935
7	Beef	0	0	South	2	Medium2	64,706	2,080	8,673	3,213
7	Beef	0	0	South	3	Medium2	14,877	190	1,846	600

Table 11-17. Regulatory Compliance Costs for the Veal Industry

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Veal	0	0	Central	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	Central	2	Medium2	0	690	1,290	600
1	Veal	0	0	Central	3	Medium2	0	190	1,210	600
1	Veal	0	0	Mid-Atlantic	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	Mid-Atlantic	2	Medium2	0	690	1,290	600
1	Veal	0	0	Mid-Atlantic	3	Medium2	0	190	1,210	600
1	Veal	0	0	Midwest	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	Midwest	2	Medium2	0	690	1,290	600
1	Veal	0	0	Midwest	3	Medium2	0	190	1,210	600
1	Veal	0	0	Pacific	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	Pacific	2	Medium2	0	690	1,290	600
1	Veal	0	0	Pacific	3	Medium2	0	190	1,210	600
1	Veal	0	0	South	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	South	2	Medium2	0	690	1,290	600
1	Veal	0	0	South	3	Medium2	0	190	1,210	600
1	Veal	0	0	Central	1	Medium1	0	1,075	1,514	1,318
1	Veal	0	0	Central	2	Medium1	0	690	1,290	600
1	Veal	0	0	Central	3	Medium1	0	190	1,210	600
1	Veal	0	0	Mid-Atlantic	1	Medium1	0	1,075	1,514	1,318
1	Veal	0	0	Mid-Atlantic	2	Medium1	0	690	1,290	600
1	Veal	0	0	Mid-Atlantic	3	Medium1	0	190	1,210	600
1	Veal	0	0	Midwest	1	Medium1	0	1,075	1,514	1,318
1	Veal	0	0	Midwest	2	Medium1	0	690	1,290	600
1	Veal	0	0	Midwest	3	Medium1	0	190	1,210	600
1	Veal	0	0	Pacific	1	Medium1	0	1,075	1,514	1,318
1	Veal	0	0	Pacific	2	Medium1	0	690	1,290	600
1	Veal	0	0	Pacific	3	Medium1	0	190	1,210	600
1	Veal	0	0	South	1	Medium1	0	1,075	1,514	1,318

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Veal	0	0	South	2	Medium1	0	690	1,290	600
1	Veal	0	0	South	3	Medium1	0	190	1,210	600
1	Veal	0	0	Central	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	Mid-Atlantic	1	Medium2	0	1,075	1,514	1,317
1	Veal	0	0	Midwest	1	Medium2	0	1,075	1,514	1,317
1	Veal	0	0	Pacific	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	South	1	Medium2	0	1,075	1,514	1,318
1	Veal	0	0	Central	1	Medium1	0	1,075	1,514	1,318
1	Veal	0	0	Mid-Atlantic	1	Medium1	0	1,075	1,514	1,317
1	Veal	0	0	Midwest	1	Medium1	0	1,075	1,514	1,317
1	Veal	0	0	Pacific	1	Medium1	0	1,075	1,514	1,318
1	Veal	0	0	South	1	Medium1	0	1,075	1,514	1,318
1	Veal	0	0	Central	2	Medium2	0	690	1,290	600
1	Veal	0	0	Mid-Atlantic	2	Medium2	0	690	1,290	600
1	Veal	0	0	Midwest	2	Medium2	0	690	1,290	600
1	Veal	0	0	Pacific	2	Medium2	0	690	1,290	600
1	Veal	0	0	South	2	Medium2	0	690	1,290	600
1	Veal	0	0	Central	2	Medium1	0	690	1,290	600
1	Veal	0	0	Mid-Atlantic	2	Medium1	0	690	1,290	600
1	Veal	0	0	Midwest	2	Medium1	0	690	1,290	600
1	Veal	0	0	Pacific	2	Medium1	0	690	1,290	600
1	Veal	0	0	South	2	Medium1	0	690	1,290	600
1	Veal	0	0	Central	3	Medium2	0	190	1,210	600
1	Veal	0	0	Mid-Atlantic	3	Medium2	0	190	1,210	600
1	Veal	0	0	Midwest	3	Medium2	0	190	1,210	600
1	Veal	0	0	Pacific	3	Medium2	0	190	1,210	600
1	Veal	0	0	South	3	Medium2	0	190	1,210	600
1	Veal	0	0	Central	3	Medium1	0	190	1,210	600
1	Veal	0	0	Mid-Atlantic	3	Medium1	0	190	1,210	600

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Veal	0	0	Midwest	3	Medium1	0	190	1,210	600
1	Veal	0	0	Pacific	3	Medium1	0	190	1,210	600
1	Veal	0	0	South	3	Medium1	0	190	1,210	600
2	Veal	0	0	Central	1	Medium1	0	1,075	1,514	1,318
2	Veal	0	0	Mid-Atlantic	1	Medium1	0	1,075	1,514	1,317
2	Veal	0	0	Midwest	1	Medium1	0	1,075	1,514	1,317
2	Veal	0	0	Pacific	1	Medium1	0	1,075	1,514	1,318
2	Veal	0	0	South	1	Medium1	0	1,075	1,514	1,318
2	Veal	0	0	Central	2	Medium1	0	690	1,290	600
2	Veal	0	0	Mid-Atlantic	2	Medium1	0	690	1,290	600
2	Veal	0	0	Midwest	2	Medium1	0	690	1,290	600
2	Veal	0	0	Pacific	2	Medium1	0	690	1,290	600
2	Veal	0	0	South	2	Medium1	0	690	1,290	600
2	Veal	0	0	Central	3	Medium1	0	190	1,210	600
2	Veal	0	0	Mid-Atlantic	3	Medium1	0	190	1,210	600
2	Veal	0	0	Midwest	3	Medium1	0	190	1,210	600
2	Veal	0	0	Pacific	3	Medium1	0	190	1,210	600
2	Veal	0	0	South	3	Medium1	0	190	1,210	600
2	Veal	0	0	Central	1	Medium2	0	1,075	1,514	1,318
2	Veal	0	0	Mid-Atlantic	1	Medium2	0	1,075	1,514	1,317
2	Veal	0	0	Midwest	1	Medium2	0	1,075	1,514	1,317
2	Veal	0	0	Pacific	1	Medium2	0	1,075	1,514	1,318
2	Veal	0	0	South	1	Medium2	0	1,075	1,514	1,318
2	Veal	0	0	Central	2	Medium2	0	690	1,290	600
2	Veal	0	0	Mid-Atlantic	2	Medium2	0	690	1,290	600
2	Veal	0	0	Midwest	2	Medium2	0	690	1,290	600
2	Veal	0	0	Pacific	2	Medium2	0	690	1,290	600
2	Veal	0	0	South	2	Medium2	0	690	1,290	600
2	Veal	0	0	Central	3	Medium2	0	190	1,210	600

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
2	Veal	0	0	Mid-Atlantic	3	Medium2	0	190	1,210	600
2	Veal	0	0	Midwest	3	Medium2	0	190	1,210	600
2	Veal	0	0	Pacific	3	Medium2	0	190	1,210	600
2	Veal	0	0	South	3	Medium2	0	190	1,210	600
3	Veal	0	0	Central	1	Medium1	250	2,795	1,519	1,318
3	Veal	0	0	Mid-Atlantic	1	Medium1	455	2,733	1,523	1,317
3	Veal	0	0	Midwest	1	Medium1	524	2,889	1,524	1,317
3	Veal	0	0	Pacific	1	Medium1	228	2,326	1,519	1,318
3	Veal	0	0	South	1	Medium1	432	3,421	1,523	1,318
3	Veal	0	0	Central	2	Medium1	250	690	1,295	600
3	Veal	0	0	Mid-Atlantic	2	Medium1	455	690	1,299	600
3	Veal	0	0	Midwest	2	Medium1	524	690	1,300	600
3	Veal	0	0	Pacific	2	Medium1	228	690	1,295	600
3	Veal	0	0	South	2	Medium1	432	690	1,299	600
3	Veal	0	0	Central	3	Medium1	250	190	1,215	600
3	Veal	0	0	Mid-Atlantic	3	Medium1	455	190	1,219	600
3	Veal	0	0	Midwest	3	Medium1	524	190	1,220	600
3	Veal	0	0	Pacific	3	Medium1	228	190	1,215	600
3	Veal	0	0	South	3	Medium1	432	190	1,219	600
3	Veal	0	0	Central	1	Medium2	1,085	2,795	1,624	1,318
3	Veal	0	0	Mid-Atlantic	1	Medium2	1,996	2,733	1,717	1,317
3	Veal	0	0	Midwest	1	Medium2	2,259	2,889	1,743	1,317
3	Veal	0	0	Pacific	1	Medium2	998	2,326	1,616	1,318
3	Veal	0	0	South	1	Medium2	1,847	3,421	1,701	1,318
3	Veal	0	0	Central	2	Medium2	1,085	690	1,400	600
3	Veal	0	0	Mid-Atlantic	2	Medium2	1,996	690	1,493	600
3	Veal	0	0	Midwest	2	Medium2	2,259	690	1,519	600
3	Veal	0	0	Pacific	2	Medium2	998	690	1,392	600
3	Veal	0	0	South	2	Medium2	1,847	690	1,477	600

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
3	Veal	0	0	Central	3	Medium2	1,085	190	1,320	600
3	Veal	0	0	Mid-Atlantic	3	Medium2	1,996	190	1,413	600
3	Veal	0	0	Midwest	3	Medium2	2,259	190	1,439	600
3	Veal	0	0	Pacific	3	Medium2	998	190	1,312	600
3	Veal	0	0	South	3	Medium2	1,847	190	1,397	600
4	Veal	0	0	Central	1	Medium1	642	2,795	7,771	1,318
4	Veal	0	0	Mid-Atlantic	1	Medium1	847	2,733	7,775	1,317
4	Veal	0	0	Midwest	1	Medium1	916	2,889	7,776	1,317
4	Veal	0	0	Pacific	1	Medium1	620	2,326	7,771	1,318
4	Veal	0	0	South	1	Medium1	824	3,421	7,775	1,318
4	Veal	0	0	Central	2	Medium1	642	690	7,547	600
4	Veal	0	0	Mid-Atlantic	2	Medium1	847	690	7,551	600
4	Veal	0	0	Midwest	2	Medium1	916	690	7,552	600
4	Veal	0	0	Pacific	2	Medium1	620	690	7,547	600
4	Veal	0	0	South	2	Medium1	824	690	7,551	600
4	Veal	0	0	Central	3	Medium1	642	190	7,467	600
4	Veal	0	0	Mid-Atlantic	3	Medium1	847	190	7,471	600
4	Veal	0	0	Midwest	3	Medium1	916	190	7,472	600
4	Veal	0	0	Pacific	3	Medium1	620	190	7,467	600
4	Veal	0	0	South	3	Medium1	824	190	7,471	600
4	Veal	0	0	Central	1	Medium2	1,477	2,795	7,876	1,318
4	Veal	0	0	Mid-Atlantic	1	Medium2	2,388	2,733	7,969	1,317
4	Veal	0	0	Midwest	1	Medium2	2,651	2,889	7,995	1,317
4	Veal	0	0	Pacific	1	Medium2	1,390	2,326	7,868	1,318
4	Veal	0	0	South	1	Medium2	2,239	3,421	7,953	1,318
4	Veal	0	0	Central	2	Medium2	1,477	690	7,652	600
4	Veal	0	0	Mid-Atlantic	2	Medium2	2,388	690	7,745	600
4	Veal	0	0	Midwest	2	Medium2	2,651	690	7,771	600
4	Veal	0	0	Pacific	2	Medium2	1,390	690	7,644	600

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
4	Veal	0	0	South	2	Medium2	2,239	690	7,729	600
4	Veal	0	0	Central	3	Medium2	1,477	190	7,572	600
4	Veal	0	0	Mid-Atlantic	3	Medium2	2,388	190	7,665	600
4	Veal	0	0	Midwest	3	Medium2	2,651	190	7,691	600
4	Veal	0	0	Pacific	3	Medium2	1,390	190	7,564	600
4	Veal	0	0	South	3	Medium2	2,239	190	7,649	600
5	Veal	0	0	Central	1	Medium1	0	1,075	1,514	1,318
5	Veal	0	0	Mid-Atlantic	1	Medium1	0	1,075	1,514	1,317
5	Veal	0	0	Midwest	1	Medium1	0	1,075	1,514	1,317
5	Veal	0	0	Pacific	1	Medium1	0	1,075	1,514	1,318
5	Veal	0	0	South	1	Medium1	0	1,075	1,514	1,318
5	Veal	0	0	Central	2	Medium1	0	690	1,290	600
5	Veal	0	0	Mid-Atlantic	2	Medium1	0	690	1,290	600
5	Veal	0	0	Midwest	2	Medium1	0	690	1,290	600
5	Veal	0	0	Pacific	2	Medium1	0	690	1,290	600
5	Veal	0	0	South	2	Medium1	0	690	1,290	600
5	Veal	0	0	Central	3	Medium1	0	190	1,210	600
5	Veal	0	0	Mid-Atlantic	3	Medium1	0	190	1,210	600
5	Veal	0	0	Midwest	3	Medium1	0	190	1,210	600
5	Veal	0	0	Pacific	3	Medium1	0	190	1,210	600
5	Veal	0	0	South	3	Medium1	0	190	1,210	600
5	Veal	0	0	Central	1	Medium2	0	1,075	1,514	1,318
5	Veal	0	0	Mid-Atlantic	1	Medium2	0	1,075	1,514	1,317
5	Veal	0	0	Midwest	1	Medium2	0	1,075	1,514	1,317
5	Veal	0	0	Pacific	1	Medium2	0	1,075	1,514	1,318
5	Veal	0	0	South	1	Medium2	0	1,075	1,514	1,318
5	Veal	0	0	Central	2	Medium2	0	690	1,290	600
5	Veal	0	0	Mid-Atlantic	2	Medium2	0	690	1,290	600
5	Veal	0	0	Midwest	2	Medium2	0	690	1,290	600

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
5	Veal	0	0	Pacific	2	Medium2	0	690	1,290	600
5	Veal	0	0	South	2	Medium2	0	690	1,290	600
5	Veal	0	0	Central	3	Medium2	0	190	1,210	600
5	Veal	0	0	Mid-Atlantic	3	Medium2	0	190	1,210	600
5	Veal	0	0	Midwest	3	Medium2	0	190	1,210	600
5	Veal	0	0	Pacific	3	Medium2	0	190	1,210	600
5	Veal	0	0	South	3	Medium2	0	190	1,210	600
6	Veal	0	0	Central	1	Medium1	0	1,075	1,514	1,318
6	Veal	0	0	Mid-Atlantic	1	Medium1	0	1,075	1,514	1,317
6	Veal	0	0	Midwest	1	Medium1	0	1,075	1,514	1,317
6	Veal	0	0	Pacific	1	Medium1	0	1,075	1,514	1,318
6	Veal	0	0	South	1	Medium1	0	1,075	1,514	1,318
6	Veal	0	0	Central	2	Medium1	0	690	1,290	600
6	Veal	0	0	Mid-Atlantic	2	Medium1	0	690	1,290	600
6	Veal	0	0	Midwest	2	Medium1	0	690	1,290	600
6	Veal	0	0	Pacific	2	Medium1	0	690	1,290	600
6	Veal	0	0	South	2	Medium1	0	690	1,290	600
6	Veal	0	0	Central	3	Medium1	0	190	1,210	600
6	Veal	0	0	Mid-Atlantic	3	Medium1	0	190	1,210	600
6	Veal	0	0	Midwest	3	Medium1	0	190	1,210	600
6	Veal	0	0	Pacific	3	Medium1	0	190	1,210	600
6	Veal	0	0	South	3	Medium1	0	190	1,210	600
6	Veal	0	0	Central	1	Medium2	0	1,075	1,514	1,318
6	Veal	0	0	Mid-Atlantic	1	Medium2	0	1,075	1,514	1,317
6	Veal	0	0	Midwest	1	Medium2	0	1,075	1,514	1,317
6	Veal	0	0	Pacific	1	Medium2	0	1,075	1,514	1,318
6	Veal	0	0	South	1	Medium2	0	1,075	1,514	1,318
6	Veal	0	0	Central	2	Medium2	0	690	1,290	600
6	Veal	0	0	Mid-Atlantic	2	Medium2	0	690	1,290	600

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
6	Veal	0	0	Midwest	2	Medium2	0	690	1,290	600
6	Veal	0	0	Pacific	2	Medium2	0	690	1,290	600
6	Veal	0	0	South	2	Medium2	0	690	1,290	600
6	Veal	0	0	Central	3	Medium2	0	190	1,210	600
6	Veal	0	0	Mid-Atlantic	3	Medium2	0	190	1,210	600
6	Veal	0	0	Midwest	3	Medium2	0	190	1,210	600
6	Veal	0	0	Pacific	3	Medium2	0	190	1,210	600
6	Veal	0	0	South	3	Medium2	0	190	1,210	600
7	Veal	0	0	Central	1	Medium1	0	1,075	1,514	1,318
7	Veal	0	0	Mid-Atlantic	1	Medium1	0	1,075	1,514	1,317
7	Veal	0	0	Midwest	1	Medium1	0	1,075	1,514	1,317
7	Veal	0	0	Pacific	1	Medium1	0	1,075	1,514	1,318
7	Veal	0	0	South	1	Medium1	0	1,075	1,514	1,318
7	Veal	0	0	Central	2	Medium1	0	690	1,290	600
7	Veal	0	0	Mid-Atlantic	2	Medium1	0	690	1,290	600
7	Veal	0	0	Midwest	2	Medium1	0	690	1,290	600
7	Veal	0	0	Pacific	2	Medium1	0	690	1,290	600
7	Veal	0	0	South	2	Medium1	0	690	1,290	600
7	Veal	0	0	Central	3	Medium1	0	190	1,210	600
7	Veal	0	0	Mid-Atlantic	3	Medium1	0	190	1,210	600
7	Veal	0	0	Midwest	3	Medium1	0	190	1,210	600
7	Veal	0	0	Pacific	3	Medium1	0	190	1,210	600
7	Veal	0	0	South	3	Medium1	0	190	1,210	600
7	Veal	0	0	Central	1	Medium2	0	1,075	1,514	1,318
7	Veal	0	0	Mid-Atlantic	1	Medium2	0	1,075	1,514	1,317
7	Veal	0	0	Midwest	1	Medium2	0	1,075	1,514	1,317
7	Veal	0	0	Pacific	1	Medium2	0	1,075	1,514	1,318
7	Veal	0	0	South	1	Medium2	0	1,075	1,514	1,318
7	Veal	0	0	Central	2	Medium2	0	690	1,290	600

Table 11-17. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
7	Veal	0	0	Mid-Atlantic	2	Medium2	0	690	1,290	600
7	Veal	0	0	Midwest	2	Medium2	0	690	1,290	600
7	Veal	0	0	Pacific	2	Medium2	0	690	1,290	600
7	Veal	0	0	South	2	Medium2	0	690	1,290	600
7	Veal	0	0	Central	3	Medium2	0	190	1,210	600
7	Veal	0	0	Mid-Atlantic	3	Medium2	0	190	1,210	600
7	Veal	0	0	Midwest	3	Medium2	0	190	1,210	600
7	Veal	0	0	Pacific	3	Medium2	0	190	1,210	600
7	Veal	0	0	South	3	Medium2	0	190	1,210	600

Table 11-18. Regulatory Compliance Costs for the Heifer Industry

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Heifers	0	0	Central	1	Large1	532	1,025	1,511	1,230
1	Heifers	0	0	Central	2	Large1	532	1,006	2,012	1,184
1	Heifers	0	0	Central	3	Large1	532	190	1,237	600
1	Heifers	0	0	Mid-Atlantic	1	Large1	1,386	1,094	1,594	1,363
1	Heifers	0	0	Mid-Atlantic	2	Large1	1,386	1,063	1,833	1,302
1	Heifers	0	0	Mid-Atlantic	3	Large1	1,386	190	1,279	600
1	Heifers	0	0	Midwest	1	Large1	1,308	1,133	1,613	1,435
1	Heifers	0	0	Midwest	2	Large1	1,308	1,102	1,898	1,374
1	Heifers	0	0	Midwest	3	Large1	1,308	190	1,275	600
1	Heifers	0	0	Pacific	1	Large1	999	1,133	1,598	1,435
1	Heifers	0	0	Pacific	2	Large1	999	1,102	2,161	1,374
1	Heifers	0	0	Pacific	3	Large1	999	190	1,260	600
1	Heifers	0	0	South	1	Large1	2,084	1,040	1,598	1,251
1	Heifers	0	0	South	2	Large1	2,084	1,010	1,859	1,190
1	Heifers	0	0	South	3	Large1	2,084	190	1,314	600
1	Heifers	0	0	Central	1	Medium1	35,474	779	1,877	759
1	Heifers	0	0	Central	2	Medium1	35,474	759	3,714	733
1	Heifers	0	0	Central	3	Medium1	7,236	190	1,538	600
1	Heifers	0	0	Mid-Atlantic	1	Medium1	38,395	798	2,035	805
1	Heifers	0	0	Mid-Atlantic	2	Medium1	38,395	767	2,941	744
1	Heifers	0	0	Mid-Atlantic	3	Medium1	10,157	190	1,684	600
1	Heifers	0	0	Midwest	1	Medium1	36,618	809	2,017	820
1	Heifers	0	0	Midwest	2	Medium1	36,584	779	4,716	759
1	Heifers	0	0	Midwest	3	Medium1	8,346	190	1,596	600
1	Heifers	0	0	Pacific	1	Medium1	38,887	809	2,129	820
1	Heifers	0	0	Pacific	2	Medium1	38,853	779	4,146	759
1	Heifers	0	0	Pacific	3	Medium1	10,615	190	1,707	600
1	Heifers	0	0	South	1	Medium1	39,071	782	2,059	764
1	Heifers	0	0	South	2	Medium1	39,071	752	3,049	723

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
1	Heifers	0	0	South	3	Medium1	10,833	190	1,718	600
1	Heifers	0	0	Central	1	Medium2	37,198	859	2,730	908
1	Heifers	0	0	Central	2	Medium2	36,983	836	2,938	877
1	Heifers	0	0	Central	3	Medium2	8,468	190	1,586	600
1	Heifers	0	0	Mid-Atlantic	1	Medium2	41,877	890	3,297	969
1	Heifers	0	0	Mid-Atlantic	2	Medium2	41,618	863	3,252	933
1	Heifers	0	0	Mid-Atlantic	3	Medium2	12,851	190	1,806	600
1	Heifers	0	0	Midwest	1	Medium2	39,428	913	3,395	1,020
1	Heifers	0	0	Midwest	2	Medium2	39,125	883	5,300	959
1	Heifers	0	0	Midwest	3	Medium2	10,174	190	1,674	600
1	Heifers	0	0	Pacific	1	Medium2	42,674	909	3,520	1,015
1	Heifers	0	0	Pacific	2	Medium2	42,409	883	3,827	959
1	Heifers	0	0	Pacific	3	Medium2	13,458	190	1,836	600
1	Heifers	0	0	South	1	Medium2	42,754	863	3,053	933
1	Heifers	0	0	South	2	Medium2	42,468	832	2,927	871
1	Heifers	0	0	South	3	Medium2	13,988	190	1,863	600
2	Heifers	0	0	Central	1	Large1	532	1,372	1,713	1,881
2	Heifers	0	0	Mid-Atlantic	1	Large1	1,386	1,202	1,657	1,565
2	Heifers	0	0	Midwest	1	Large1	1,308	1,152	1,624	1,472
2	Heifers	0	0	Pacific	1	Large1	999	1,325	1,710	1,798
2	Heifers	0	0	South	1	Large1	2,084	1,139	1,656	1,439
2	Heifers	0	0	Central	2	Large1	532	2,038	2,295	3,139
2	Heifers	0	0	Mid-Atlantic	2	Large1	1,386	1,485	2,052	2,092
2	Heifers	0	0	Midwest	2	Large1	1,308	1,247	1,929	1,646
2	Heifers	0	0	Pacific	2	Large1	999	1,548	2,565	2,205
2	Heifers	0	0	South	2	Large1	2,084	1,378	2,222	1,890
2	Heifers	0	0	Central	3	Large1	532	190	1,237	600
2	Heifers	0	0	Mid-Atlantic	3	Large1	1,386	190	1,279	600
2	Heifers	0	0	Midwest	3	Large1	1,308	190	1,275	600

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
2	Heifers	0	0	Pacific	3	Large1	999	190	1,260	600
2	Heifers	0	0	South	3	Large1	2,084	190	1,314	600
2	Heifers	0	0	Central	1	Medium1	36,722	901	2,816	990
2	Heifers	0	0	Mid-Atlantic	1	Medium1	38,836	844	2,511	890
2	Heifers	0	0	Midwest	1	Medium1	36,821	829	2,218	858
2	Heifers	0	0	Pacific	1	Medium1	39,674	890	3,037	971
2	Heifers	0	0	South	1	Medium1	39,701	858	2,818	909
2	Heifers	0	0	Central	2	Medium1	37,038	945	4,782	1,076
2	Heifers	0	0	Mid-Atlantic	2	Medium1	38,877	841	5,176	878
2	Heifers	0	0	Midwest	2	Medium1	36,946	825	3,368	847
2	Heifers	0	0	Pacific	2	Medium1	39,481	869	4,530	931
2	Heifers	0	0	South	2	Medium1	39,399	830	3,590	859
2	Heifers	0	0	Central	3	Medium1	7,236	190	1,538	600
2	Heifers	0	0	Mid-Atlantic	3	Medium1	10,157	190	1,684	600
2	Heifers	0	0	Midwest	3	Medium1	8,346	190	1,596	600
2	Heifers	0	0	Pacific	3	Medium1	10,615	190	1,707	600
2	Heifers	0	0	South	3	Medium1	10,833	190	1,718	600
2	Heifers	0	0	Central	1	Medium2	40,313	1,088	3,877	1,341
2	Heifers	0	0	Mid-Atlantic	1	Medium2	42,915	978	3,833	1,133
2	Heifers	0	0	Midwest	1	Medium2	39,888	951	3,605	1,090
2	Heifers	0	0	Pacific	1	Medium2	44,488	1,065	4,499	1,308
2	Heifers	0	0	South	1	Medium2	44,339	1,004	4,039	1,191
2	Heifers	0	0	Central	2	Medium2	42,350	1,259	7,144	1,672
2	Heifers	0	0	Mid-Atlantic	2	Medium2	43,575	1,039	4,862	1,262
2	Heifers	0	0	Midwest	2	Medium2	40,362	990	4,101	1,160
2	Heifers	0	0	Pacific	2	Medium2	44,653	1,086	5,442	1,349
2	Heifers	0	0	South	2	Medium2	44,527	1,028	4,789	1,228
2	Heifers	0	0	Central	3	Medium2	8,468	190	1,586	600
2	Heifers	0	0	Mid-Atlantic	3	Medium2	12,851	190	1,806	600

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
2	Heifers	0	0	Midwest	3	Medium2	10,174	190	1,674	600
2	Heifers	0	0	Pacific	3	Medium2	13,458	190	1,836	600
2	Heifers	0	0	South	3	Medium2	13,988	190	1,863	600
3	Heifers	0	0	Central	1	Large1	17,194	3,781	2,609	1,881
3	Heifers	0	0	Mid-Atlantic	1	Large1	63,166	3,883	4,861	1,565
3	Heifers	0	0	Midwest	1	Large1	48,366	4,206	4,107	1,472
3	Heifers	0	0	Pacific	1	Large1	34,401	3,431	3,437	1,798
3	Heifers	0	0	South	1	Large1	64,315	3,786	4,872	1,439
3	Heifers	0	0	Central	2	Large1	17,194	2,038	3,191	3,139
3	Heifers	0	0	Mid-Atlantic	2	Large1	63,166	1,485	5,256	2,092
3	Heifers	0	0	Midwest	2	Large1	48,366	1,247	4,412	1,646
3	Heifers	0	0	Pacific	2	Large1	34,401	1,548	4,293	2,205
3	Heifers	0	0	South	2	Large1	64,315	1,378	5,438	1,890
3	Heifers	0	0	Central	3	Large1	17,194	190	2,132	600
3	Heifers	0	0	Mid-Atlantic	3	Large1	63,166	190	4,483	600
3	Heifers	0	0	Midwest	3	Large1	48,366	190	3,758	600
3	Heifers	0	0	Pacific	3	Large1	34,401	190	2,987	600
3	Heifers	0	0	South	3	Large1	64,315	190	4,531	600
3	Heifers	0	0	Central	1	Medium1	44,768	3,083	3,216	990
3	Heifers	0	0	Mid-Atlantic	1	Medium1	66,364	3,248	3,883	890
3	Heifers	0	0	Midwest	1	Medium1	59,466	3,671	3,346	858
3	Heifers	0	0	Pacific	1	Medium1	54,895	2,375	3,796	971
3	Heifers	0	0	South	1	Medium1	67,532	2,627	4,206	909
3	Heifers	0	0	Central	2	Medium1	45,084	945	6,546	1,076
3	Heifers	0	0	Mid-Atlantic	2	Medium1	66,404	841	5,422	878
3	Heifers	0	0	Midwest	2	Medium1	59,591	825	5,767	847
3	Heifers	0	0	Pacific	2	Medium1	54,702	869	6,498	931
3	Heifers	0	0	South	2	Medium1	67,230	830	4,978	859
3	Heifers	0	0	Central	3	Medium1	15,282	190	1,939	600

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
3	Heifers	0	0	Mid-Atlantic	3	Medium1	37,684	190	3,057	600
3	Heifers	0	0	Midwest	3	Medium1	30,991	190	2,724	600
3	Heifers	0	0	Pacific	3	Medium1	25,836	190	2,466	600
3	Heifers	0	0	South	3	Medium1	38,664	190	3,106	600
3	Heifers	0	0	Central	1	Medium2	51,275	3,270	4,488	1,341
3	Heifers	0	0	Mid-Atlantic	1	Medium2	81,183	3,381	5,862	1,133
3	Heifers	0	0	Midwest	1	Medium2	70,809	3,793	5,281	1,090
3	Heifers	0	0	Pacific	1	Medium2	65,502	2,550	5,607	1,308
3	Heifers	0	0	South	1	Medium2	83,247	2,773	6,090	1,191
3	Heifers	0	0	Central	2	Medium2	53,312	1,259	6,051	1,672
3	Heifers	0	0	Mid-Atlantic	2	Medium2	81,842	1,039	8,370	1,262
3	Heifers	0	0	Midwest	2	Medium2	71,283	990	7,263	1,160
3	Heifers	0	0	Pacific	2	Medium2	65,666	1,086	6,550	1,349
3	Heifers	0	0	South	2	Medium2	83,435	1,028	6,840	1,228
3	Heifers	0	0	Central	3	Medium2	19,431	190	2,197	600
3	Heifers	0	0	Mid-Atlantic	3	Medium2	51,119	190	3,834	600
3	Heifers	0	0	Midwest	3	Medium2	41,096	190	3,350	600
3	Heifers	0	0	Pacific	3	Medium2	34,472	190	2,944	600
3	Heifers	0	0	South	3	Medium2	52,896	190	3,913	600
4	Heifers	0	0	Central	1	Large1	17,586	3,781	8,861	1,881
4	Heifers	0	0	Mid-Atlantic	1	Large1	63,558	3,883	11,113	1,565
4	Heifers	0	0	Midwest	1	Large1	48,758	4,206	10,359	1,472
4	Heifers	0	0	Pacific	1	Large1	34,793	3,431	9,689	1,798
4	Heifers	0	0	South	1	Large1	64,707	3,786	11,124	1,439
4	Heifers	0	0	Central	2	Large1	17,586	2,038	9,443	3,139
4	Heifers	0	0	Mid-Atlantic	2	Large1	63,558	1,485	11,508	2,092
4	Heifers	0	0	Midwest	2	Large1	48,758	1,247	10,664	1,646
4	Heifers	0	0	Pacific	2	Large1	34,793	1,548	10,545	2,205
4	Heifers	0	0	South	2	Large1	64,707	1,378	11,690	1,890

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
4	Heifers	0	0	Central	3	Large1	17,586	190	8,384	600
4	Heifers	0	0	Mid-Atlantic	3	Large1	63,558	190	10,735	600
4	Heifers	0	0	Midwest	3	Large1	48,758	190	10,010	600
4	Heifers	0	0	Pacific	3	Large1	34,793	190	9,239	600
4	Heifers	0	0	South	3	Large1	64,707	190	10,783	600
4	Heifers	0	0	Central	1	Medium1	45,160	3,083	9,468	990
4	Heifers	0	0	Mid-Atlantic	1	Medium1	66,756	3,248	10,135	890
4	Heifers	0	0	Midwest	1	Medium1	59,858	3,671	9,598	858
4	Heifers	0	0	Pacific	1	Medium1	55,287	2,375	10,048	971
4	Heifers	0	0	South	1	Medium1	67,924	2,627	10,458	909
4	Heifers	0	0	Central	2	Medium1	45,476	945	11,434	1,076
4	Heifers	0	0	Mid-Atlantic	2	Medium1	66,796	841	11,674	878
4	Heifers	0	0	Midwest	2	Medium1	59,983	825	10,748	847
4	Heifers	0	0	Pacific	2	Medium1	55,094	869	11,541	931
4	Heifers	0	0	South	2	Medium1	67,622	830	11,999	859
4	Heifers	0	0	Central	3	Medium1	15,674	190	8,191	600
4	Heifers	0	0	Mid-Atlantic	3	Medium1	38,076	190	9,309	600
4	Heifers	0	0	Midwest	3	Medium1	31,383	190	8,976	600
4	Heifers	0	0	Pacific	3	Medium1	26,228	190	8,718	600
4	Heifers	0	0	South	3	Medium1	39,056	190	9,358	600
4	Heifers	0	0	Central	1	Medium2	51,667	3,270	10,740	1,341
4	Heifers	0	0	Mid-Atlantic	1	Medium2	81,575	3,381	12,114	1,133
4	Heifers	0	0	Midwest	1	Medium2	71,201	3,793	11,533	1,090
4	Heifers	0	0	Pacific	1	Medium2	65,894	2,550	11,859	1,308
4	Heifers	0	0	South	1	Medium2	83,639	2,773	12,342	1,191
4	Heifers	0	0	Central	2	Medium2	53,704	1,259	12,303	1,672
4	Heifers	0	0	Mid-Atlantic	2	Medium2	82,234	1,039	14,622	1,262
4	Heifers	0	0	Midwest	2	Medium2	71,675	990	13,515	1,160
4	Heifers	0	0	Pacific	2	Medium2	66,058	1,086	12,802	1,349

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
4	Heifers	0	0	South	2	Medium2	83,827	1,028	13,092	1,228
4	Heifers	0	0	Central	3	Medium2	19,823	190	8,449	600
4	Heifers	0	0	Mid-Atlantic	3	Medium2	51,511	190	10,086	600
4	Heifers	0	0	Midwest	3	Medium2	41,488	190	9,602	600
4	Heifers	0	0	Pacific	3	Medium2	34,864	190	9,196	600
4	Heifers	0	0	South	3	Medium2	53,288	190	10,165	600
5	Heifers	0	0	Central	1	Large1	9,689	1,372	2,199	1,881
5	Heifers	0	0	Mid-Atlantic	1	Large1	10,542	1,202	2,142	1,565
5	Heifers	0	0	Midwest	1	Large1	10,465	1,152	2,110	1,472
5	Heifers	0	0	Pacific	1	Large1	10,156	1,325	2,195	1,798
5	Heifers	0	0	South	1	Large1	11,241	1,139	2,141	1,439
5	Heifers	0	0	Central	2	Large1	9,689	2,038	2,768	3,139
5	Heifers	0	0	Mid-Atlantic	2	Large1	10,542	1,485	2,522	2,092
5	Heifers	0	0	Midwest	2	Large1	10,465	1,247	2,398	1,646
5	Heifers	0	0	Pacific	2	Large1	10,156	1,548	3,002	2,205
5	Heifers	0	0	South	2	Large1	11,241	1,378	2,679	1,890
5	Heifers	0	0	Central	3	Large1	9,689	190	1,722	600
5	Heifers	0	0	Mid-Atlantic	3	Large1	10,542	190	1,765	600
5	Heifers	0	0	Midwest	3	Large1	10,465	190	1,761	600
5	Heifers	0	0	Pacific	3	Large1	10,156	190	1,745	600
5	Heifers	0	0	South	3	Large1	11,241	190	1,800	600
5	Heifers	0	0	Central	1	Medium1	45,878	901	3,114	990
5	Heifers	0	0	Mid-Atlantic	1	Medium1	47,993	844	2,809	890
5	Heifers	0	0	Midwest	1	Medium1	45,978	829	2,516	858
5	Heifers	0	0	Pacific	1	Medium1	48,831	890	3,335	971
5	Heifers	0	0	South	1	Medium1	48,858	858	3,116	909
5	Heifers	0	0	Central	2	Medium1	46,194	945	5,055	1,076
5	Heifers	0	0	Mid-Atlantic	2	Medium1	48,034	841	5,467	878
5	Heifers	0	0	Midwest	2	Medium1	46,103	825	4,933	847

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
5	Heifers	0	0	Pacific	2	Medium1	48,638	869	4,798	931
5	Heifers	0	0	South	2	Medium1	48,556	830	3,868	859
5	Heifers	0	0	Central	3	Medium1	16,393	190	1,836	600
5	Heifers	0	0	Mid-Atlantic	3	Medium1	19,314	190	1,982	600
5	Heifers	0	0	Midwest	3	Medium1	17,503	190	1,893	600
5	Heifers	0	0	Pacific	3	Medium1	19,772	190	2,005	600
5	Heifers	0	0	South	3	Medium1	19,990	190	2,016	600
5	Heifers	0	0	Central	1	Medium2	49,469	1,088	4,435	1,341
5	Heifers	0	0	Mid-Atlantic	1	Medium2	52,072	978	4,392	1,133
5	Heifers	0	0	Midwest	1	Medium2	49,044	951	4,163	1,090
5	Heifers	0	0	Pacific	1	Medium2	53,644	1,065	5,057	1,308
5	Heifers	0	0	South	1	Medium2	53,495	1,004	4,598	1,191
5	Heifers	0	0	Central	2	Medium2	51,507	1,259	5,962	1,672
5	Heifers	0	0	Mid-Atlantic	2	Medium2	52,731	1,039	5,380	1,262
5	Heifers	0	0	Midwest	2	Medium2	49,519	990	4,638	1,160
5	Heifers	0	0	Pacific	2	Medium2	53,809	1,086	5,952	1,349
5	Heifers	0	0	South	2	Medium2	53,684	1,028	5,317	1,228
5	Heifers	0	0	Central	3	Medium2	17,625	190	2,145	600
5	Heifers	0	0	Mid-Atlantic	3	Medium2	22,008	190	2,364	600
5	Heifers	0	0	Midwest	3	Medium2	19,331	190	2,233	600
5	Heifers	0	0	Pacific	3	Medium2	22,615	190	2,394	600
5	Heifers	0	0	South	3	Medium2	23,145	190	2,421	600
6	Heifers	0	0	Central	1	Large1	532	1,372	1,713	1,881
6	Heifers	0	0	Mid-Atlantic	1	Large1	1,386	1,202	1,657	1,565
6	Heifers	0	0	Midwest	1	Large1	1,308	1,152	1,624	1,472
6	Heifers	0	0	Pacific	1	Large1	999	1,325	1,710	1,798
6	Heifers	0	0	South	1	Large1	2,084	1,139	1,656	1,439
6	Heifers	0	0	Central	2	Large1	532	2,038	2,295	3,139
6	Heifers	0	0	Mid-Atlantic	2	Large1	1,386	1,485	2,052	2,092

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
6	Heifers	0	0	Midwest	2	Large1	1,308	1,247	1,929	1,646
6	Heifers	0	0	Pacific	2	Large1	999	1,548	2,565	2,205
6	Heifers	0	0	South	2	Large1	2,084	1,378	2,222	1,890
6	Heifers	0	0	Central	3	Large1	532	190	1,237	600
6	Heifers	0	0	Mid-Atlantic	3	Large1	1,386	190	1,279	600
6	Heifers	0	0	Midwest	3	Large1	1,308	190	1,275	600
6	Heifers	0	0	Pacific	3	Large1	999	190	1,260	600
6	Heifers	0	0	South	3	Large1	2,084	190	1,314	600
6	Heifers	0	0	Central	3	Medium1	7,236	190	1,538	600
6	Heifers	0	0	Mid-Atlantic	3	Medium1	10,157	190	1,684	600
6	Heifers	0	0	Midwest	3	Medium1	8,346	190	1,596	600
6	Heifers	0	0	Pacific	3	Medium1	10,615	190	1,707	600
6	Heifers	0	0	South	3	Medium1	10,833	190	1,718	600
6	Heifers	0	0	Central	1	Medium1	36,722	901	2,816	990
6	Heifers	0	0	Mid-Atlantic	1	Medium1	38,836	844	2,511	890
6	Heifers	0	0	Midwest	1	Medium1	36,821	829	2,218	858
6	Heifers	0	0	Pacific	1	Medium1	39,674	890	3,037	971
6	Heifers	0	0	South	1	Medium1	39,701	858	2,818	909
6	Heifers	0	0	Central	2	Medium1	37,038	945	4,782	1,076
6	Heifers	0	0	Mid-Atlantic	2	Medium1	38,877	841	4,049	878
6	Heifers	0	0	Midwest	2	Medium1	36,946	825	3,368	847
6	Heifers	0	0	Pacific	2	Medium1	39,481	869	4,530	931
6	Heifers	0	0	South	2	Medium1	39,399	830	3,590	859
6	Heifers	0	0	Central	1	Medium2	40,313	1,088	3,877	1,341
6	Heifers	0	0	Mid-Atlantic	1	Medium2	42,915	978	3,833	1,133
6	Heifers	0	0	Midwest	1	Medium2	39,888	951	3,605	1,090
6	Heifers	0	0	Pacific	1	Medium2	44,488	1,065	4,499	1,308
6	Heifers	0	0	South	1	Medium2	44,339	1,004	4,039	1,191
6	Heifers	0	0	Central	2	Medium2	42,350	1,259	5,440	1,672

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
6	Heifers	0	0	Mid-Atlantic	2	Medium2	43,575	1,039	4,862	1,262
6	Heifers	0	0	Midwest	2	Medium2	40,362	990	4,101	1,160
6	Heifers	0	0	Pacific	2	Medium2	44,653	1,086	5,442	1,349
6	Heifers	0	0	South	2	Medium2	44,527	1,028	4,789	1,228
6	Heifers	0	0	Central	3	Medium2	8,468	190	1,586	600
6	Heifers	0	0	Mid-Atlantic	3	Medium2	12,851	190	1,806	600
6	Heifers	0	0	Midwest	3	Medium2	10,174	190	1,674	600
6	Heifers	0	0	Pacific	3	Medium2	13,458	190	1,836	600
6	Heifers	0	0	South	3	Medium2	13,988	190	1,863	600
7	Heifers	0	0	Central	1	Large1	532	1,372	1,713	1,881
7	Heifers	0	0	Central	2	Large1	532	2,038	2,295	3,139
7	Heifers	0	0	Central	3	Large1	532	190	1,237	600
7	Heifers	0	0	Mid-Atlantic	1	Large1	1,386	1,202	1,657	1,565
7	Heifers	0	0	Mid-Atlantic	2	Large1	1,386	1,485	2,052	2,092
7	Heifers	0	0	Mid-Atlantic	3	Large1	1,386	190	1,279	600
7	Heifers	0	0	Midwest	1	Large1	1,308	1,152	1,624	1,472
7	Heifers	0	0	Midwest	2	Large1	1,308	1,247	1,929	1,646
7	Heifers	0	0	Midwest	3	Large1	1,308	190	1,275	600
7	Heifers	0	0	Pacific	1	Large1	999	1,325	1,710	1,798
7	Heifers	0	0	Pacific	2	Large1	999	1,548	2,565	2,205
7	Heifers	0	0	Pacific	3	Large1	999	190	1,260	600
7	Heifers	0	0	South	1	Large1	2,084	1,139	1,656	1,439
7	Heifers	0	0	South	2	Large1	2,084	1,378	2,222	1,890
7	Heifers	0	0	South	3	Large1	2,084	190	1,314	600
7	Heifers	0	0	Central	1	Medium1	36,722	901	2,816	990
7	Heifers	0	0	Central	2	Medium1	37,038	945	6,146	1,076
7	Heifers	0	0	Central	3	Medium1	7,236	190	1,538	600
7	Heifers	0	0	Mid-Atlantic	1	Medium1	38,836	844	2,511	890
7	Heifers	0	0	Mid-Atlantic	2	Medium1	38,877	841	4,049	878

Table 11-18. (Continued)

Option	Animal	Man type	Operation	Region	Category	Size ID	Capital	Fixed	O & M	3 yr rec
7	Heifers	0	0	Mid-Atlantic	3	Medium1	10,157	190	1,684	600
7	Heifers	0	0	Midwest	1	Medium1	36,821	829	2,218	858
7	Heifers	0	0	Midwest	2	Medium1	36,946	825	3,368	847
7	Heifers	0	0	Midwest	3	Medium1	8,346	190	1,596	600
7	Heifers	0	0	Pacific	1	Medium1	39,674	890	3,037	971
7	Heifers	0	0	Pacific	2	Medium1	39,481	869	4,530	931
7	Heifers	0	0	Pacific	3	Medium1	10,615	190	1,707	600
7	Heifers	0	0	South	1	Medium1	39,701	858	2,818	909
7	Heifers	0	0	South	2	Medium1	39,399	830	4,359	859
7	Heifers	0	0	South	3	Medium1	10,833	190	1,718	600
7	Heifers	0	0	Central	1	Medium2	40,313	1,088	3,877	1,341
7	Heifers	0	0	Central	2	Medium2	42,350	1,259	7,144	1,672
7	Heifers	0	0	Central	3	Medium2	8,468	190	1,586	600
7	Heifers	0	0	Mid-Atlantic	1	Medium2	42,915	978	3,833	1,133
7	Heifers	0	0	Mid-Atlantic	2	Medium2	43,575	1,039	4,862	1,262
7	Heifers	0	0	Mid-Atlantic	3	Medium2	12,851	190	1,806	600
7	Heifers	0	0	Midwest	1	Medium2	39,888	951	3,605	1,090
7	Heifers	0	0	Midwest	2	Medium2	40,362	990	4,101	1,160
7	Heifers	0	0	Midwest	3	Medium2	10,174	190	1,674	600
7	Heifers	0	0	Pacific	1	Medium2	44,488	1,065	4,499	1,308
7	Heifers	0	0	Pacific	2	Medium2	44,653	1,086	5,442	1,349
7	Heifers	0	0	Pacific	3	Medium2	13,458	190	1,836	600
7	Heifers	0	0	South	1	Medium2	44,339	1,004	4,039	1,191
7	Heifers	0	0	South	2	Medium2	44,527	1,028	4,789	1,228
7	Heifers	0	0	South	3	Medium2	13,988	190	1,863	600

CHAPTER 12

POLLUTANT REDUCTION ESTIMATES

12.1 Feeding Operation Runoff Pollutant Loads

Runoff from feedlots can be a significant contributor of pollutants to surface waters. Table 12-1 presents feedlot nutrient loads for the beef, dairy, poultry, and swine industries. Beef operations have the most feedlot runoff because the animals are typically housed in open lots. During periods of heavy rain, pollutants can leave the facility as surface runoff. For the purposes of this analysis, it was assumed that no pollutant loads leached directly to ground water from feedlots because feedlot surfaces are generally trampled down by the animals and are highly impermeable to water. The pollutant load from feedlot runoff depends on the rainfall amount and varies by AFO region.

Table 12-1. Nutrient Loads from Feedlot Runoff by Animal Sector and AFO Regions

Sector	AFO Region									
	Central		Mid-Atlantic		Midwest		Pacific		South	
	N	P	N	P	N	P	N	P	N	P
	---------- pounds per year ----------									
Beef	864	233	2,796	756	1,455	393	3,020	817	3,324	899
Dairy	195	52	117	169	117	88	117	183	117	201
Poultry	173	47	259	141	291	79	604	163	645	180
Swine	0	0	0	0	0	0	0	0	0	0

The model facility approach described in chapter 11 was used to estimate pollutant load reductions. For baseline conditions, the model assumes that beef, dairy, and swine facilities with more than 1,000 animal units have no feedlot runoff because they are covered under the current regulation. No such restriction exists for poultry operations because they are not covered under the current regulation. To estimate loads from runoff, the solids in the runoff, the excreted solids, and the constituents in the excreted solids were calculated. The annual amount of runoff from a model feedlot was calculated for each of the five AFO regions using average precipitation from the National Climatic Data Center. The volume of runoff was calculated using this amount of runoff and the estimated area of the dry lot and feedlot handling areas for each animal type (MWPS, 1987) was assumed that runoff from dry lots contains 1.5 percent solids (MWPS, 1993). From this assumption, the quantity of solids that runs off the feedlot was calculated using annual runoff estimates and the percent solids.

Characteristics of manure as-excreted from ASAE (1998) were used to estimate the mass loading per day per animal unit of each constituent of interest (Table 12-2). These loads were converted to a dry basis to calculate the total annual loading from each model feedlot. The total solids excreted were calculated using the total wet weight excreted and the moisture content. It was then assumed that the ratio of the quantity of each constituent in runoff to the quantity excreted is proportional to the ratio of the total solids in runoff to the total solids produced at the feedlot. Results for individual sectors are presented in Tables 12-3, 12-4, and 12-5.

Table 12-2. Constituents of Manure Presented in ASAE (1998).

Item	**Mature Cow**	**Calf**	**Poultry**
	pounds per 1000 pounds animal per day		
TKN	0.3400	0.2700	1.1000
Phosphorus	0.0920	0.0660	0.3000
Volatile Solids	7.2000	2.3000	17.0000
BOD_5	1.6000	1.7000	---
COD	7.8000	5.3000	16.0000
Zinc	0.0011	0.0130	0.0036
Copper	0.0003	0.00005	0.00098

TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.

Table 12-3. Annual Beef Feedlot Runoff Loading

Item	Central	Mid Atlantic	Midwest	Pacific	South
Annual Runoff (ft^3)	172,120	556,995	289,886	601,772	662,337
Solids	2,582	8,355	4,348	9,027	9,935
TKN	864	2,796	1,455	3,020	3,324
Phosphorus	234	756	394	817	900
Volatile Solids	18,294	59,201	30,811	63,960	70,397
BOD5	4,065	13,156	6,847	14,213	15,644
COD	19,818	64,134	33,378	69,290	76,263
Zinc	3	9	5	10	11
Copper	1	3	1	3	3

TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.

Table 12-4. Annual Dairy Feedlot Runoff Loading

Item	Central	Mid Atlantic	Midwest	Pacific	South
Annual Runoff (ft^3)	41,664	134,827	70,170	145,666	160,326
Solids	625	2,022	1,053	2,185	2,405
TKN	195	632	329	682	751
Phosphorus	52	169	88	183	202
Volatile Solids	3,915	12,668	6,593	13,686	15,064
BOD5	946	3,061	1,593	3,308	3,640
COD	4,421	14,306	7,445	15,456	17,011
Zinc	1	5	2	5	5
Copper	1	1	0	1	1

TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.

Table 12-5. Annual Poultry Feedlot Runoff Loading

Item	Central	Mid Atlantic	Midwest	Pacific	South
Annual Runoff (ft^3)	34,424	111,399	57,977	120,344	132,467
Solids	516	1,671	870	1,805	1,987
TKN	173	559	291	604	665
Phosphorus	47	151	79	163	180
Volatile Solids	3,659	11,848	6,162	12,792	14,079
BOD5	---	---	---	---	---
COD	3,964	12,827	6,676	13,858	15,253
Zinc	1	2	1	2	2
Copper	<1	1	<1	1	1

TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.

12.2 Land Application Field Runoff Loads

Nutrient, metal, and pathogen loading to surface water was estimated for beef, dairy, poultry, and swine operations with more than 300 animal units. Loads prior to implementing the proposed regulatory options (baseline loads) were compared with loads after implementation (post-regulation loads). See Chapter 5 of this document for details on the regulatory options under consideration. Estimation of nutrient, pathogen, and metal loads on a national scale required representative facility conditions to simulate loads. These facility conditions consist of animal groupings of various size classes, current management practices and animal waste management systems, and regionally based physiographic information regarding soil, rainfall, hydrology, crop rotation, and other factors for a given region of the country. Although based on model facilities from the Cost Model Documentation, Sample Farms contain more detailed information on the physiographic information. These representative Sample Farms were developed from several data sources shown in Figure 12-1. Figure 12-1 illustrates the general scope of the types of data used to develop the Sample Farms and the scale of these data sources.

Simulations were conducted using representative Sample Farm information on manure pollutant generation and the cropping system specific to animal operations as they exist under pre-regulation and post-regulation model simulation conditions. Pre-regulation (baseline) Sample Farm conditions are the current management practices in use across the Nation. Pre-regulation model facility simulations assume that all manure was applied to baseline cropland acreage (which included owned and rented acres), with additional acreage receiving commercial fertilizer.

Post-regulation Sample Farm conditions generally affect the distribution of manure on cropland acres and include land-applying manure based on agronomic requirements. Application of manure on an agronomic nitrogen basis generally results in an over application of phosphorus. Application of manure on an agronomic phosphorus basis results in a deficit of nitrogen. Under P-based conditions, supplemental commercial nitrogen fertilizer was applied to fulfill crop requirements.

12.2.1 Industry Characterization

Several sources of data were used to characterize facilities throughout the U.S. The locations of the Sample Farms were selected after an analysis of the 1997 Census of Agriculture (USDA NASS, 1999a). Animal sector-specific determinations were made to select the state with the

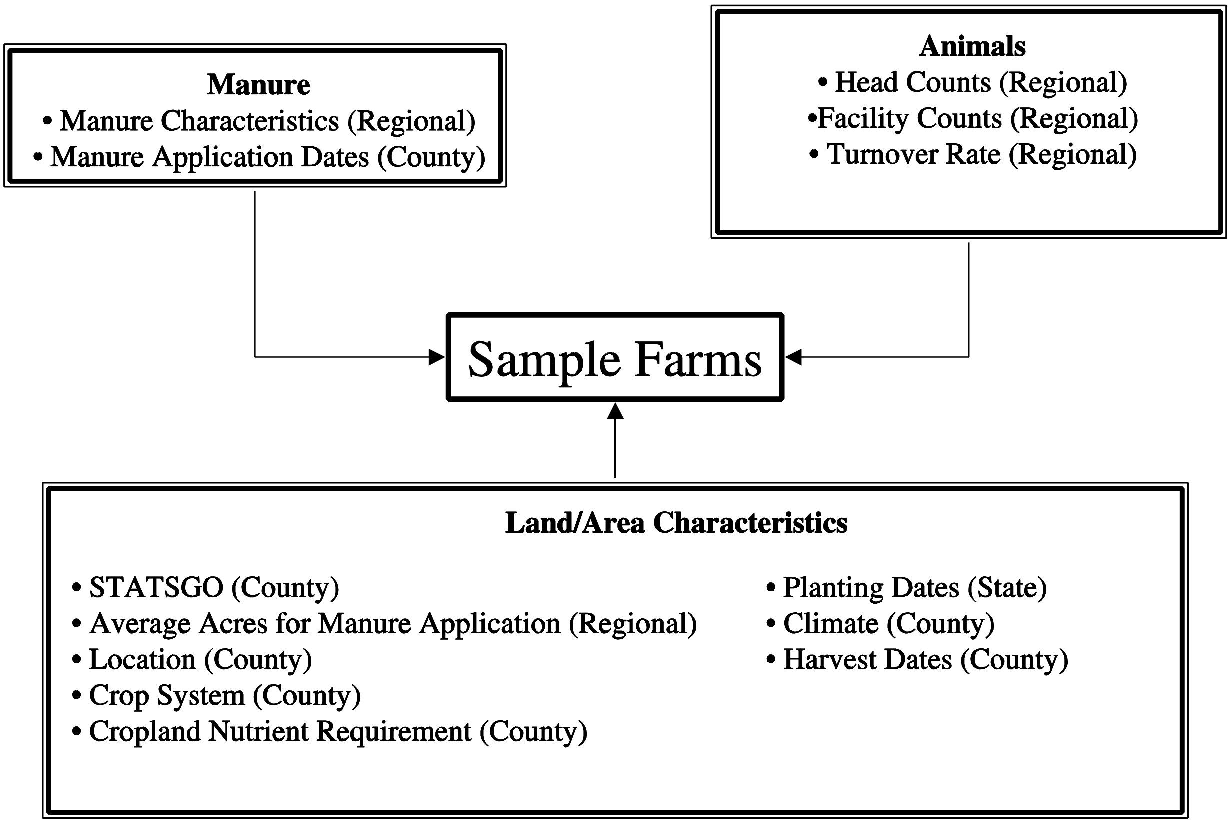


Figure 12-1. Data Used to Develop Sample Farms and the Scale of the Data Sources

largest amount of production in a given AFO region. Once this state determination was made, the county within this state with the largest amount of production was selected as the model facility location. Figure 12-2 presents the counties selected to represent the model facility for each sector and region.

Head counts on model facilities are based on queries of the 1997 Census of Agriculture (USDA NASS, 1999b). The number of animals (head) is important for calculating manure, nutrient, metal, and pathogen production. EPA animal units were used to report the results, and this entailed grouping certain size ranges from the 1997 Census of Agriculture queries (USDA NASS, 1999b).

The number of facilities was calculated using the queries from 1997 Census of Agriculture (USDA NASS, 1999b). The regional totals were split into facilities which have enough land to apply manure (Category 1 facilities), facilities that do not have enough land to apply manure (Category 2 facilities), and those facilities which have no land (Category 3 facilities). The basis for categorization was *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the U.S.* (Kellogg et al., 2000). This data source was also used to calculate the number of acres for Category 2 type facilities.

Manure production from the various animal sectors was based on an analysis performed by USDA NRCS (1998). A recoverable manure correction factor further refined the manure production figures. USDA NRCS (1998) values for nutrient content of manure were applied to the mass of manure produced. Similarly, metal and pathogen concentrations in manure as determined by the American Society of Agricultural Engineers (ASAE, 1998) were used to estimate metals and pathogens of concern produced at the sample farms. In addition, in situ soil concentrations for metals were incorporated into the analysis based on a memo from EPA (Clipper, 2000).

Typical cropping systems information was based on personal communications with state extension specialists in the counties selected to represent each model facility. Once the cropping

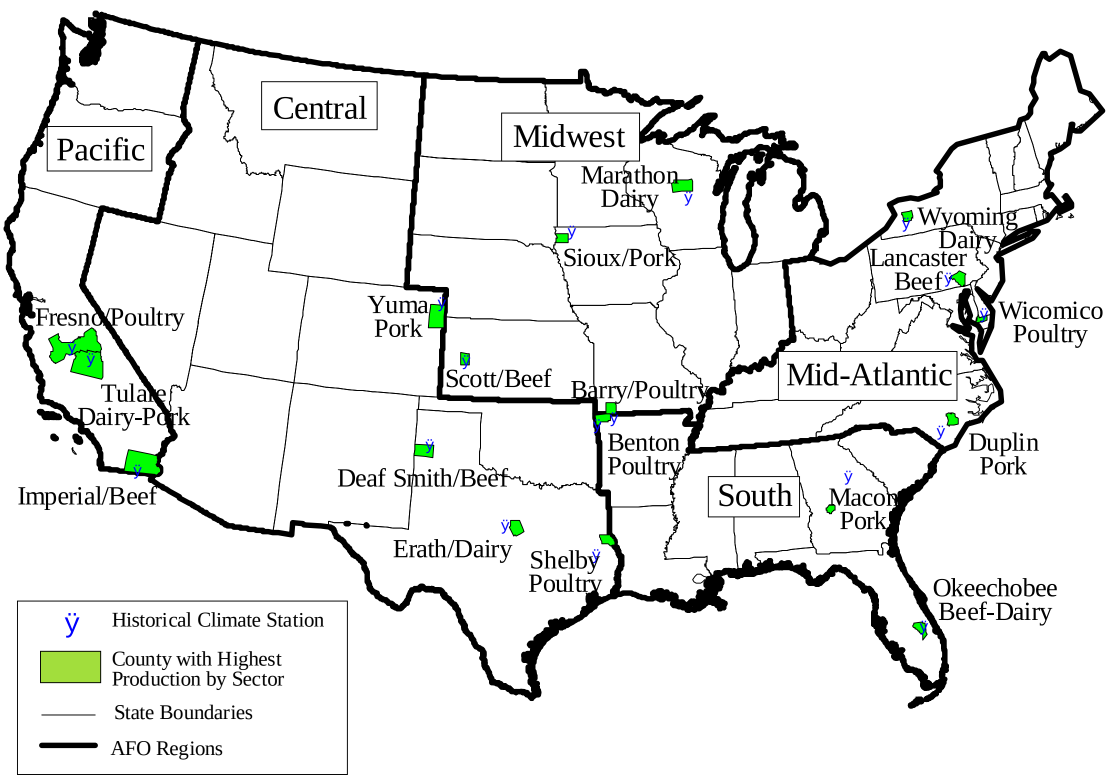


Figure 12-2. Distribution of Animal Sectors by AFO Region

systems were identified, average county yields for each of the crops were determined from the 1997 Census of Agriculture (USDA NASS, 1999a). Using common removal coefficients presented in the *Agriculture Waste Management Field Handbook* (USDA NRCS, 1996), nitrogen and phosphorus removal rates (pounds per acre) were calculated using average county yields. For nitrogen, the removal was modified according to Sutton (1985) to account for losses, mainly volatilization, after land application. The number of acres required to apply all the manure produced at Category 1 type operations was calculated by dividing the nutrient production by the removal rates.

Planting and harvesting dates for the selected crops were based on a USDA NASS (1997) report detailing typical planting and harvesting dates for U.S. field crops. Manure application dates were determined by contacting local USDA Extension agents and referring to the crop planting and harvesting data mentioned previously.

Soils information was obtained from the State Soil Geographic (STATSGO) database that is collected, stored, maintained, and distributed by the National Cooperative Service Survey under the federal leadership of the USDA's Natural Resources Conservation Service (USDA NRCS, 1999). Climate data were prepared by using the CLIGEN program, which is a synthetic climate generator that has been widely used in the Water Erosion Prediction Project (WEPP; Foster and Lane, 1987), and other sources.

12.2.2 Estimation of Sample Farm Loads

Figure 12-3 illustrates the methodology used to simulate the nutrient, pathogen, and metal model facility loads, which were subsequently extrapolated to AFO regional loads and to national pollutant loads. Because EPA's effluent limitation guidelines apply at the facility level, it was essential to use a field-scale loading estimate tool to evaluate the effect of the proposed regulation. The field-scale loading estimate tool GLEAMS (Groundwater Loading Effects of Agricultural Management Systems; Knisel et al., 1993) was selected to model edge-of-field pollutant loads in surface runoff, sediment, and ground water leaching from the sample farms.

The GLEAMS model is a field-scale, physically based continuous model that evaluates the effects of various agricultural management systems on the movement of water, soil, and agricultural pollutants to water sources. GLEAMS estimates runoff and erosion using a modified Universal Soil Loss Equation (USLE). Enhancements to the USLE allow the model to simulate daily loads to reflect manure application, plant growth stage, and changes in the hydrologic cycle that vary from day to day.

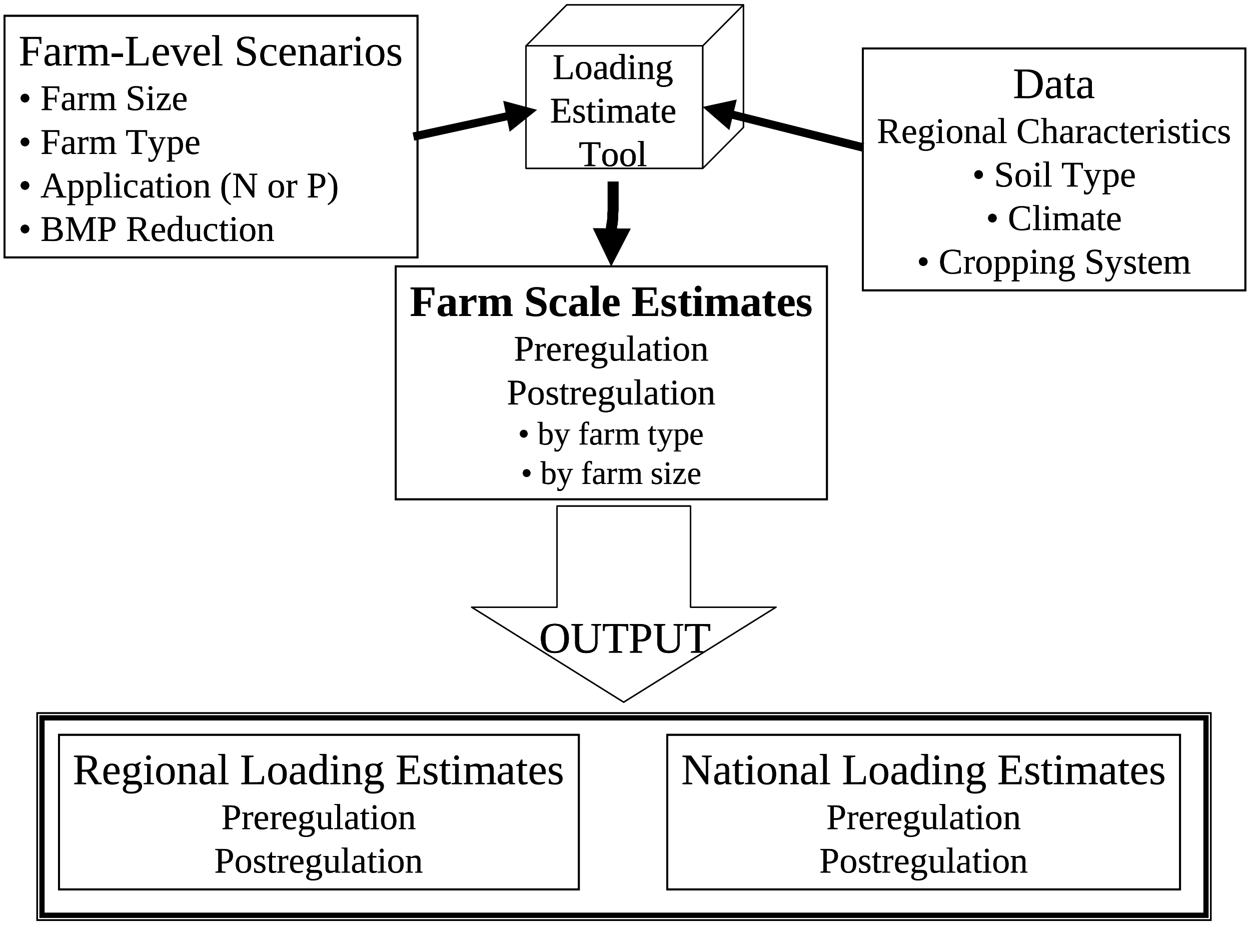


Figure 12-3. Overview of Methodology Used to Estimate Nutrient, Pathogen, and Metal Loads

12.2.3 Evaluation of Modeling Results

GLEAMS model simulations for the five AFO regions were performed for a 50-year period. Fifty years was selected to normalize results for natural variations in climate and to allow the model to equilibrate. The result of the time series is an estimate of the annual pollutant loading from runoff, erosion, and ground water leaching. Results from the second half of the 50-year period of simulated results were averaged and provided as model output. The output was compared with nutrient, metal, and pathogen loads found throughout the literature. In general, simulated results of pollutant loads were within the range of loads presented in the literature.

12.2.4 Results of the National Loading Analysis

The GLEAMS model provides edge-of-field loads in terms of pounds per acre. These rates were converted to total edge-of-field loads by multiplying them by the number of acres on each model facility. The total facility pollutant load was multiplied by the number of facilities specific to the given region, size, and sector to obtain regional pollutant loads. These regional pollutant loads were summed to obtain the national pollutant load.

The selected size classes for national nutrient loads are facilities with 300 to 500 animal units, 500 to 1,000 animal units, and more than 1,000 animal units. Additional size classes were used in the simulations, and these were grouped to produce results for the desired size classes. Nutrient loading results for the three size classes are presented in Table 12-6 for pre- and post-regulation options (see section 2 for option details). Table 12-7 presents metal and pathogen loads for facilities with 300 to 500 animal units, 500 to 1,000 animal units, and more than 1,000 animal units.

Table 12-6. Nutrient Loads (and Percentage Reduction Over Baseline) for Pre- and Post-Regulation Conditions

Size and Option	Surface Nitrogen		Surface Phosphorus	
300 to 500 AU	------------------------ pounds per year ---------------------------			
Baseline	57,060,885		101,862,258	
Option 1	39,819,463	(30.22)	48,264,373	(52.62)
Option 2	30,202,675	(47.07)	29,847,511	(70.70)
Option 3/4	30,202,675	(47.07)	29,847,511	(70.70)
Option 5	30,202,675	(47.07)	29,847,511	(70.70)
500 to 1,000 AU				
Baseline	105,117,967		194,875,167	
Option 1	75,404,509	(28.27)	81,025,690	(58.42)
Option 2	54,778,644	(47.89)	50,076,572	(74.30)
Option 3/4	54,778,644	(47.89)	50,076,572	(74.30)
Option 5	54,778,644	(47.89)	50,076,572	(74.30)
More than 1,000 AU				
Baseline	323,497,304		534,983,410	
Option 1	251,230,661	(22.34)	197,389,009	(63.11)
Option 2	175,135,392	(45.86)	117,998,827	(77.95)
Option 3/4	175,135,392	(45.86)	117,998,827	(77.95)
Option 5	175,135,392	(45.86)	117,998,827	(77.95)

Values in parentheses represent percentage reduction from baseline.
Percentage reduction = (baseline - option)/baseline.

Table 12-7. Pathogen and Metal Loads from Animal Feeding Operations

Sector	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
300-500 AU	---------- 10^{16} cfu/year[a] ----------		--- pounds per year ---					
Baseline	27,911	63,707	10,328,500	667,232	15,488	276,996	440,668	104,910
Option 1	9,011 (67.81)	51,357 (19.38)	4,888,760 (52.67)	313,775 (52.97)	2,877 (81.38)	122,161 (55.90)	226,509 (48.60)	64,821 (38.21)
Options 2-5	6,521 (76.70)	37,326 (41.41)	3,140,550 (69.59)	201,163 (69.85)	1,514 (92.53)	71,797 (74.08)	150,842 (65.77)	36,243 (65.45)
500-1000 AU								
Baseline	58,350	137,572	38,511,413	2,042,789	61,447	635,912	1,667,616	212,551
Option 1	15,557 (73.34)	75,838 (42.77)	10,870,014 (71.77)	643,227 (68.51)	5,981 (90.27)	209,875 (67.00)	519,127 (68.87)	108,416 (48.99)
Options 2-5	11,808 (79.76)	56,316 (57.50)	7,027,431 (81.75)	418,751 (79.50)	2,399 (96.10)	124,002 (80.50)	347,798 (79.14)	61,092 (71.26)
>1,000 AU								
Baseline	105,980	260,423	67,398,568	3,319,711	108,948	1,020,801	2,869,196	539,818
Option 1	32,364 (69.46)	110,828 (57.44)	20,819,432 (69.11)	1,206,740 (63.65)	14,337 (86.84)	483,173 (52.67)	980,044 (65.84)	295,561 (45.25)
Options 2-5	26,514 (74.96)	92,766 (64.38)	13,325,674 (80.23)	784,528 (76.37)	5,866 (94.62)	298,207 (70.79)	649,482 (77.36)	165,094 (69.42)

[a] cfu/year, colony forming units per year.
Values in parentheses represent percentage reduction from baseline.
Percentage reduction = (baseline - option)/baseline.

12.3 <u>Subsurface Leaching</u>

Using the modeling results described in Section 12.2, subsurface losses from land application of nitrogen were evaluated for pre- and post-regulation conditions. Additional subsurface losses of nitrogen occur from manure storage structures. Subsurface losses from the feedlot and from land application were combined.

Potentially significant loads can occur from nutrients seeping from manure storage structures. Earthen manure storage structures are integral components of many concentrated animal operations. Manure storage structures contain high concentrations of nutrients and other constituents that are applied to cropland as fertilizer, however, while solid and liquid manures are stored in the manure storage structures, pollutants can leach into ground water.

For the purposes of this analysis, it was assumed that virtually all lagoons and other storage structures leak. Most of the lagoon leakage simulations estimated ground water loads by simulating transport of pollutants through ground water aquifers. Seepage estimates were obtained from Ham and DeSutter (1999) who measured nitrogen that leaked from three established swine-waste lagoons in Kansas. In their study, lagoon walls and bottoms had either an indigenous silt loam soil that was compacted to a thickness of 12 to 18 inches or an 18-inch-thick clay liner. Their results showed that lagoon ammonium-N export loads ranged from 1,952 pounds per acre per year to 2,434 pounds per acre per year. From these results, it was assumed that 2,000 pounds per acre per year leaked from manure storage structures lined with silt loam soils. These referenced values were used to develop direct and indirect loads form manure storage structure leakage according to soil permeabilities referenced by Clapp and Hornberger (1978). The Clapp and Hornberger (1978) soil permeability rates were matched with soil types in the areas where the Sample Farms were located. Clapp and Hornberger (1978) reported that soil permeabilities range two orders of magnitude over all soil types. For example, they reported that water flowed through sand about 100 times faster than through clayey soils and about 10 times faster than through silty soils. Using this analogy of flow rates for various textures, the ammonium export estimated by Ham and DeSutter (1999) was scaled to reflect changes in soil texture for model facilities. Thus, for silt loam soils, 2,000 pounds of nitrogen per acre per year were assumed to seep out of manure storage structures; for sandy soils, 20,000 pounds of nitrogen per acre per year; and for clay soils, only 200 pounds of nitrogen per acre per year.

The values reported by Ham and DeSutter (1999) are for ammonium, which is not mobile in soils. For ammonium to mobilize, oxygen must be present to oxidize the ammonium to nitrate. Once nitrate is formed it can leach in to ground water. Because soil under lagoons generally remains wet and anaerobic, only the outer fringe of the lagoon will oxidize and leach. It was estimated that 10 percent of the ammonia-nitrogen load that seeps out of the bottom of the manure storage structure reaches ground water in the form of nitrate-nitrogen.

Sobecki and Clipper (1999) estimated the number of storage structures that had a direct link to surface water by evaluating the ground water pollution potential of AFO manure storage structures according to AFO region land characteristics. For structures with a direct ground water to surface water link, pollutant loads were assumed to directly connect with surface water, and it was assumed that no ground water aquifer pollutant assimilation took place. Consequently, for manure storage structures that had a high groundwater pollution potential under the Sobecki and Clipper (1999) analysis, once lagoon leakage occurred it was assumed that there was no pollutant reductions before the pollutant load reached surface water. Sobecki and Clipper assumed that if regional characteristics indicated there was a relatively high ground water pollution potential, these manure storage structures would leak. Some of the criteria they used to determine ground water pollution potential were the presence of sandy soils through the soil profile, the presence of a shallow ground water table, and the presence of karst or karst-like terrain. These criteria were evaluated, and percentages of land area were developed for each AFO region. The percentages were applied to each Sample Farm in an AFO region, and these percentages defined baseline levels for manure storage structure leakage to ground water sources.

Table 12-8 presents the combined subsurface nitrogen losses from the feedlot and from land application. Although phosphorus may leach to ground water, it occurs in relatively low amounts and was not included.

Table 12-8. Direct and Indirect Subsurface Nitrogen and Phosphorus Loads

Size and Option	Subsurface Nitrogen				Subsurface Phosphorus	
	Direct		Indirect		Direct	
300 to 500 AU	----------pounds per year----------					
Baseline	776,427		158,530,618		177,924	
Option 1	776,424	(0.00)	65,517,112	(58.67)	177,924	(0.00)
Option 2	776,424	(0.00)	50,783,872	(67.97)	131,844	(25.90)
Option 3/4	0	(100.00)	50,783,872	(67.97)	131,844	(25.90)
Option 5	0	(100.00)	50,107,541	(68.39)	131,844	(25.90)
500 to 1,000 AU						
Baseline	1,350,312		305,760,799		363,524	
Option 1	1,350,312	(0.00)	126,258,616	(58.71)	363,524	(0.00)
Option 2	1,350,312	(0.00)	97,262,902	(68.19)	265,685	(26.91)
Option 3/4	0	(100.00)	97,262,902	(68.19)	265,685	(26.91)
Option 5	0	(100.00)	96,328,571	(68.50)	265,685	(26.91)
>1,000 AU						
Baseline	2,669,024		1,177,131,012		1,165,286	
Option 1	2,669,024	(0.00)	537,327,332	(54.31)	1,165,286	(0.00)
Option 2	2,669,024	(0.00)	362,770,757	(69.16)	815,258	(30.04)
Option 3/4	0	(100.00)	362,770,757	(69.16)	815,258	(30.04)
Option 5	0	(100.00)	356,921,180	(69.70)	815,258	(30.04)

12.4 Volatilization and Deposition

This analysis considered nutrients and metals that reach the air and are redeposited by rain on the land or directly in to surface water. Pollutants that reach the air either through volatilization or in dust will drift. All nutrients reaching the air were assumed to be eventually redeposited. The pollutant load that reaches surface water was calculated based on the surface area covered by water and the percentage of runoff. Table 12-9 shows the regional coefficients used to calculate loads from atmospheric deposition. The areal percentages of water and land were determined based on 1997 NRI data for each state. States were grouped by region and summed. The relative percentages of water range from 1.3 percent to over 5 percent depending on region. Runoff estimates were based on USGS coverages containing average annual runoff and rainfall. For example, in the southern region rainfall rates generally range from 40 to 60 inches annually, with runoff ranging from 14 to 26 inches annually. The amount of runoff was divided by the rainfall (for the southern region, 50 inches was assumed) to obtain runoff percentages from 28 percent (low) to 52 percent (high).

Nitrogen volatilization from the feedlot area was calculated based on USDA values reported by USDA NRCS (1998). The difference in "as excreted" and "after losses" values for nitrogen was used to calculate the amount of volatilization. Nitrogen volatilization after land application of manure was calculated using the GLEAMS version 2.10 (Knisel et al., 1993). The GLEAMS model takes into account common agricultural practices, and it was run for each model facility. Sulfur volatilization was calculated based on a report by Zhang et al. (1990). In their paper, they suggest sulfide emissions from swine slurry of approximately 1.5 mg S per liter manure. Thus, the manure volume was calculated and converted to pounds of sulfide per year. Little information exists on net loading of sulfur from lagoons or drier manure, and the values presented here should be used cautiously.

The remaining sources of pollutants were estimated from dust produced by the feedlot. Again, little information exists on dust production. It was assumed that 0.001 percent of manure is lost as dust. This production value probably overestimates the indirect loads from these sources. The concentrations of metals in the manure dust were assumed to be the same as those in the manure. Metal concentrations were calculated based on the ASAE standards handbook (1998).

Table 12-9. Percentages of Land and Water Areas and Runoff for Five Regions under Consideration

Region	Water*	Land*	Runoff (low)†	Runoff (high)†
Central	1.3%	98.7%	25.0%	50.0%
Mid Atlantic	5.3%	94.7%	24.0%	44.0%
Midwest	2.3%	97.7%	17.0%	47.0%
Pacific	2.1%	97.9%	27.0%	50.0%
South	5.2%	94.8%	28.0%	52.0%

* Data from 1997 NRI report.
† USGS Arc/View coverages.

Table 12-10 presents loads from atmospheric deposition.

Table 12-10. Annual Indirect Pollutant Loads to Surface Waters from Animal Feeding Operations With More Than 300 Animal Units

Pollutant (source)	Lower Estimate	Higher Estimate
	pounds to surface water annually	
Nitrogen (volatilization from feedlot)	755,028,602	1,539,710,650
Nitrogen (volatilization from land application)	456,566,444	878,949,831
Nitrogen (dust)	6,133	12,132
Phosphorus (dust)	3,291	6,658
Sulfur (volatilization from feedlot)	10,143,898	20,177,030
Zinc (dust)	51	103
Copper (dust)	10	21
Cadmium (dust)	0	0
Nickel (dust)	9	18
Lead (dust)	3	6
Arsenic (dust)	273	516

12.5 References

ASAE. 1998. *ASAE Standards 1998.* 45th edition. American Society of Agricultural Engineers, St. Joseph, Michigan.

Clapp, R.B., and G.M. Hornberger. 1978. Empirical equations for some hydraulic properties. *Water Resources Research* 14:601-604.

Clipper, M. 2000. National background concentrations of pollutants in U.S. soil. Facsimile table on February 14, 2000.

Foster, G.R., and L.J. Lane. 1987. *User requirements USDA-Water Erosion Prediction Project (WEPP).* NSERL Report No. 1. National Soil Erosion Research Laboratory, West Lafayette, Indiana.

Ham, J.M. and T.M. DeSutter. 1999. Seepage losses and nitrogen export from swine-waste lagoons: A water balance study. *Journal of Environmental Quality* 28:1090-1099.

Kellogg, R.L., C.H. Lander, D. Moffitt, and N. Gollehon. 2000. *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal*

Trends for the U.S. United States Department of Agriculture Natural Resources Conservation Service, Washington, DC.

Knisel, W.G., F.M. Davis, R.A. Leonard, and A.D. Nicks. 1993. *GLEAMS: Groundwater Loading Effects of Agricultural Management Systems*, Version 2.10.

MWPS. 1987. Structures and Environment Handbook. Eleventh Edition. Midwest Plan Service, Iowa State University, Ames, Iowa.

MWPS. 1993. *Livestock Waste Facilities Handbook*, MWPS-18. Midwest Plan Service, Iowa State University, Ames, Iowa.

Sobecki, T.M., and M. Clipper. 1999. Identification of acreage of U.S. agricultural land with a significant potential for siting of animal waste facilities and associated limitations from potential of ground water contamination DRAFT 12/15/99, U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USDA NASS. 1997. *Usual Planting and Harvesting Dates for U.S Field Crops.* Agricultural Handbook Number 628. U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

USDA NASS. 1999a. *1997 Census of Agriculture*. U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

USDA NASS. 1999b. Queries run for EPA on the 1997 Census of Agriculture. U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

USDA NRCS. 1996. *National Engineering Handbook: Agricultural Waste Management Field Handbook.* U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia.

USDA NRCS. 1998. *Nutrients available from livestock manure relative to crop growth requirements*, United States Department of Agriculture Natural Resources Conservation Service, Washington, DC.

USDS NRCS. 1999. State Soil Geographic (STATSGO) Data Base. U.S. Department of Agriculture, National Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska.

Zhang, R.H., D.L. Day, and K. Ishibashi. 1990. Generation and transport of gases in and out of liquid swine manure in under-floor pits. In *Proceedings of the Sixth International Symposium on Agricultural and Food Processing Wastes*, American Society of Agricultural Engineers, December 17-18, 1990. Chicago, Illinois.

CHAPTER 13

NON-WATER QUALITY IMPACTS

13.0 INTRODUCTION

The elimination or reduction of one form of pollution may create or aggravate other environmental problems. Sections 304(b) and 306 of the Clean Water Act (CWA) require that the U.S. Environmental Protection Agency (EPA) consider the non-water quality environmental impacts (NWQI) of effluent limitations guidelines and standards. This section presents the methodology and estimates of the NWQI for the seven Best Available Technology (BAT) regulatory options that are being considered for beef, heifer, dairy, veal, swine, and poultry (including broiler, layer, and turkey) feeding operations. These non-water quality environmental impacts include:

- Air emissions from the feedlot operation, including animal housing and animal waste storage and treatment areas;
- Air emissions from land application activities;
- Air emissions from vehicles, including those involved in off-site transport of waste and on-site composting operations; and
- Energy impacts from land application activities and the use of digesters.

Typically, NWQIs also include the generation of solid waste. Under the effluent limitations guidelines being considered, the handling of the manure by-product is affected in order to control the wastewater that is generated from animal feeding operations. Because the manure is considered a by-product of animal feeding operations and is not regulated directly, the solid waste NWQIs of the manure are not considered. In addition, although the chemical content of the manure may change, the amount of manure generated is not expected to change under any of the regulatory options being considered; therefore, a discussion of solid waste NWQIs is not included in this section. Also not addressed in this section are the benefits of water reuse/reduction that are obtained under some options; for example, under Option 5B swine and wet layers convert to dry housing, which reduces the amount of fresh water used as flush water.

The remainder of this section contains the following information:

- Section 13.1 presents an overview of the analysis and pollutants;

- Section 13.2 discusses the methodology for air emissions from animal confinement operations;

- Section 13.3 discusses the methodology for air emissions from land application activities;

- Section 13.4 discusses the methodology for air emissions from vehicles;

- Section 13.5 discusses the methodology for energy impacts;

- Section 13.6 provides a summary of the industry-wide non-water quality impacts for two regulatory thresholds considered by EPA; and

- Section 13.7 provides a list of references used in this section.

This section presents results based on available data and methodologies developed as of November 2000. A more detailed description of the analysis is provided in the Non-Water Quality Impact Report (ERG, 2000). EPA's Office of Air Quality Planning and Standards is currently conducting an in-depth study of air emissions from animal feeding operations and is expected to publish results in early 2001.

13.1 Overview of Analysis and Pollutants

Figure 13-1 identifies the pollutants that are included in the air emission analyses for the animal housing areas, the animal waste treatment and storage areas, off-site transportation of the wastes, and land application of the wastes. The pollutants included in this analysis are:

- Ammonia. Nitrogen is the primary component of animal waste that is most likely to generate air emissions. There are many different forms of nitrogen (i.e., ammonia, nitrous oxide, nitric oxide, nitrogen gas, organic nitrogen, ammonium, nitrite, nitrate) that are created during various stages of nitrogen's life cycle. Figure 13-2 depicts the basic nitrogen cycle, which consists of mineralization (organic nitrogen to ammonium), nitrification (ammonium to nitrite and nitrate), denitrification (nitrate to nitrous oxide, nitric oxide, and nitrogen gas), immobilization (ammonium and nitrate to organic nitrogen), and volatilization (urea and ammonium to ammonia).

  Ammonia is the form of nitrogen that is most readily emitted to the atmosphere from animal wastes. The major source of ammonia in animal manure is urea from urine, or uric acid in the case of poultry, which easily converts to ammonia. Urea plus ammonia nitrogen from urine usually accounts for 40 to 50 percent of the total nitrogen excreted in manure (Van Horn et al., 1994). In aqueous solution, ammonia reacts with acid to form ammonium, which is not gaseous. The chemical equilibrium in an acid environment promotes rapid conversion of ammonia to ammonium with little release of ammonia to the atmosphere. Because most animal manures, lagoons, and feedlot surfaces have a pH greater than 7.0 (i.e., a non-acidic

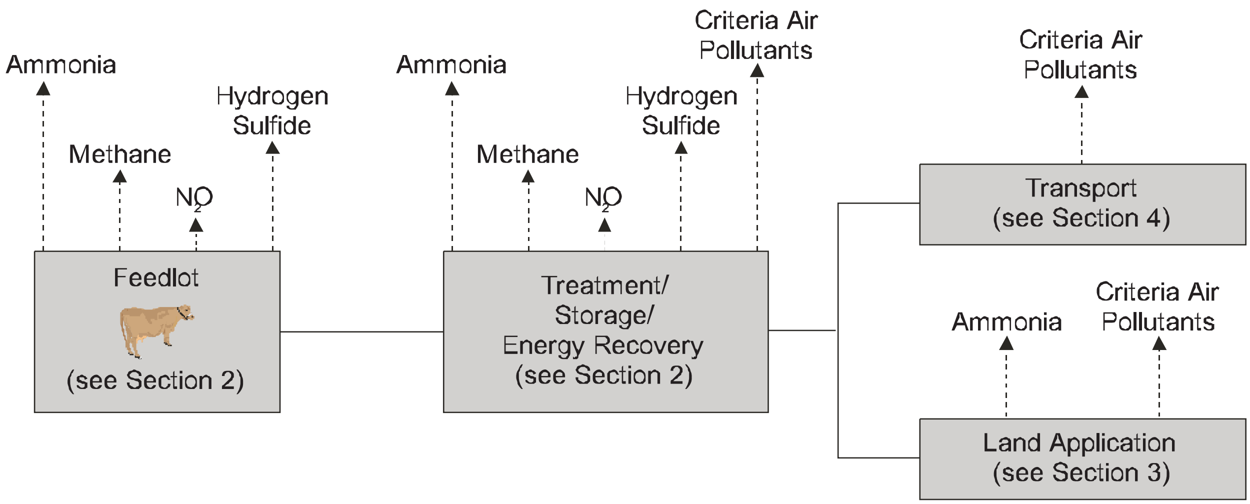


Figure 13-1. Air Emissions from Animal Feeding Operations

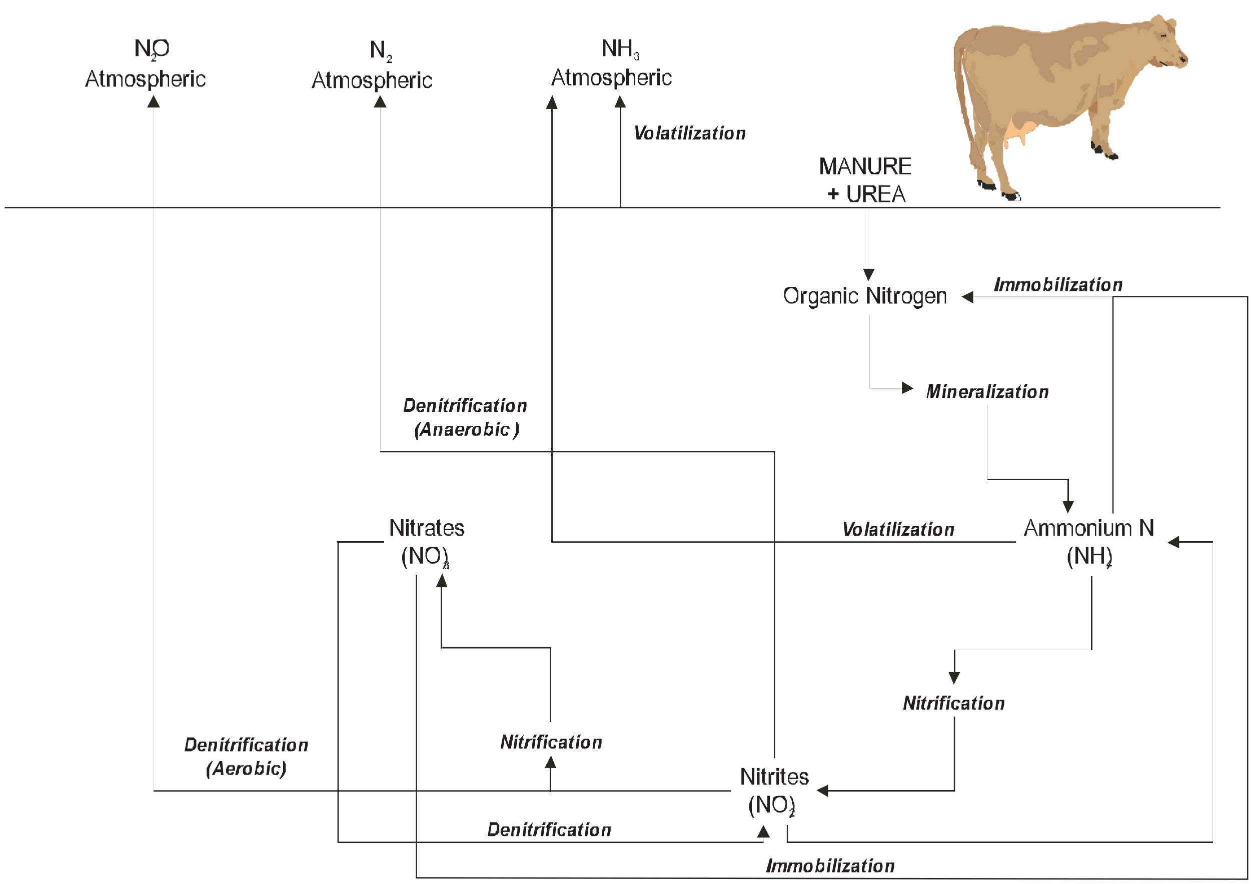


Figure 13-2. Basic Nitrogen Cycle

environment), rapid loss of ammonia to the atmosphere occurs. As a consequence, nitrogen losses from animal manures, as ammonia, can easily exceed 50 percent (Van Horn et al., 1994).

- Nitrous oxide. Most nitrous oxide from agriculture is produced in the soil during nitrification and denitrification. Both processes are carried out by bacteria living in the soil. Research indicates that aerobic manure storage, such as composting, produces more nitrous oxide than anaerobic storage, such as lagoons (AAF Canada, 2000). In general, manure that is handled as a liquid tends to produce less nitrous oxide than manure that is handled as a solid. The quantity of nitrous oxide generated, however, is typically small and varies significantly depending on environmental conditions, such as pH.

- Methane. With respect to livestock emissions, methane is produced during the normal digestive processes of animals and the decomposition of animal manure. This analysis assesses only the amount of methane produced during decomposition of animal manure. Livestock manure is principally composed of organic material. When this organic material decomposes in an anaerobic environment, methanogenic bacteria, as part of an interrelated population of microorganisms, produce methane. The principal factors affecting methane emission from animal manure are the methane-producing potential of the waste and the portion of the manure that decomposes anaerobically. The portion of manure that decomposes anaerobically depends on how the manure is managed. When manure is stored or treated as a liquid (e.g., lagoons, ponds, tanks, or pits), it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid (e.g., in stacks or pits) or when it is deposited on pastures and rangelands, it tends to decompose aerobically and little or no methane is produced (IPCC, 2000).

- Carbon dioxide. Carbon dioxide is an end product of animal respiration and the microbial degradation of animal manure under aerobic and anaerobic conditions. Note, however, that this analysis did not consider carbon dioxide emissions from animal respiration. As with methane emissions, wastes stored as a liquid produce more carbon dioxide than wastes stored as a solid. Carbon dioxide emissions can also occur from the combustion of biogas from anaerobic digesters used to recover energy.

- Hydrogen sulfide. The formation and subsequent emission of hydrogen sulfide from animal manure occurs only under anaerobic conditions and is the result of the mineralization of organic sulfur compounds and the reduction of the more oxidized inorganic forms of sulfur, including sulfites and sulfates. In animal manures, the principal organic sulfur compounds are the sulfur amino acids, and the principal sources of inorganic sulfur are minerals, such as copper and zinc, that are added to diets to correct nutritional deficiencies or to serve as growth stimulants. High concentrations of hydrogen sulfide can be released by agitation and pumping of liquid wastes. Although only small amounts of hydrogen sulfide are produced in a manure tank compared with the other major gases, this gas is heavier than air and becomes more concentrated in the tank over time. Research has determined that hydrogen sulfide production from animal feeding operations depends on the average outside air temperature, the size of the housing or waste management areas, the air retention time in the housing areas, and the daily sulfur intake of the animals.

- Criteria air pollutants. Animal feeding operations that transport their manure off site and/or compost their manure on site use equipment (e.g., trucks, tractors) that releases criteria air pollutants when operated. Criteria air pollutants are also released when biogas, generated from energy recovery systems for anaerobic digesters, is used for fuel (e.g., in an engine or flared). The criteria air pollutants included in this analysis are volatile organic compounds, nitrogen oxides, particulate matter, and carbon monoxide.

Where possible, the NWQI estimates for each regulatory option are presented in relation to the baseline conditions under which animal feeding operations generate air emissions and use energy (i.e., prior to implementation of a regulatory option). In some cases, however, there is insufficient data to quantify baseline NWQI; in these cases, the impacts presented in this section reflect only the change in impacts expected to result from implementation of the regulatory options.

13.2 Air Emissions from Animal Feeding Operations

Animal feeding operations generate various types of animal wastes, including manure (feces and urine), waste feed, water, bedding, dust, and wastewater. Air emissions are generated from the decomposition of the wastes from the point of generation through the management and treatment of these wastes on site. The rate at which emissions are generated varies as a result of a number of operational variables (e.g., animal species, type of housing, waste management system) and weather conditions (e.g., temperature, humidity, wind, time of release).

Air releases occurring from animal confinement areas and manure management systems have been evaluated under baseline conditions and seven regulatory options considered by EPA. The data on these releases is insufficient for a complete analysis of all possible compounds; therefore, this analysis has focused on the release of greenhouse gases (methane, carbon dioxide, and nitrous oxide) from animal confinement and waste management systems, ammonia and hydrogen sulfide from animal confinement and waste management systems, and certain criteria air pollutants (carbon monoxide, nitrogen oxides, volatile organic compounds, and particulate matter) from energy recovery systems.

This section presents the methodology and results for the following air emission calculations from the animal feeding operation:

- Section 13.2.1 - Greenhouse gases from animal confinement and waste management systems;

- Section 13.2.2 - Ammonia and hydrogen sulfide from animal confinement and waste management systems; and

- Section 13.2.3 - Criteria air pollutants from energy recovery systems.

A detailed description of the data inputs and equations used to calculate these air emissions is provided in the Non-Water Quality Impact Report (ERG, 2000).

13.2.1 Greenhouse Gas Emissions from Manure Management Systems

Manure management systems, including animal confinement areas, produce methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) emissions. Methane production is directly related to the quantity and quality of waste, the type of waste management system used, and the temperature and moisture of the waste (USEPA, 1992). In general, manure that is handled in a manner that promotes anaerobic conditions will produce more methane, while manure that is handled in aerobic management systems produces little methane. Certain animal populations, such as beef cattle on feedlots, may produce more methane if they are fed higher energy diets.

Certain regulatory options evaluated for animal feeding operations are based on the use of different waste management systems that may increase or decrease methane emissions from animal operations. Methane is also produced from the digestive processes of ruminant livestock as a result of enteric fermentation. Because the proposed regulatory options do not establish requirements dictating specific feeding strategies that affect diet, the effect on enteric fermentation methane emissions is difficult to predict and is not discussed further.

Carbon dioxide is a naturally occurring greenhouse gas and is continually emitted into and removed from the atmosphere. Certain human activities, such as fossil fuel burning, result in the release of additional quantities of carbon dioxide into the atmosphere. In animal feeding operations, the anaerobic degradation of manure generates methane and carbon dioxide emissions. In addition, certain regulatory options among those evaluated involve the use of lagoon covers to capture biogas for energy recovery or flaring. The combustion process from these options also produces carbon dioxide (while destroying methane).

Nitrous oxide is produced as part of the nitrogen cycle through the nitrification and denitrification of the organic nitrogen in livestock manure and urine. The emission of nitrous oxide from manure management systems is a function of the nitrogen content of the manure, as well as the length of time the manure is stored and the specific type of system used. In general, the amount of nitrous oxide emitted from manure management systems tends to be small because conditions are often not suitable for nitrification to occur; however, when nitrous oxide is generated, manure that is handled as a liquid tends to produce less nitrous oxide than manure that is handled as a solid. Certain regulatory options evaluated for animal feeding operations are based on the use of different waste management systems which may increase nitrous oxide emissions from animal operations.

The methane and nitrous oxide emissions presented in this section are based on the guidance developed for international reporting of greenhouse gas emissions (IPCC, 2000) and used by EPA's Office of Air and Radiation. Emission estimates for carbon dioxide are based on the relationship of carbon dioxide generation compared with methane generation.

13.2.2 Ammonia and Hydrogen Sulfide Emissions From Animal Confinement Areas and Manure Management Systems

Nitrogen is the primary component of animal waste that is most likely to generate air emissions. Total nitrogen is comprised of organic nitrogen, ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3). The primary source of nitrogen emissions from animal feeding operations to the atmosphere occurs as ammonia.

The major source of ammonia in animal manure is urea from urine, or uric acid in the case of poultry, which easily converts to ammonia. Urea plus ammonia N from urine usually accounts for 40 to 50 percent of the total N excreted in manure (Van Horn et al., 1994). In aqueous solution, ammonia reacts with acid (H^+) to form the ion ammonium (NH_4^+), which is not gaseous. The chemical equilibrium in an acid environment promotes rapid conversion of ammonia to ammonium with little loss of ammonia to the atmosphere. Most animal manures, lagoons, and feedlot surfaces have a pH greater than 7.0 (i.e., non-acidic), which permits rapid loss of ammonia to the atmosphere. As a consequence, nitrogen emissions from animal manure, as ammonia, can easily exceed 50 percent (Van Horn et al., 1994). For the purposes of this analysis, emissions of ammonia are quantified for the animal confinement and manure management areas.

Hydrogen sulfide is produced by anaerobic decomposition of organic wastes such as animal manure. High concentrations can be released by agitation and pumping of liquid wastes. Although only small amounts of hydrogen sulfide are produced in a manure tank compared with the other major gases, this gas is heavier than air and becomes more concentrated in the tank over time. Research has determined that hydrogen sulfide production from animal feeding operations depends on the average outside air temperature, the size of the housing or waste management areas, the air retention time in the housing areas, and the daily sulfur intake of the animals.

Livestock may be confined in a number of different ways that impact the type and amount of ammonia emissions. Some animals are housed in traditional confined housing (e.g., tie stall barns, freestall barns), while others are confined in outdoor areas (e.g., drylots, paddocks). Studies have shown that the type of confinement used has a great effect on the emission of ammonia (Jacobson et al., 2000). Management of waste within the confinement area (e.g., litter system, deep pit, freestall) also influences emissions.

Anaerobic lagoons and waste storage ponds are major components of the waste management systems at many animal feeding operations. These systems rely on microbes that biodegrade organic nitrogen to ammonium (NH_4^+) and ammonia (NH_3). The ammonia continuously volatilizes from the surface of lagoons and ponds. The high sulfur content of swine waste also results in hydrogen sulfide emissions from lagoons and ponds.

Under Option 6, wastewater is treated in an anaerobic digester before being released into a secondary storage lagoon. There is typically little to no ammonia gas present in digester gas collected for energy recovery. According to Jewell et al., (1997) the total nitrogen in the waste stream entering the digester equals the total nitrogen in the treated effluent (exiting the digester and entering the secondary storage lagoon); thus, it is assumed that the quantity of ammonia entering the secondary storage lagoon is the same as that entering the primary lagoon for the other options; therefore, the same nitrogen oxides emissions are generated under Option 6 as are generated under the other options, except Option 7.

Under Options 3 and 4, solid wastes are stored on impermeable pads (e.g., concrete pads). Although concrete pads have negligible leachate, the volatilization potential remains almost the same as for a stockpile; therefore, for a specific region, the percentage of ammonia that volatilizes from stockpiles and concrete pads is the same. The negligible leachate from concrete pads results in a slightly higher nitrogen content of waste for land application. The percentage of nitrogen emitted through volatilization from concrete pads and stockpiles depends primarily on the region in which the facility is located.

13.2.3 Criteria Air Emissions From Energy Recovery Systems

Criteria air pollutants are those pollutants for which a national ambient air quality standard has been set. The criteria pollutants evaluated as non-water quality impacts include volatile organic carbons (VOCs) and oxides of nitrogen (NO_x) (precursors to ozone), particulate matter (PM), and carbon monoxide (CO). These criteria pollutants are formed from the transport of waste, operation of compost equipment, and combustion of biogas.

Criteria pollutant air emissions from energy recovery systems are expected only under Option 6. Option 6 is based on the implementation of anaerobic digester systems with energy recovery for the largest swine and dairy operations. The operation of the digester system greatly reduces the emission of methane through the capture of the biogas; however, the use of the biogas in an energy recovery system does generate certain criteria air pollutants when the recovered biogas is burned for fuel.

13.3 Air Emissions from Land Application Activities

The application of animal waste from animal feeding operations on cropland generates air emissions. The emissions result primarily from the volatilization of ammonia at the point the material is applied to land (Anderson, 1994). Additional emissions of nitrous oxide are released from farmlands when nitrogen applied to the soil undergoes nitrification and denitrification. Loss through denitrification is dependent on the oxygen levels of the soil to which manure is applied. Low oxygen levels, resulting from wet, compacted, or warm soil, increase the amount of nitrate-nitrogen released into the air as nitrogen gas or nitrous oxide (OSUE, 2000). A study by Sharpe et. al., which compared losses of ammonia and nitrous oxide from sprinkler irrigation of swine effluent, concluded that ammonia emissions made the larger contribution to airborne nitrogen losses (Sharpe and Harper, 1997). The analysis of air emissions from land application activities is focused on the volatilization of nitrogen as ammonia because the emission of other constituents is expected to be less significant.

The amount of nitrogen released into the environment from the application of animal waste is affected by the rate and method by which it is applied, the quantity of material applied, and site-specific factors such as air temperature, wind speed, and soil pH. There is insufficient data to quantify the effect of site-specific factors; therefore, they are not addressed in this section.

The non-water quality impact analysis evaluated the effects of application rates and methods on air emissions, as well as the quantity of animal waste and commercial nitrogen applied to cropland. A detailed description of the data inputs and equations used to calculate these air emissions is provided in the Non-Water Quality Impact Report (ERG, 2000).

13.4 Air Emissions From Vehicles

Animal feeding operations that transport their manure off site and/or compost their manure on site use equipment (e.g., trucks, tractors) that releases criteria air pollutants when operated. The NWQI analysis evaluated the increased criteria air pollutant emissions from off-site transportation and composting of manure at animal feeding operations. A detailed description of the data inputs and equations used to calculate these air emissions is provided in the Non-Water Quality Impact Report (ERG, 2000).

Criteria air emissions from the off-site transportation of animal manure are evaluated for each of the regulatory options considered by EPA, as all options will result in an increase of off-site transportation of manure at some operations.

Two different waste transportation options are analyzed. One considers the cost of purchasing trucks to transport waste, and the other option evaluates the cost of paying a contractor to haul the waste off site. Because of the different methods used to estimate the costs of the two transportation options, two methods are used to calculate air emissions. Estimates of air emissions from operations purchasing waste transportation vehicles are based on the cost model calculations of the number of trucks purchased and the annual number of miles traveled. Estimates of contract hauling emissions are based on the cost model calculations of the annual amount of waste generated, the annual number of miles traveled, and truck sizes.

Farm equipment used in on-site composting also affects generation of air emissions. Composting of waste results in a reduction in transportation air emissions if there is a reduction in the volume or weight of material composted. Option 5 for beef and dairy is based on all operations composting their waste; therefore, criteria air emissions from on-site composting of manure are shown only for beef and dairy Option 5.

13.5 Energy Impacts

Certain regulatory options evaluated for animal feeding operations entail the use of different waste management systems and land application practices which may increase energy usage. Energy impacts related to land application, digesters, and hog high-rise housing are evaluated under baseline conditions and under the seven regulatory options considered by EPA. A detailed description of the data inputs and equations used to calculate these impacts is provided in the Non-Water Quality Impact Report (ERG, 2000).

The proposed regulatory options assume that all beef and dairy animal feeding operations that have cropland apply their manure and wastewater using agronomic application rates; therefore, the manure application rates are calculated to be no greater than the nutrient uptake requirements of the crops grown in the fields on which the manure is applied. In many instances, facilities have to limit the amount of manure applied to the land, which may result in decreased on-site energy usage; however, an equivalent amount of energy is expended elsewhere because, if there is not enough land to apply on site, the manure and wastewater are applied off site.

Option 6 includes the use of anaerobic digesters with energy recovery to manage animal waste for the largest dairy and swine operations. Digesters require a continuous input of energy to operate the holding tank mixer and an engine to convert captured methane into energy. The energy required to continuously operate these devices and the amount of energy generated by the system have been determined from the *FarmWare* model, which is used in the cost model.

Option 5B is based on the conversion of all flush swine systems to non-flush (e.g., hog high-rise systems). Additional energy is required in the hog high-rise to operate the fans and blowers.

13.6 Industry-Level NWQI Estimates

This section provides a summary of the industry-level NWQI estimates for each of the regulatory options under the two applicability thresholds being proposed.

13.6.1 Summary of Air Emissions for Beef and Dairy Subcategories

Tables 13-1 and 13-2 present estimates for Threshold 1 and Tables 13-7 and 13-8 present estimates for Threshold 2.

Option 1

Emissions of methane and carbon dioxide from beef and dairy operations decrease under Option 1 due to the added step of solids separation in the waste management system. The separated solids are stockpiled rather than held in waste storage ponds or anaerobic lagoons. Using this drier method of handling the waste, anaerobic conditions and the potential for the volatile solids to convert to methane decrease. This method also results in the conversion of more nitrogen to nitrous oxide; thus, nitrous oxide emissions from dairies increase.

No changes in losses of ammonia are associated with confinement areas. Because less manure nitrogen is applied under this option, on-site emissions of ammonia generally decrease.

Option 1 is based on the application of animal waste to cropland at agronomic rates for nitrogen. Animal feeding operations that have excess nitrogen for their crops need to transport their waste to another location. Due to the additional transportation of waste off site, the generation of criteria pollutants under Option 1 increases from baseline.

Options 2-4 and 7

No change in the emissions of methane, carbon dioxide, or nitrous oxide under Option 1 occurs because no further changes in waste management are needed. Under Options 2-4 and Option 7, emissions of ammonia decrease slightly compared with Option 1. Facilities are required to apply animal waste at agronomic phosphorus rates, which means there will be less application of animal nitrogen to cropland. The application of animal waste is supplemented with commercial nitrogen fertilizer. Although the same amount of nitrogen is applied to cropland as in Option 1, there will be fewer emissions of ammonia because commercial nitrogen is expected to be more stable.

Under these options, the generation of criteria pollutants increases in relation to Option 1, for beef because of an increase in the amount of waste transported off site. Although dairies also experience an increase in waste requiring transport, it is expected that more facilities will find hiring a contract hauler more affordable. Emissions from contract haul vehicles are expected to be less overall because waste from more than one farm may be transported in the same trip.

Option 5B

Emissions of greenhouse gases and ammonia from beef and dairy operations increase under Option 5B (i.e., mandated technology of composting). Compost operations include the addition of organic material to the waste pile to aid in the decomposition of the waste. This additional material also decomposes and contributes to increased methane emissions compared with other options. In addition, compost operations release more emissions than stockpiles because the windrows are turned regularly. Stockpiles tend to form outer crusts that reduce the potential for air emissions to occur.

Option 5B generates slightly more criteria air pollutants compared with Option 2 for beef and dairy operations because composting operations require turning equipment which uses fuel and generates additional air emissions from tractors.

Option 6

Emissions of methane from dairy waste under Option 6 significantly decrease because an anaerobic digester is used. A significant portion of the methane generated is collected as biogas and converted to energy. Drylot areas at the dairy still generate methane. Carbon dioxide emissions significantly increase as methane is converted during the combustion process.

No change in beef ammonia emissions occur compared with Option 2, because there is no change in land application or housing practices. Although large dairy waste is digested, no change in ammonia emissions occurs. The nitrogen stays in solution in the digester, and when the digester effluent is stored in an open lagoon, the ammonia is released.

Option 6 emissions of criteria pollutants at beef operations are similar to the emissions under Options 2-4 and 7, because there is little difference in the amount of waste transported off site. Option 6 emissions of criteria pollutants for dairy operations slightly decrease compared with Options 2-4 and 7.

13.6.2 Summary of Air Emissions for Swine, Poultry, and Veal Subcategories

Tables 13-3 through 13-6 present estimates for Threshold 1 and Tables 13-9 through 13-12 present estimates for Threshold 2.

Option 1

Emissions of greenhouse gases from dry poultry operations (broilers, turkeys, and dry layers) do not change under Option 1 in relation to the baseline because no change in the waste handling practices are expected. These operations are already handling the waste as a dry material. Although indoor storage of poultry litter is included in this option, it is not expected to significantly alter air emissions from the litter (only runoff). Emissions of greenhouse gases from veal, swine, and wet poultry operations also do not change because the waste handling practices are not expected to change.

Ammonia emissions occur primarily from liquid waste storage areas, which are not expected to change under Option 1. Because less manure nitrogen is applied under this option, ammonia emissions decrease slightly. Option 1 is based on the application of animal waste to cropland at agronomic rates for nitrogen. Animal feeding operations that have excess nitrogen for their crops transport their waste to another location. The generation of criteria pollutants increases under Option 1 in relation to baseline due to the additional transportation of waste off site.

Options 2-4 and 7

No change in emissions of greenhouse gases occurs because under these options no change in the waste handling practices are expected. There is no change in ammonia emissions compared with Option 1 as there are no changes in waste management systems.

Under these options, emissions of ammonia decrease compared with Option 1. These options are based on facilities applying animal waste at agronomic phosphorus rates where conditions warrant, which results in decreased application of animal nitrogen to cropland. The application of animal waste is supplemented with commercial nitrogen fertilizer. Although the same amount of nitrogen is applied to cropland as in Option 1, commercial nitrogen is more stable and results in lower emissions of ammonia.

Because these options are based on the application of animal waste to cropland at agronomic rates for phosphorus where necessary, animal feeding operations that have excess phosphorus for their crops transport their waste to another location. The generation of criteria pollutants increases in relation to Option 1 because more waste is transported off site to meet agronomic rates for phosphorus.

Option 5A

Emissions of greenhouse gases significantly decrease under Option 5A, which is based on covered lagoons. Because it is assumed that animal operations included in this option (veal, poultry, and swine) flare the gas that is generated in the lagoon, the methane will be converted, which will result in an increase in carbon dioxide emissions.

Because the lagoon cover prevents the ammonia from leaving solution, on-site ammonia emissions decrease. Ammonia in the effluent from the covered lagoon is released as soon as it is exposed to air. Option 5A, however, is based on covered storage at all times; thus, depending on the application methods (e.g., if the waste is incorporated into the soil), ammonia emissions could substantially decrease. Due to the restriction of nitrogen application at the animal feeding operation, there is no change in relation to Option 2 in the amount of material applied to on-site land; therefore, the use of a covered lagoon lowers the on-site ammonia emissions. It should be noted, however, that ammonia is lost from material transported off site, either during transport or at the point of off-site application.

Option 5A emissions of criteria air pollutants for poultry operations are equal to the emissions under Options 2-4 and 7, because there is little difference in the amount of waste transported off site. The emissions of criteria air pollutants for swine operations increase compared with Options 2-4 and 7; however, the emissions of SO_x decrease.

Option 5B

Emissions of methane and carbon dioxide under Option 5B are lower than under Option 2 due to the conversion of liquid manure handling systems (e.g., flush lagoons) to dry manure handling systems for chickens and swine. Dry manure generates less methane than liquid systems. Because turkey operations are already dry, the emissions of methane and carbon dioxide remain the same. Nitrous oxide emissions for swine and chickens operations, however, increase under Option 5B in relation to Option 2.

Ammonia emissions from the confinement of chickens and ammonia and hydrogen sulfide emissions for swine decrease under Option 5B in relation to Option 2 due to the conversion of liquid manure handling systems (e.g., flush lagoons) to dry manure handling; however, there is no change in ammonia emissions due to land application.

Option 5B emissions of criteria pollutants for poultry operations are equal to the emissions under Options 2-4 and 7, because there is no difference in the amount of waste transported off site. The emissions from swine operations are significantly lower than under Option 2 because the conversion of flush operations to dry housing significantly decreases the volume of waste transported off site.

Option 6

Emissions of methane from swine waste under Option 6 are significantly lower than under Option 2 due to the addition of the anaerobic digester. A significant portion of the methane generated is collected as biogas and converted to energy. Carbon dioxide emissions significantly increase because methane is converted during the combustion process.

No change in ammonia emissions occur compared with Option 2 because there is no change in land application or housing practices. Although large swine waste is digested, essentially no change will occur to ammonia emissions. The ammonia nitrogen, which is highly soluble, remains in solution in the digester. When the digester effluent is stored in an open lagoon, the ammonia is released.

Option 6 emissions of criteria pollutants for poultry operations are equal to the emissions under Options 2-4 and 7 because there is no difference in the amount of waste transported off site. The VOCs, NO_x, SO_x, and CO emissions from swine operations decrease. Hydrogen sulfide contained in the biogas is collected in the digester and is subsequently combusted and converted into to SO_x.

13.6.3 Energy Impacts

Certain regulatory options evaluated for animal feeding operations are based on the use of different waste management systems and land application practices which may affect energy usage. Increased electricity usage occurs at beef and dairy operations under all options for the land application of surface runoff from the feedlot which is collected and stored. Increased electricity usage occurs at swine operations under Option 6 due to the conversion of wet operations to high-rise housing because additional energy is required to operate the fans and blowers.

An overall decrease in energy occurs at those operations which use anaerobic digesters in Option 6. Large swine and dairies that digest their waste and recover and use the biogas to operate an engine will have excess energy that can be used to operate other machinery or that can be sold.

Table 13-1. Threshold 1 NWQIs for Beef (Includes Heifers)

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	80,800	77,600	77,600	77,600	77,600		104,000	77,600	77,600
Carbon Dioxide (CO_2)	34,600	33,300	33,300	33,300	33,300		44,500	33,300	33,300
Nitrous Oxide (N_2O)	37,000	37,000	37,000	37,000	37,000		37,900	37,000	37,000
Ammonia (NH_3)	536,000	537,000	529,000	529,000	529,000		759,000	529,000	530,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 519	Baseline + 597	Baseline + 597	Baseline + 597		Baseline + 632	Baseline + 598	Baseline + 597
Nitrogen Oxides (NO_x)	NC	Baseline + 1,995	Baseline + 2,298	Baseline + 2,298	Baseline + 2,298		Baseline + 2,430	Baseline + 2,299	Baseline + 2,298
Particulate Matter (PM)	NC	Baseline + 39.9	Baseline + 46.0	Baseline + 46.0	Baseline + 46.0		Baseline + 48.6	Baseline + 46.0	Baseline + 46.0
Carbon Monoxide (CO)	NC	Baseline + 6,180	Baseline + 7,120	Baseline + 7,120	Baseline + 7,120		Baseline + 7,540	Baseline + 7,130	Baseline + 7,120
Baseline + Energy Usage (kW-hr/yr)									
Electricity Usage	432,000,000	454,000,000	701,000,000	701,000,000	701,000,000		701,000,000	701,000,000	701,000,000

NC = Not calculated

Table 13-2. Threshold 1 NWQIs for Dairy

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	214,000	137,000	137,000	137,000	137,000		176,000	44,500	137,000
Carbon Dioxide (CO_2)	92,500	59,300	59,300	59,300	59,300		92,400	316,000	59,300
Nitrous Oxide (N_2O)	4,390	8,420	8,420	8,420	8,420		30,900	9,490	8,420
Ammonia (NH_3)	188,000	185,000	182,000	182,000	182,000		223,000	182,000	179,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 456	Baseline + 386	Baseline + 386	Baseline + 386		Baseline + 393	Baseline + 378	Baseline + 386
Nitrogen Oxides (NO_x)	NC	Baseline + 1,750	Baseline + 1,480	Baseline + 1,480	Baseline + 1,480		Baseline + 1,510	Baseline + 1,460	Baseline + 1,480
Particulate Matter (PM)	NC	Baseline + 35.1	Baseline + 29.7	Baseline + 29.7	Baseline + 29.7		Baseline + 30.3	Baseline + 29.1	Baseline + 29.7
Carbon Monoxide (CO)	NC	Baseline + 5,430	Baseline + 4,600	Baseline + 4,600	Baseline + 4,600		Baseline + 4,690	Baseline + 4,510	Baseline + 4,600
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline + 158,000,000	Baseline + 170,000,000	Baseline + 170,000,000	Baseline + 170,000,000		Baseline + 170,000,000	Baseline + (972,000,000)	Baseline + 170,000,000

NC = Not calculated

Table 13-3. Threshold 1 NWQIs for Veal

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	79.8	79.8	79.8	79.8	79.8	30.3	79.8	79.8	79.8
Carbon Dioxide (CO_2)	34.2	34.2	34.2	34.2	34.2	149.0	34.2	34.2	34.2
Nitrous Oxide (N_2O)	11.8	11.8	11.8	11.8	11.8	11.2	11.8	11.8	11.8
Ammonia (NH_3)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Volatile Organic Compounds (VOCs)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Nitrogen Oxides (NO_x)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Particulate Matter (PM)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Carbon Monoxide (CO)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Energy Usage (kW-hr/yr)									
Electricity Usage	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000

NC = Not calculated

Table 13-4. Threshold 1 NWQIs for Swine

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	296,000	296,000	296,000	296,000	296,000	133,000	125,000	115,000	296,000
Carbon Dioxide (CO_2)	127,000	127,000	127,000	127,000	127,000	575,000	537,000	625,000	127,000
Nitrous Oxide (N_2O)	569	569	569	569	569	364	11,400	241	569
Ammonia (NH_3)	155,000	155,000	155,000	155,000	155,000	139,000	139,000	155,000	167,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 29.0	Baseline + 32.6	Baseline + 32.6	Baseline + 32.6	Baseline + 116	Baseline + 0.985	Baseline + 12.1	Baseline + 32.6
Nitrogen Oxides (NO_x)	NC	Baseline + 112	Baseline + 125	Baseline + 125	Baseline + 125	Baseline + 447	Baseline + 3.79	Baseline + 46.6	Baseline + 125
Particulate Matter (PM)	NC	Baseline + 2.23	Baseline + 2.51	Baseline + 2.51	Baseline + 2.51	Baseline + 8.95	Baseline + 0.076	Baseline + 1.83	Baseline + 2.51
Carbon Monoxide (CO)	NC	Baseline + 331	Baseline + 418	Baseline + 418	Baseline + 418	Baseline + 684	Baseline + 11.7	Baseline + 155	Baseline + 418
Hydrogen Sulfide (H_2S)	70,000	70,000	70,000	70,000	70,000	7,700	11,500	69,200	101,000
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline + 356,000,000	Baseline + (1,247,213,400)	Baseline

NC = Not calculated

Table 13-5. Threshold 1 NWQIs for Chickens

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	69,900	69,900	69,900	69,900	69,900	28,600	29,600	69,900	69,900
Carbon Dioxide (CO_2)	29,900	29,900	29,900	29,900	29,900	143,000	12,700	29,900	29,900
Nitrous Oxide (N_2O)	18,000	18,000	18,000	18,000	18,000	18,000	18,600	18,000	18,000
Ammonia (NH_3)	153,000	152,000	144,000	144,000	144,000	141,000	142,000	144,000	144,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 4.78	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9
Nitrogen Oxides (NO_x)	NC	Baseline + 18.4	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8
Particulate Matter (PM)	NC	Baseline + 0.368	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837
Carbon Monoxide (CO)	NC	Baseline + 57.0	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

Table 13-6. Threshold 1 NWQIs for Turkeys

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons\yr)									
Methane (CH_4)	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
Carbon Dioxide (CO_2)	3,390	3,390	3,390	3,390	3,390	3,390	3,390	3,390	3,390
Nitrous Oxide (N_2O)	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250
Ammonia (NH_3)	26,300	26,000	23,500	23,500	23,500	23,500	23,500	23,500	23,500
Volatile Organic Compounds (VOCs)	NC	Baseline + 1.12	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05
Nitrogen Oxides (NO_x)	NC	Baseline + 4.31	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58
Particulate Matter (PM)	NC	Baseline + 0.086	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312
Carbon Monoxide (CO)	NC	Baseline + 13.4	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

Table 13-7. Threshold 2 NWQIs for Beef (Includes Heifers)

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	79,700	76,500	76,500	76,500	76,500		102,000	76,500	76,500
Carbon Dioxide (CO_2)	34,200	32,800	32,800	32,800	32,800		43,900	32,800	32,800
Nitrous Oxide (N_2O)	36,500	36,500	36,500	36,500	36,500		37,400	36,500	36,500
Ammonia (NH_3)	355,000	321,000	314,000	314,000	314,000		540,000	314,000	315,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 513	Baseline + 591	Baseline + 591	Baseline + 591		Baseline + 626	Baseline + 591	Baseline + 591
Nitrogen Oxides (NO_x)	NC	Baseline + 1,970	Baseline + 2,270	Baseline + 2,274	Baseline + 2,274		Baseline + 2,406	Baseline + 2,275	Baseline + 2,274
Particulate Matter (PM)	NC	Baseline + 39.5	Baseline + 45.5	Baseline + 45.5	Baseline + 45.5		Baseline + 48.1	Baseline + 45.5	Baseline + 45.5
Carbon Monoxide (CO)	NC	Baseline + 6,120	Baseline + 7,051	Baseline + 7,051	Baseline + 7,051		Baseline + 7,460	Baseline + 7,052	Baseline + 7,051
Energy Usage (kW-hr/yr)									
Electricity Usage	427,000,000	457,000,000	705,000,000	705,000,000	705,000,000		705,000,000	705,000,000	705,000,000

NC = Not calculated

Table 13-8. Threshold 2 NWQIs for Dairy

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	225,000	144,000	144,000	144,000	144,000		186,000	51,700	144,000
Carbon Dioxide (CO_2)	97,000	62,400	62,400	62,400	62,400		98,100	319,000	62,400
Nitrous Oxide (N_2O)	4,840	8,770	8,770	8,770	8,770		27,000	9,830	8,770
Ammonia (NH_3)	195,000	191,000	189,000	189,000	189,000		229,000	189,000	186,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 447	Baseline + 371	Baseline + 371	Baseline + 371		Baseline + 379	Baseline + 363	Baseline + 371
Nitrogen Oxides (NO_x)	NC	Baseline + 1,720	Baseline + 1,430	Baseline + 1,430	Baseline + 1,430		Baseline + 1,460	Baseline + 1,400	Baseline + 1,430
Particulate Matter (PM)	NC	Baseline + 34.4	Baseline + 28.5	Baseline + 28.5	Baseline + 28.5		Baseline + 29.2	Baseline + 27.9	Baseline + 28.5
Carbon Monoxide (CO)	NC	Baseline + 5,330	Baseline + 4,420	Baseline + 4,420	Baseline + 4,420		Baseline + 4,520	Baseline + 4,330	Baseline + 4,420
Baseline + Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline + 132,000,000	Baseline + 230,000,000	Baseline + 230,000,000	Baseline + 230,000,000		Baseline + 230,000,000	Baseline + (912,000,000)	Baseline + 230,000,000

NC = Not calculated

Table 13-9. Threshold 2 NWQIs for Veal

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	80.1	80.1	80.1	80.1	80.1	30.4	80.1	80.1	80.1
Carbon Dioxide (CO_2)	34.3	34.3	34.3	34.3	34.3	150	34.3	34.3	34.3
Nitrous Oxide (N_2O)	11.7	11.7	11.7	11.7	11.7	11.1	11.7	11.7	11.7
Ammonia (NH_3)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Volatile Organic Compounds (VOCs)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Nitrogen Oxides (NO_x)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Particulate Matter (PM)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Carbon Monoxide (CO)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Energy Usage (kW-hr/yr)									
Electricity Usage	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000

NC = Not calculated

Table 13-10. Threshold 2 NWQIs for Swine

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	275,000	275,000	275,000	275,000	275,000	118,000	115,000	93,900	275,000
Carbon Dioxide (CO_2)	118,000	118,000	118,000	118,000	118,000	549,000	49,100	616,000	118,000
Nitrous Oxide (N_2O)	518	518	518	518	518	321	10,400	190	518
Ammonia (NH_3)	142,000	142,000	142,000	142,000	142,000	128,000	128,000	142,000	154,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 27.4	Baseline + 34.0	Baseline + 34.0	Baseline + 34.0	Baseline + 60.0	Baseline + 0.848	Baseline + 11.2	Baseline + 34.0
Nitrogen Oxides (NO_x)	NC	Baseline + 105	Baseline + 116	Baseline + 116	Baseline + 116	Baseline + 231	Baseline + 3.26	Baseline + 43.2	Baseline + 116
Particulate Matter (PM)	NC	Baseline + 2.11	Baseline + 2.32	Baseline + 2.32	Baseline + 2.32	Baseline + 4.62	Baseline + 0.065	Baseline + 0.86	Baseline + 2.32
Carbon Monoxide (CO)	NC	Baseline + 327	Baseline + 360	Baseline + 360	Baseline + 360	Baseline + 716	Baseline + 10.1	Baseline + 133	Baseline + 360
Hydrogen Sulfide (H_2S)	66,000	64,900	64,900	64,900	64,900	6,780	10,800	64,100	6,780
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline + 342,000,000	Baseline + (1,250,000,000)	Baseline

NC = Not calculated

Table 13-11. Threshold 2 NWQIs for Chickens

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	68,300	68,300	68,300	68,300	68,300	28,900	29,900	68,300	68,300
Carbon Dioxide (CO_2)	29,300	29,300	29,300	29,300	29,300	138,000	12,800	29,300	29,300
Nitrous Oxide (N_2O)	18,300	18,300	18,300	18,300	18,300	18,300	18,900	18,300	18,300
Ammonia (NH_3)	156,000	155,000	147,000	147,000	147,000	145,000	146,000	147,000	149,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 4.49	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2
Nitrogen Oxides (NO_x)	NC	Baseline + 17.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3
Particulate Matter (PM)	NC	Baseline + 0.345	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785
Carbon Monoxide (CO)	NC	Baseline + 53.5	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

Table 13-12. Threshold 2 NWQIs for Turkeys

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	8,330	8,330	8,330	8,330	8,330	8,330	8,330	8,330	8,330
Carbon Dioxide (CO_2)	3,570	3,570	3,570	3,570	3,570	3,570	3,570	3,570	3,570
Nitrous Oxide (N_2O)	5,520	5,520	5,520	5,520	5,520	5,520	5,520	5,520	5,520
Ammonia (NH_3)	28,700	28,400	26,000	26,000	26,000	26,000	26,000	26,000	26,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 1.01	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63
Nitrogen Oxides (NO_x)	NC	Baseline + 3.88	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0
Particulate Matter (PM)	NC	Baseline + 0.078	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279
Carbon Monoxide (CO)	NC	Baseline + 12.0	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

13.7 References

AAF Canada. 2000. Estimates of Emissions–Reducing Nitrous Oxide Emissions. In *The Health of Our Air*. Agriculture and Agri-Food Canada. <http://res2.agr.ca/research-recherche/science/Healthy_Air/2d8.html>. October 10.

Anderson, B. 1994. *Animal Manure as a Plant Resource*. <http://www.agcom.purdue.edu/AgCom/Pubs/ID/ID-101.html>. Purdue University. July 5, 2000.

ERG. 2000. *Non-Water Quality Impact Estimates for Animal Feeding Operations*. Prepared for U.S. Environmental Protection Agency, Engineering and Analysis Division, Washington, DC. December.

IPCC. 2000. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Chapter 4, Agriculture. Intergovernmental Panel on Climate Change, NGGIP..

Jacobson, L. D., R. Moon, J. Bicudo., K. Janni, S. Noll, G. Shurson, J. Zhu, D. Schmidt, P. McGinley, R. Nicolai, C. Clanton, K. Davis, L. Brosseau, J. Bruns, C. Pijoan, T. Blaha, B. Curgan, and K. Draeger. 2000. *Generic Environmental Impact Statement on Animal Agriculture: A Summary of the Literature Related to Air Quality and Odor*. Prepared for Minnesota Department of Agriculture, Environmental Quality Board, St. Paul Minnesota.

Jewell, W.J., P.E. Wright, N.P. Fleszar, G. Green, A. Safinski, and A. Zucker. 1997. *Evaluation of Anaerobic Digestion Options for Groups of Dairy Farmers in Upstate New York.* Department of Agriculture and Biological Engineering, College of Agriculture and Life Sciences. Cornell University, Ithaca, NewYork. June.

OSUE. 2000. *Selecting Forms of Nitrogen Fertilizer*. <http://www2.ag.ohio-state.edu/~ohioline/agf-fact/0205.html>. Ohio State University Extension. July 5.

Sharpe, R.R., and L.A. Harper. 1997. Ammonia and Nitrous Oxide Emissions from Sprinkler Irrigation Applications of Swine Effluent. *Journal of Environmental Quality* 26:1703-1706.

USEPA. 1992. Global Methane Emissions From Livestock and Poultry Manure. EPA/400/1-91-048. U.S. Environmental Protection Agency, Washington, DC.

Van Horn, H.H., A.C. Wilkie, W.J. Powers, and R.A. Nordstedt. 1994. Components of Dairy Manure Management Systems. *Journal of Dairy Science* 77:7.

CHAPTER 14

GLOSSARY

aeration	the process of bringing air into contact with a liquid by one or more of the following methods: (1) spraying the liquid in the air, (2) bubbling air through the liquid, and (3) agitating the liquid to promote absorption of oxygen through the air liquid interface
aerobic	having or occurring in the presence of the free oxygen
aerobic lagoon	a holding and/or treatment pond that speeds up the natural process of biological decomposition of organic waste by stimulating the growth and activity of bacteria that degrade organic waste in an oxygen-rich environment
Ag Census	the census of agriculture conducted every 5 years; a major source of information about the structure and activities of agricultural production at the national, state, and county levels
agitation	thorough mixing of liquid or slurry manure at a storage structure to provide a more consistent fertilizer material and allow the producer to empty as much of the storage as possible
agronomic rates	the land application of animal wastes at rates of application that provide the crop or forage growth with needed nutrients for optimum health and growth
air emissions	release of any pollutant into the air
ammonia volatilization	the loss of ammonia gas to the atmosphere
anaerobic	the absence of molecular oxygen, or capable of living and growing in the absence of oxygen, such as anaerobic bacteria
anaerobic lagoon	a holding and/or treatment pond that speeds up the natural process of biological decomposition of organic waste by stimulating the growth and activity of bacteria that degrade organic waste in an oxygen-depleted environment

animal feeding operation (AFO)	a lot or facility (other than an aquatic animal production facility) where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and the animal confinement areas do not sustain crops, vegetation, forage growth, or postharvest residues in the normal growing season. Two or more animal feeding operations under common ownership are a single animal feeding operation if they adjoin each other or if they use a common area or system for the disposal of wastes.
APHIS	Animal and Plant Health Inspection Service, United States Department of Agriculture
baffle	a device (as a plate, wall, or screen) to deflect, check, or regulate flow (fluid, light, or sound)
barrow	a castrated male pig
berm	a narrow shelf, path, or ledge typically at the top or bottom of a slope; a mound or wall of earth
best available technology (BAT)	the best available technology that is economically achievable established under 301(b) and 402 of the Federal Water Pollution Control Act as amended, also known as the Clean Water Act, found at 33 USC 1251 et seq. The criteria and standards for imposing technology-based treatment requirements are listed in 40 CFR 125.3.
best conventional technology (BCT)	the best conventional pollutant control technology that is economically achievable established under 301(b) and 402 of the Federal Water Pollution Control Act as amended, also known as the Clean Water Act, found at 33 USC 1251 et seq. The criteria and standards for imposing technology-based treatment requirements are listed in 40 CFR 125.3.
best management practice (BMP)	a practice or combination of practices found to be the most effective, practicable (including economic and institutional considerations) means of preventing or reducing the amount of pollution generated
bioavailability	the degree and rate at which a substance is absorbed into a living system or is made available at the site of physiological activity
biochemical oxygen demand (BOD)	an indirect measure of the concentration of biodegradable substances present in an aqueous solution. Determined by the amount of dissolved oxygen required for the aerobic degradation of the organic matter at 20 °C. BOD_5 refers to that oxygen demand for the initial 5 days of the degradation process

biogas	a mixture of methane and carbon dioxide produced by the bacterial decomposition of organic wastes and used as a fuel
biosecurity	a defensive health plan and hygiene procedures that can help keep an animal feeding operation disease free
biosolids	solid organic matter recovered from a sewage treatment process and used especially as fertilizer
BPJ	best professional judgement
BPT	best practicable technology
broadcasting	method of application (seed or fertilizer) to the soil surface
broilers	chickens of either sex specifically bred for meat production and marketed at approximately 8 weeks of age
carcass-weight	weight of the dead body of an animal, slaughtered and gutted
certified specialist	someone who has been certified to prepare Comprehensive Nutrient Management Plans (CNMPs) by USDA or a USDA sanctioned organization
compaction	an increase in soil bulk density, limiting both root penetration, and water and nutrient uptake induced by tillage- and vehicular-traffic
composting	a process of aerobic biological decomposition of organic material characterized by elevated temperatures that, when complete, results in a relatively stable product suitable for a variety of agricultural and horticultural uses
concentrated animal feeding operation (CAFO)	an "animal feeding operation" that meets the criteria in 40 CFR Part 122, Appendix B, or an operation designated as a significant contributor of pollution pursuant to 40 CFR 122.23
costing	a systematic method or procedure used to develop the estimated costs of a technology or practice
cover crop	a close-growing crop, whose main purpose is to protect and improve the soil and use excess nutrients or soil moisture during the absence of the regular crop, or in the nonvegetated areas of orchards and vineyards

crop removal rate	the application rate for manure or wastewater which is determined by the amount of phosphorus which will be taken up by the crop during the growing season and subsequently removed from the field through crop harvest. Field residues do not count towards the amount of phosphorus removed at harvest.
crop rotation	a planned sequence of crops
denitrification	the chemical or biological reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen (N_2) or as an oxide of nitrogen (N_2O)
detention pond	a basin whose outlet has been designed to detain the storm water runoff from a design storm (e.g., 25 year/24 hour storm) for some minimum time to allow particles and associated pollutants to settle
digestion	the process whereby organic matter breaks down into simpler and/or more biologically stable products, e.g., ammonia to organic nitrogen
disking	cultivating with an implement that turns and loosens the soil with a series of discs
dry lots	open feedlots sloped or graded from 4 to 6 percent to promote drainage away from the lot to provide consistently dry areas for cattle to rest
effluent	the liquid discharge from a waste treatment process
endogenous	growing or produced by growth from deep tissue (e.g., plant roots)
ephemeral erosion	a shallow, concentrated flow path that develops as a response to a specific storm and disappears as a result of tillage or natural processes
erosion	the wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep
ERS	Economic Research Service, United States Department of Agriculture
evapotranspiration	the loss of water from an area by evaporation from the soil or snow cover and transpiration by plants
farrowing	the act of giving birth to pigs by the sow
farrow-to-finish	contains all three hog production phases: farrow, nursery, finish
fecal coliform	the bacterial count (Parameter 1) at 40 CFR 136.3 in Table 1A, which also cites the approved methods of analysis.

feedlot	a concentrated, confined animal or poultry growing operation for meat, milk, or egg production, or stabling, in pens or houses wherein the animals or poultry are fed at the place of confinement and crop or forage growth or production is not sustained in the area of confinement, and is subject to 40 CFR 412
fertilizer value	the value of noncommercial fertilizer (e.g., manure)
flushing system	a system that collects and transports or moves waste material with the use of water, such as in washing of pens and flushing of confinement livestock facilities
freeboard	the height above the recorded high-water mark of a structure (as a dam) associated with the water
FRN	federal registrar notice
frequency factor	the regional compliance of animal feeding operations with BMPs associated with a nutrient management plan, facility upgrades, or strategies to reduce excess nutrients
FORTRAN	one of the most widely used programming languages for solving problems in science and engineering
gilt	a young or immature female pig
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
ground water	water filling all the unblocked pores of underlying material below the water table
hen	a mature female chicken
incorporation	mixing manure into the soil, either by tillage or by subsurface injection, to increase manure nutrient availability for use by crops
injection	a tillage implement that cuts into the soil depositing liquid or slurry
integrators	poultry companies, under contract with growers, who supply birds, feed, medicines, transportation, and technical help
irrigation	application of water to lands for agricultural purposes (Soil Conservation Society of America, 1982)

lagoon	an all-inclusive term commonly given to a water impoundment in which organic wastes are stored or stabilized, or both. Lagoons may be described by the predominant biological characteristics (aerobic, anaerobic, or facultative), by location (indoor, outdoor), by position in a series (primary, secondary, or other), and by the organic material accepted (sewage, sludge, manure, or other)
land application	application of manure, sewage sludge, municipal wastewater, and industrial wastes to land for reuse of the nutrients and organic matter for their fertilizer and soil conditioning values
land application area	any land under the control of the CAFO operator, whether it is owned, rented, or leased, to which manure and process wastewater is or may be applied
layer	a mature hen that is producing eggs
leaching	(1) the removal of soluble constituents, such as nitrates or chlorides, from soils or other material by the movement of water; (2) the removal of salts and alkali from soils by irrigation combined with drainage; (3) the removal of a liquid through a non-watertight artificial structure, conduit, or porous material by downward or lateral drainage, or both, into the surrounding permeable soil
load	quantity of substance entering the receiving body
macronutrient	a chemical element required, in relatively large amounts, for proper plant growth
manure	the fecal and urinary excretions of livestock and poultry
micronutrient	a chemical element required, in relatively small amounts, for proper plant growth
mulch	any substance that is spread on the soil surface to decrease the effects of raindrop impact, runoff, and other adverse conditions and to retard evaporation
NAHMS	National Animal Health Monitoring System, United States Department of Agriculture
NASS	National Agricultural Statistics Service, United States Department of Agriculture

new source	a source that is subject to subparts C or D of 40 CFR 412 and, not withstanding the criteria codified at 40 CFR 122.29(b)(1): (i) is constructed at a site at which no other source is located; or (ii) replaces the housing including animal holding areas, exercise yards, and feedlot, waste handling system, production process, or production equipment that causes the discharge or potential to discharge pollutants at an existing source; or (iii) constructs a production area that is substantially independent of an existing source at the same site. Whether processes are substantially independent of an existing source, depends on factors such as the extent to which the new facility is integrated with the existing facility; and the extent to which the new facility is engaged in the same general type of activity as the existing source.
nitrification	the biochemical transformation by oxidation of ammonium (NH_4^+) to nitrite (NO_2^-) or nitrate (NO_3^-)
nitrogen	a chemical element, commonly used in fertilizer as a nutrient, that is also a component of animal wastes. Plant available nitrogen forms include nitrate (NO_3^-) and ammonium (NH_4^+).
no-till	a planting procedure that requires no tillage except that done in the immediate area of the crop row
NRCS	Natural Resource Conservation Service, United States Department of Agriculture
NSPS	New Source Performance Standards are uniform national EPA air emission and water effluent standards that limit the amount of pollution allowed from new sources or from modified existing sources
nutrient management	a planning tool used to control the amount, source, placement, form, and timing of the application of nutrients and soil amendments (USDA, 1999)
nutrient management plan	an approach for managing the form, rate, timing, and method of application of nutrients, including nutrients from biosolids, being applied to the soil in a manner that provides adequate plant nutrition but minimizes the environmental impact of these nutrients
nutrient removal rate	the removal of nutrients in harvested material on a per acre basis
NWPCAM	National Water Pollution Control Assessment Model
organic matter	the organic fraction of the soil exclusive of undecayed plant and animal residue

overflow	the process wastewater discharge resulting from the filling of wastewater or liquid manure storage structures to the point at which no more liquid can be contained by the structure
permit nutrient plan (PNP)	a plan developed in accordance with 40 CFR 412.33 (b) and §412.37. This plan shall define the appropriate rate for applying manure or wastewater to crop or pasture land. The plan accounts for soil conditions, concentration of nutrients in manure, crop requirements and realistic crop yields when determining the appropriate application rate.
phosphorus	one of the primary nutrients required for the growth of plants. Phosphorus is often the limiting nutrient for the growth of aquatic plants and algae.
phosphorus level	a system of weighing a number of measures that relate the potential for phosphorus loss due to site and transport characteristics. The phosphorus index must at a minimum include the following factors when evaluating the risk for phosphorus runoff from a given field or site: (1) Soil erosion. (2) Irrigation erosion. (3) Run-off class. (4) Soil phosphorus test. (5) Phosphorus fertilizer application rate. (6) Phosphorus fertilizer application method. (7) Organic phosphorus application rate. (8) Method of applying organic phosphorus.
phosphorus threshold (TH level)	a specific soil test concentration of phosphorus established by states. The concentration defines the point at which soluble phosphorus may pose a surface runoff risk.
photoperiod	the time between sunrise and sunset
phytase	an enzyme effective at increasing the breakdown of phytase phosphorus in the digestive tract and reducing the phosphorous excretion in the feces
point source	the release of a contaminant or pollutant, often in concentrated form, from a conveyance system, such as a pipe, into a waterbody
porous dam	a runoff control structure that reduces the rate of runoff so that solids settle out in the settling terrace or basin. The structure may be constructed of rock, expanded metal, or timber arranged with narrow slots.

potassium	one of the primary nutrients required for the growth of plants
poult	a young, immature turkey
precipitation	a deposit on the earth of hail, mist, rain, sleet, or snow; *also* **:** the quantity of water deposited
pretreatment	a process used to reduce, eliminate, or alter the nature of wastewater pollutants from nondomestic sources before they are discharged into publicly owned treatment works
process wastewater	water directly or indirectly used in the operation of the CAFO for any or all of the following: spillage or overflow from animal or poultry watering systems; washing, cleaning, or flushing pens, barns, manure pits, or other CAFO facilities; direct contact swimming, washing or spray cooling of animals; litter or bedding; dust control; and stormwater which comes into contact with any raw materials, products or by-products of the operation.
production area	that part of the CAFO that includes the animal confinement area, the manure storage area, the raw materials storage area, and the waste containment areas. The animal confinement area includes but is not limited to open lots, housed lots, feedlots, confinement houses, stall barns, free stall barns, milkrooms, milking centers, cowyards, barnyard, exercise yards, animal walkways, and stables. The manure storage area includes but is not limited to lagoons, sheds, under house or pit storage, liquid impoundments, static piles, and composting piles. The raw materials storage area includes but is not limited to feed silos, silage bunkers, and bedding materials. The waste containment area includes but is not limited to settling basins, and areas within berms, and diversions which separate uncontaminated stormwater . Also included in the definition of production area is any egg washing or egg processing facility.
production phase	the animal life cycles grouped into discreet categories based on age and maturity
protease	any of numerous enzymes that hydrolyze proteins and are classified according to the most prominent functional group (as serine or cysteine) at the active site
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
pullet	an immature female chicken

reduced-till	a management practice whereby the use of secondary tillage operations is significantly reduced
residue cover	unharvested material left on the soil surface designed to reduce water and wind erosion, maintain or increase soil organic matter, conserve soil moisture, stabilize temperatures, and provide food and escape cover for wildlife
RFA	Regulatory Flexibility Analysis
rill erosion	an erosion process in which numerous small channels of only several centimeters in depth are formed; occurs mainly on recently cultivated soils
runoff	the part of precipitation or irrigation water that appears in surface streams of waterbodies; expressed as volume (acre-inches) or rate of flow (gallons per minute, cubic feet per second)
SBA	Small Business Administration
SBREFA	Small Business Regulatory Enforcement Fairness Act
setback	a specified distance from surface waters or potential conduits to surface waters where manure and wastewater may not be land applied. Examples of conduits to surface waters include, but are not limited to, tile line intake structures, sinkholes, and agricultural well heads.
sheet erosion	soil erosion occurring from a thin, relatively uniform layer of soil particles on the soil surface; also called interrill erosion
side-dressing	the application of fertilizer alongside row crop plants, usually on the soil surface. Nitrogen materials are most commonly side-dressed.
sludge	settled sewage solids combined with varying amounts of water and dissolved materials that are removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion
slurry	a thin mixture of a liquid and finely divided particles
soil test phosphorus	the measure of the phosphorus content in soil as reported by approved soil testing laboratories using a specified analytical method
sow	a mature female hog
spreader	a farm implement used to scatter fertilizer
supernatant	the liquid fraction in a lagoon

surface runoff	the portion of precipitation on an area that is discharged from the area through stream channels
surface water	all water whose surface is exposed to the atmosphere (Soil Conservation Society of America, 1982)
suspended solids	(1) undissolved solids that are in water, wastewater, or other liquids and are largely removable by filtering or centrifuging; (2) the quantity of material filtered from wastewater in a laboratory test, as prescribed in APHA Standard Methods for the Examination of Water and Wastewater or similar reference
tanker	a vehicle constructed to transport bulk liquids
tom	a male turkey
total suspended solids (TSS)	the weight of particles that are suspended in water. Suspended solids in water reduce light penetration in the water column, can clog the gills of fish and invertebrates, and are often associated with toxic contaminants because organics and metals tend to bind to particles. Differentiated from total dissolved solids by a standardized filtration process whereby the dissolved portion passes through the filter.
USDA	United States Department of Agriculture
volatilization	the loss of gaseous components, such as ammonium nitrogen, from animal manure
waste management system	a combination of conservation practices formulated to appropriately manage a waste product that, when implemented, will recycle waste constituents to the fullest extent possible and protect the resource base in a nonpolluting manner
wastewater	the spent or used water from a home, a community, a farm, or an industry that contains dissolved or suspended matter
water quality	the excellence of water in comparison with its intended use or uses