Comments to the USEPA
On the

CONCENTRATED ANIMAL FEEDING OPERATION PROPOSED RULE

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DATE: JULY 26, 2001

Executive Summary of the Report

The USEPA's review and update of the National Pollutant Discharge Elimination System Permit Regulation and the Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations seeks to protect water quality. Our objective in submitting these comments is to help ensure that the final rule is based on sound science and proven agricultural practices.

Within the proposed USEPA rules are a large number of options and proposals that will have implications on the costs and feasibility of phosphorus-based manure management. Will the USEPA insist on annual phosphorus limits or allow 5-year rotation limits? Will lagoon operations be required to agitate lagoons to ensure land application of all excreted phosphorus? The many potential outcomes of the phosphorus rule make a straightforward, concise analysis difficult.

The USEPA, in their analysis of the proposed rule, focused primarily on the costs associated with the proposed rule. In our analysis of the rule, we determine that feasibility issues, not costs, are the most obvious barriers to a farmer implementing its requirements.

The USEPA also addressed the impact of proposed rules on components of a concentrated animal feeding operation but frequently failed to address the effect of component changes throughout the whole swine production system.

Our analysis includes an extensive evaluation of the impacts of implementing phosphorus limits and "zero discharge" on swine operations within the midwestern, northeastern, southeastern, and western regions of the U.S., as defined by the USEPA. The three most important recommendations are:

Recommendation 1. The USEPA adopt 5-year rotation phosphorus limits on manure applications, not annual phosphorus limits.

We propose replacing the existing wording in FR 3142, 412.37 (a)(2) *i* and *ii* with the following text:

> "Multi-year phosphorus applications are permissible as long as they do not exceed the nitrogen limit for the current crop year. The phosphorus store should not exceed 5 years of crop need if there is a high or very high risk of phosphorus loss."

Recommendation 2. The USEPA must clearly define design criteria and provide upset and bypass provisions in permits for open manure storages.

Recommendation 3. The USEPA needs to reconsider its economic study of the proposed rule to include the following:

- All costs associated with adopting the rule are considered costs to the CAFO – none are the responsibility of non-CAFO recipients of manure.
- Include an estimate of the impact of compliance on liquidity.
- Recognize the difference in gross revenue and ability to pay between contract producers and independent producers.

We also respectfully submit the following observations and recommendations:

Annual phosphorus limits are infeasible for most swine slurry operations.

- Annual phosphorus limits are below those feasible for currently available injection equipment.
- Annual limits were infeasible with any method of application on 30% of the operations.
- Most other operations would need to modify equipment to reduce discharge rate, maximize surface application swath width and maximize travel speed to attain the desired rate. (Chapter 3 and 4)

Phosphorus limits increase land requirements for land application of manure.

- Phosphorus limits increased land requirements per animal unit from 0.3 to 1.0 on slurry based operations in our study.
- Phosphorus limits increased land requirements per animal unit from 0.09 to 0.13 for unagitiated lagoon effluent and to 1.3 for agitated lagoon effluent. (Chapter 4)

Most unagitated lagoon operations moving to a phosphorus rule will experience minor impacts in the short term.

- Unagitated lagoon effluent has a relatively high $N:P_2O_5$ ratio because most of the phosphorus is retained in the sludge at the bottom of the lagoon (Chapter 2).
- Fourteen of 16 analyzed farms had ample controlled acres for the increased land requirements. The exceptions were both in North Carolina. (Chapter 4)

Agitating lagoons makes phosphorus-based applications infeasible with irrigation technology.

- These operations would need to adopt dragline injection or tanker technologies to spread manure. (Chapter 4)

Most slurry operations and some lagoon operations would be unable to rely on a single season land application of manure.

- Average storage capacity of the analyzed farms was 7 months for slurry systems and 9 months for lagoons.
- Average duration of land application time already exceeds 50% of the spring field work days for corn among slurry operations.
- Operations that inject lagoon effluent on row crop land face the same time issues as slurry operations. (Chapter 4)

Zero-discharge creates a design dilemma for any existing or new open manure storage structure.

- Without a design criteria (e.g. 24-hour, 25-day storm) it is impossible for an engineer to design or certify any structure that captures rainfall or runoff.
- Open structures require an upset and bypass provision in the permit.
- We encourage the USEPA to consider more stringent design storm criteria to address concerns with open storages. (Chapter 5).

Technical challenges limiting the use of impermeable covers include;

- Storm water collection and disposal
- Gas collection and utilization/disposal
- Maintaining structural integrity
- Impact of freezing conditions (Chapter 5)

We predict that the EPA's economic assessment of farms in the moderate to stress categories is underestimated.

- We estimate 20% of operations will be in the moderate or stress category, as defined by the USEPA, from implementing only a rotational phosphorus limit.
- We estimate 100% of operations implementing both a zero discharge requirement and a rotational phosphorus rule will be in the moderate or stress categories.
- Table 10-6 of the Preamble (Federal Register, p 3090) reports that the EPA estimates that 20% of the hog producers will be in the moderate to stress categories. Their estimate includes those who will be financially stressed by implementing an annual phosphorus rule and by attaining zero discharge.

As an alternative to an absolute zero discharge we evaluated the economic impact of additional storage options.

- Additional storage options do not meet the zero discharge rule as proposed and will provide additional protection to the environment by reducing the likelihood of overflow.
- Increasing storage capacity to 18 months resulted in only 50% of modeled farms being in the EPA's Moderate to Financial Stress 3 categories.
- Adding an emergency storage cell designed to contain a 10-year, 10-day frequency storm plus 30 days of manure and facility wastewater production resulted in all modeled farms being in the EPA's Affordable 1 category.

Improving water management by implementing water reduction methods will not appreciably reduce effluent volumes to open storages.

- Compared to rainwater inputs, wash water is a small percentage of the total water volume of most operations.
- Reduced water increases nutrient concentration, which will affect the feasibility of phosphorus application rates. (Chapters 3, 4 and 5)

The USEPA underestimated the costs to the CAFO of writing, implementing and maintaining a nutrient management plan.

- The USEPA assumed nutrient management plan costs were $5 per acre and record keeping costs were fixed at $880, independent of operation size.
- We anticipate combined costs for nutrient management and record keeping will be close to $10 per acre on all land receiving manure, and that record keeping costs will increase on larger operations.
- We recommend that the USEPA increase the estimated costs of developing, managing and updating a nutrient management plan and assume that the CAFO operator will incur those costs on all controlled and uncontrolled acres. (Chapter 4)

Regional differences are much more significant than recognized in the USEPA economic analysis.

- North Carolina and Pennsylvania manure storage, land application techniques and cropping systems have nothing in common, yet the USEPA considers them a single region (Chapter 4).
- Differences in land productivity, crop selection and manure characteristics can result in 0 to 10 times more land required for phosphorus-based applications.

The USEPA failed to recognize the financial differences between contract producers and independent producers.

- Gross revenue per animal unit for independent producers is significantly different than that for contract producers.
- The impact of environmental compliance is significantly more costly for contract producers than independent producers.

The USEPA makes unjustifiable distinctions between controlled (owned and rented) land and uncontrolled land receiving manure.

- The USEPA assumes nitrogen-based application rates will be sustainable on uncontrolled land although the receiving farmer has strong incentives to allow only phosphorus-based rates under the proposed rules.
- The USEPA assumes that farmers receiving CAFO manure will pay for nutrient management planning on their farm and for the manure transportation costs. There is no incentive for these farmers to absorb these costs.
- We recommend the USEPA assume the CAFO will manage and incur all the costs of the nutrient management plan on all acres receiving manure.
- We recommend that the USEPA assume that manure application on all land (including non-CAFO land) receiving manure will be limited by phosphorus crop removal in the long term, in accordance with the provisions of the proposed rule. (Chapter 1)

The USEPA assumes the ratio of animals to land is higher on larger farms.

- Our analysis of 31 swine farms in four USEPA regions indicated a weak, but positive effect of operation size on animal density (see 4.5.1.1).
- Regional differences were much more pronounced; North Carolina had significantly higher animal densities than four other analyzed states. Pennsylvania farms were the most dependent on land not owned or rented by the CAFO. (Chapter 4)

We recommend the USEPA consider alternatives to animal number or animal units when defining operations that pose significant risk to water quality.

- Within the swine sector, animal units was highly correlated with the quantity of nutrients (phosphorus and nitrogen) excreted by the animals.
- Nutrient management sustainability is better measured as the ratio of nutrients excreted, or nutrients land applied and the nutrient assimilation capacity of the land base. (Chapter 4)

The environmental objectives of co-permitting may be obtained with market mechanisms or other regulatory rules.

Co-permitting, as recommended by the EPA, may result in:

- a negative impact on market transactions for excess manure,
- Increased administrative and manure management costs,
- Increased regulatory monitoring and enforcement costs.

Sludge accumulation in lagoons needs to be treated as a fertilizer rather than a manure.

- Current data on nutrient concentration in sludge indicates it is too concentrated to be applied on a phosphorus basis.
- Technologies for processing the sludge into a concentrated fertilizer are being developed and should be fostered by allowing markets for manure nutrients.

We recommend that the USEPA take care to promote appropriate application of manure nutrients by promoting markets for manure.

- Adoption of a phosphorus rule will require that farmers gain spreading rights to more land.
- The current proposal that all land receiving manure have a nutrient management plan creates a barrier to non-CAFO acceptance of manure.

Chapter 1
INTRODUCTION

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1.1 INDEX

1.2 THE RESEARCH TEAM

Members of the Commercial Agriculture Program of the University of Missouri have authored this report. The Commercial Agriculture Program consists of teams of faculty and staff who research and educate farmers who make a living in agriculture on how to improve profitable production. Members of the crops focus and swine focus teams joined together to address manure management from a systems perspective.

The teams developed models for on-farm evaluation of manure management that included feeding management, storage structures, cropping activities and land application techniques. These integrated models allowed the analysis of "what if" scenarios so that producers learn what the land, time and economic impacts of changes in management would mean to them.

The UM Commercial Agriculture Program was contacted by the National Pork Producers to help producers understand the implications of proposed USEPA regulations of confined animal feeding operations. By interviewing pork producers in five states and modeling their current manure management practices, the team developed a database of current practices. These same farms were then subjected to various changes in manure management according to the proposed EPA CAFO rules.

This report is a summation of the results from the analysis of the 31 farms in five states.

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1.3 BACKGROUND

On January 12, 2001, the United States Environmental Protection Agency (USEPA) published proposed changes to the National Pollutant Discharge Elimination System Permit Regulation and the Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations in the Federal Register (Federal Register, p 2960-3145). These two regulations describe the approach the USEPA uses to define and regulate concentrated animal feeding operations (CAFOs) under provisions of the Clean Water Act.

The *National Pollutant Discharge Elimination System* (NPDES) provisions define which operations are CAFOs and establish the permit requirements for those operations. The existing NPDES rules used to regulate CAFOs were issued March 18, 1976. The *Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations* (ELG) establish the technology-based effluent discharge standards for CAFOs. The existing ELG for CAFOs were issued February 14, 1974.

The USEPA is considering extensive revision of the current rules governing manure management for (CAFOs) under provisions of the Clean Water Act. Their objective is to update and otherwise revise the current rules to better protect and restore water quality and address changes in the structure of the animal feeding industry (Federal Register, p 2972).

1.4 REPORT OBJECTIVES

This report addresses the feasibility and costs of two proposed revisions of the ELG on U.S. animal feeding operations. Chapters 2, 3 and 4 evaluate the feasibility and costs of implementing restrictions on nutrient applications so as to not exceed the crop and soil requirements for nutrients, particularly phosphorus, as proposed in part 412.31 (Federal Register p 3142; provision 412.31(b)(1)(iv). This provision is known as the “phosphorus rule”, and is considered the best practicable control technology currently available (BPT). As a BPT, all CAFOs are expected to meet the requirements of this provision.

Chapter 2 presents the theoretical analysis used to define the challenges facing an operation changing from nitrogen-based management to rotational phosphorus-based management. Rotational phosphorus-based management is defined as the application of manure, based on crop nitrogen need, but no additional manure is applied until crops remove the excess phosphorus. Our theoretical model shows that phosphorus limits will have the largest impact on producers of crops with high nitrogen to phosphorus ratios (e.g. alfalfa and other hays) and on those farmers that produce manure types with low nitrogen to phosphorus ratios (e.g. poultry litter and other solid manure types). Phosphorus limits will increase land need from 0% to 900% depending on crop and manure characteristics. The greatest increase in land needed to appropriately distribute manure will occur in those regions of the country that have low crop productivity and that are dependent on crops having relatively high nitrogen to phosphorus ratios.

Chapter 2 also establishes that switching to a rotational phosphorus limit will cause application time for tractor-pulled spreader systems to increase due to the additional time needed to reach the additional acres required. The primary potential effect on application time for an irrigation spreader system is the additional setup time needed to reach the additional acres required to meet the phosphorus rule.

Chapter 3 demonstrates why the rotational phosphorus approach is the only feasible method for implementing phosphorus limits on many farms. Annual phosphorus limits are shown to require farmers to reduce the annual, per acre application rate of manure by up to 90%. Current slurry manure application technologies cannot apply some concentrated manures (e.g. swine pit slurry and poultry litter) at annual phosphorus rates. Those types of manure that can be applied at annual phosphorus rates will require producer investment in new or modified application equipment. Compliance with an annual phosphorus limit will reduce spreading discharge rate, increasing the time required for application of manure. Additionally, it will promote surface application of manure and require farmers to apply supplemental nitrogen to all nitrogen-requiring crops that receive manure.

Chapter 3 commends rotational phosphorus limits as allowing farmers to: 1) rotate fields receiving manure, targeting crops that need both nitrogen and phosphorus; 2) use manure to meet all fertilizer needs of the crop in the year manure is applied, eliminating the cost and time required to apply fertilizers other than manure to the crop; and 3) apply manure at rates that are able to use current equipment complements, minimizing expense and time increases that would result from a phosphorus limit. Chapter 3 also establishes that there will be little or no difference in water quality benefit from mandating an annual phosphorus rule instead of a rotational phosphorus limit.

Chapter 3 concludes by proposing that the existing wording in Federal Register, p 3142, provision 412.37 (a)(2) *i* and *ii* be replaced with the following text: “Multi-year phosphorus applications are permissible as long as they do not exceed the nitrogen limit for the current crop year. The phosphorus store should not exceed five years of crop need if there is a high or very high risk of phosphorus loss.”

Chapter 4 presents the results of a simulation analysis of 31 farms in five states switching from a nitrogen limit to a phosphorus limit. Our analysis estimates that one farm could not comply due to low productivity soils receiving manure and six of the remaining 30 farmers capable of applying manure under a phosphorus rule (20%) fall under the EPA’s definition of moderate impact to stress. All are contract producers. Five are in PA and one is in IA. All apply pit slurry with a tanker. Forty-six percent of contract producers are in the stress category. We predict that the EPA’s economic assessment of farms in the moderate to stress categories is underestimated. Table 10-6 of the Preamble (Federal Register, p 3090) reports that the EPA estimates that 20% of the hog producers will be in the moderate to stress categories. Their estimate of 20% includes the cost of attaining zero discharge. Our estimate of 20% considers only the cost of implementing a rotational phosphorus limit.

Chapter 5 addresses the technical feasibility of attaining the “zero discharge” rule on existing swine operations as proposed by USEPA (Federal Register, p 3144). The USEPA states that this standard is considered the “best available technology economically achievable (BAT).” All BATs are to be implemented on existing swine farms under the new ELG. The USEPA recommended the following three strategies for the swine industry to meet the “zero discharge” rule:

1. Improved water management,
2. Impermeable lagoon covers, and
3. Additional storage.

In Chapter 5, each of these strategies was evaluated to determine the technical feasibility of the swine industry adopting the strategies to meet the “zero discharge” rule. Improving water management by implementing water reduction methods will not reduce effluent volumes that flow into earthen manure storages and anaerobic lagoons enough to provide any appreciable increase in storage period. An increased storage period, if it existed, would help swine operations meet the “zero discharge” rule. A number of technical feasibility issues and challenges exist that significantly limit the potential for successful implementation of impermeable covers for a significant portion of the swine industry. The potential of implementing additional storage was evaluated and does have the potential to help meet the “zero discharge” rule. However, the suggested scenarios do not guarantee a “zero discharge” because the storage may overflow when a rainfall event occurs that is greater than the design storm used to size the structure. The only structures that can be assured to meet a “zero discharge” criterion due to rainfall are covered structures that do not have rainfall or runoff entering the storage structure.

Chapter 6 presents the agronomic and economic impact of mandating “zero discharge” for swine operations by implementing the use of impermeable covers for anaerobic lagoons. The initial cost of installing an impermeable cover and the annual expense of land applying manure from the covered storage was evaluated for a portion of the surveyed farms. With a covered anaerobic lagoon, a system change for the nutrient balances within the swine operation would occur. The plant available nutrient concentrations of the effluent from a covered lagoon would be more like covered pit slurry than anaerobic lagoon effluent. Since more plant available nutrients were available from covered anaerobic lagoon effluent, the amount of crop acres needed to assimilate the plant nutrients increased significantly. The added economic expenses related to implementing the use of an impermeable cover and the increased land application costs make the implementation of a “zero discharge” rule prohibitive for most anaerobic lagoon based swine production facilities.

Chapter 6 evaluates the agronomic and economic impact of alternative methods to potentially meet the “zero discharge” rule. The alternative methods included building additional second storage cells, constructing emergency storage cells, and converting to slurry storage tanks. Converting to a slurry storage tank system had very similar results as implementing impermeable covers and makes this conversion prohibitive for most anaerobic lagoon based swine production facilities. Adding a second storage cell to expand storage capability to 18 months appears to be a feasible option for a large portion of lagoon based swine production facilities. Building an emergency storage cell provide expanded storage capability and appears to be feasible for all lagoon based swine production facilities. However, the second storage cell and the emergency storage cell options cannot meet the “zero discharge” rule as the EPA has stated. The additional storage capability does have the ability to protect the environment by reducing overflow potential. If adopted, an “upset and bypass” provision will be needed in the permit to implement either of the additional storage options, additional storage cells or emergency storage cells.

Chapter 7 presents issues related to the co-permitting options discussed in the proposed rule. With co-permitting, the EPA and associated permitting authorities would require both owners and operators of CAFOs to hold NPDES permits.

Three environmental objectives of co-permitting are:

- to improve manure management by contractors/growers via regulatory pressure on the integrators;
- to create a nutrient management system for manure that cannot be utilized on site by the CAFO owners; and
- to create an incentive for the integrator to minimize source loading of nutrients and compounds (e.g. in feed) that directly or indirectly impact the composition of the manure.

Co-permitting will result in an increase in administrative and manure management costs as well as regulatory monitoring and enforcement costs related to excess manure that had previously been transferred from CAFOs. Co-permitting will likely have a negative impact on market transactions for excess manure. The environmental objectives of co-permitting may be obtained with market mechanisms or other regulatory rules.

1.5 INTENTION OF THE “PHOSPHORUS RULE”

The proposed changes to the NPDES and ELG provide conflicting signals on the intent and scope of the proposed “phosphorus rule.” The phosphorus rule states that “State approved indices, thresholds and soil test limits shall be utilized such that application does not exceed the crop and soil requirement for nutrients” (Federal Register, p 3142).

Assumptions made regarding how the phosphorus rule is imposed and to what extent it is imposed directly affect projected costs and feasibility of such a rule. The USEPA includes proposals that all land receiving manure must utilize the phosphorus standard. However, the USEPA’s economic analysis of the proposed rules assumes that manure applied to uncontrolled acres (i.e. land not owned/rented by the CAFO) was applied based on the nitrogen content of the manure.

USEPA clearly intends that all land under control of the CAFO fall under the provisions of the phosphorus rule. All controlled land receiving manure is required to have a permit nutrient plan (PNP) that includes an evaluation of the phosphorus status of the soil (Federal Register, p 3142).

The USEPA wants to ensure that manure spread on land is applied in accordance with the phosphorus rule through at least four mechanisms. First, the USEPA is proposing that CAFO operators obtain a letter from all farmers receiving manure on uncontrolled acres certifying that they are following the phosphorus rule provision (Federal Register, p 3138). The text explicitly states that people receiving manure certify that they do not apply manure "in quantities that exceed the land application rates calculated using the method specified in Federal Register, p 3142, provision 412.31(b)(1)(*iv*) …"

A second approach to ensuring a phosphorus rule is used on all acres receiving manure is through the co-permitting provisions of the proposed rule. It is the USEPA's intent that integrators would "develop and implement a program to ensure proper management and/or disposal of excess manure." Through this program, the USEPA intends for the integrator to develop innovative incentives that ensure manure applied to CAFO controlled land is done in accordance with permit limits (Federal Register, p 3025).

USEPA is also proposing that land receiving manure from CAFOs ("either from their own operations or obtained from a CAFOs") not qualify for the agricultural storm water exemption unless manure is applied in accordance with "proper agricultural practices" as defined by the PNP. Farmers receiving manure from a CAFO and applying it on their land could be cited as a point source if they failed to use the phosphorus rule to establish manure application rates (see Federal Register, p 3029-3031).

Finally, the USEPA is using a large voluntary effort by animal feeding operations to implement comprehensive nutrient management plans (CNMPs) on their farms (Federal Register, p 2966). These CNMPs, as defined by the Natural Resource Conservation Service (NRCS), will have a phosphorus assessment analogous to the phosphorus rule on all land receiving manure.

Given the oft repeated objective that manure applied both to CAFO controlled land and uncontrolled land be applied in a manner in accordance with the permit requirements of the CAFO, this report assumes that all fields receiving manure will incur the requirements of a PNP. This includes expenses for the phosphorus assessment, PNP implementation and record keeping.

It is further assumed that phosphorus-based application rates will be limited by the phosphorus removal capacity of crops produced on the land. While nitrogen-based rates may be appropriate in the short term, manure applications on *all* land receiving manure will be limited by phosphorus rate over the long term. Farmers must assume nitrogen-based rates will not be tenable on all land receiving manure under the proposed rules.

The proposed phosphorus rule states that one of three approaches will be adopted statewide at the discretion of the USEPA and the NRCS state conservationists (Federal Register, p 3056). The three approaches are the phosphorus index, the phosphorus threshold level and the soil test phosphorus level. Two of these approaches (threshold and soil test) are predicated on the concept that a soil has a finite capacity for added phosphorus (i.e. increasing soil test phosphorus will cause phosphorus limits to be imposed with these approaches). In the case of the soil test approach, many agricultural soils will already have a phosphorus level that requires manure application based on the phosphorus removal capacity of the crop grown or may even preclude manure applications. Soil test phosphorus is also a prominent component of most phosphorus indexes.

Crop farmers receiving manure from CAFOs will have a strong disincentive to allow manure applications above phosphorus crop removal rates once their soil is at the agronomic optimum phosphorus level under the proposed USEPA rules. Allowing a neighboring CAFO to apply manure and raise soil test phosphorus up to or near the "very high" level lowers the value of the farmers land for any future expansion into an animal feeding operation. A new CAFO on a farm that has no history of manure applications may have an abundance of land near the buildings available for manure application. Prudent crop farmers will choose to conserve the value of their land by requiring the CAFO to apply manure at rates that do not exceed the phosphorus removal capacity of the land.

In summary, this report assumes that long-term land needs of CAFOs for manure application must be based on the phosphorus removal capacity of the cropped land. This decision was based on:

- The USEPA's intent that a phosphorus assessment be used on all land receiving manure;
- The uncertainty on how the phosphorus rule will be implemented in each state; and
- The disincentive farmers receiving manure will have for taking manure phosphorus in excess of crop need.

It follows that the USEPA underestimates land requirements for the phosphorus rule by assuming that CAFOs can apply manure on uncontrolled acres based on the nitrogen need of the crop. Our approach also may underestimate CAFO land need because we assume that all land on controlled and uncontrolled acres can receive manure. It is likely that on some CAFOs' land the phosphorus assessment will rate "very high," triggering a ban on manure application on those acres.

1.6 REFERENCES

Federal Register, Washington, DC., January 12, 200. pages 2960-3145.

Chapter 2
FEASIBILITY OF ADOPTING PHOSPHORUS-ROTATION LIMITS VERSUS NITROGEN LIMITS FOR MANURE APPLICATION

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2.1 INDEX

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2.2 EXECUTIVE SUMMARY

Chapter 2 discusses eutrophication problems that result from excess phosphorus entering surface water. Analyses of phosphorus application strategies that include a phosphorus rotation based approach are presented. These analyses provide a basis for evaluating strategies that allow flexibility in manure application and that are environmentally sound.

Changing from nitrogen based manure application rates to phosphorus limiting application rates requires evaluation of variables that affect the different phosphorus limiting application strategies. Variables evaluated in this study include crop nutrient removal capability; yield variations, soil productivity and manure nutrient concentrations from different manure collection, storage and handling systems. Case study farms were used to evaluate how implementation of manure phosphorus application rate limits would increase land area and manure application time requirements. Results also include effects of the application variables as they influence manure application.

Specific results are listed below:

- This analysis evaluated converting from nitrogen-based application rates to a phosphorus rotation based rate approach where manure is applied based on crop nitrogen need, but where no additional manure is applied until subsequent crops remove the phosphorus.

- Phosphorus limits will have a major impact on producers of crops such as alfalfa and other hays in which the harvested portion of the crop has a high nitrogen to phosphorus ratio.

- Phosphorus limits will also have a major impact on those farmers who produce manure types with low nitrogen to phosphorus ratios such as poultry litter and other solid manure types.

- Regions of the country that have low crop productivity and are dependent on crops that use relatively high amounts of nitrogen compared to phosphorus (e.g. hay crops), will require the greatest increase in land to meet a phosphorus application standard.

- Phosphorus application limits will increase land needed for manure application as much as 900% and as little as 0%, depending on crop removal capabilities and manure characteristics.

- The primary effect on application time for a truck-mounted or tractor-pulled spreader system is the additional travel time required to reach the additional acres required to comply with the phosphorus application rule. Actual land application time increases only if the phosphorus rotation application rate has an upper limit that causes the application rate to be reduced such that the equipment discharge rate must be

reduced. No effect on loading time existed because the same volume of manure is being loaded into the same size spreader, regardless of nutrient limit.

- The main potential effect on application time for an irrigation spreading system is the increased setup time required to reach the additional acres required to meet the phosphorus rule. Discharge time and moving the irrigation system between pipe risers has little effect on the time required to irrigate because the manure volume applied is the same as under a nitrogen limit.

- Unagitated lagoon effluent systems will require little additional land under a phosphorus application rule because the effluent typically has a high nitrogen to phosphorus ratio. A requirement to agitate the lagoon will reduce the N:P ratio and increase land requirements for applying the effluent.

2.3 INTRODUCTION

Phosphorus is typically the most limiting nutrient in most freshwater aquatic systems (Sharpley et al., 1994). Increasing the quantity of phosphorus reaching a stream or lake will promote growth of aquatic flora and fauna. Excessive phosphorus will degrade water quality through the process of eutrophication. Negative attributes of eutrophic water bodies include reduced water clarity, excessive algal growth, low oxygen content, altered fisheries, increased filtration costs and objectionable taste for drinking water sources, and in excessively eutrophic waters, water-born toxins from cyanobacteria.

Mismanagement of fertilizers such as manure increases the quantity of phosphorus in runoff from agricultural fields. Increasing soil test phosphorus in a field will increase the concentration of phosphorus in runoff from the field (Pote et al., 1999; Sharpley et al., 1994). Runoff from fields soon after a surface application of phosphorus as chemical fertilizer or manure also results in high phosphorus concentrations in runoff (Daniel et al., 1993; Shrever et al., 1995)

Manure nutrients have been regulated based on the nitrogen content of the manure. Manure application rates could not exceed the annual nitrogen need of the crop. Many manure sources contain more phosphorus and other nutrients than the crop requires when applied based on the nitrogen requirement of the crop. Soil test phosphorus and other soil nutrient tests increase rapidly when these sources of manure are applied every year based on the nitrogen requirement of the crop.

The potential for water quality degradation from mismanagement of manure phosphorus has resulted in voluntary and regulatory efforts to include phosphorus restrictions on manure application rates for agricultural fields. The NRCS agronomy standard (NRCS, 2000) and the proposed EPA rules governing confined animal feeding operations (Federal Register, 01/12/2001) include provisions that manure be applied based on the phosphorus removal rate of the crop. In both standards, phosphorus status of the soil is assessed by one of three methods: the phosphorus index, the phosphorus threshold or the soil test phosphorus level. Manure can be applied every year based on the annual nitrogen requirements of the crop to fields with a low or medium rating in accordance with the chosen assessment method. Phosphorus and nitrogen limits must be observed on fields with a high rating by the selected assessment method. No manure applications are allowed on fields rated very high.

Phosphorus-based strategies for manure application

There are at least two potential strategies for implementing phosphorus limits for manure application. Phosphorus rotation is the term we use to describe the practice of applying more than one year of phosphorus to a soil and then not applying manure until an equivalent amount of phosphorus has been harvested from the field as crops, meat or milk. In a nitrogen-based phosphorus rotation approach, manure is applied to the crop based on the nitrogen needs of the crop. After a manure application based on nitrogen, no additional manure is applied until an equivalent amount of phosphorus has been harvested from the field by crops, meat or milk. A nitrogen-based phosphorus banking strategy allows the farmer to apply manure to a field at the same rate he has in the past, but requires that he reduce the number of times manure is applied to a specific field. A farmer using a nitrogen-based phosphorus banking strategy will be able to use the same land-application equipment, pumping rates and application speeds as were previously used for nitrogen-based management.

Alternatively, phosphorus could be limited to the annual crop needs of the crop. In this strategy, crop phosphorus removal capacity will be met each year with a manure application. However, the manure will frequently provide insufficient nitrogen to meet crop needs and additional fertilizer nitrogen may be required each year. Many farmers adopting annual phosphorus limits will likely need to reduce manure application rates.

In Chapter 3 we detail the benefits of the nitrogen-based phosphorus rotation method compared to the annual phosphorus limit approach. Benefits of the phosphorus rotation strategies include: 1) allowing the farmer to continue to use the same equipment to apply manure and 2) the ability to use manure to meet the full fertilizer need of the crop in years manure is applied, thus increasing the value of the manure and reducing fertilization costs on fields receiving manure.

Constraining farmers to apply only one year of manure phosphorus per pass of the manure spreader will result in greater costs. This is due to more time being needed for manure application and for new equipment or modifications to existing equipment to attain lower manure application rates. These costs will affect most farmers applying manure with a low nitrogen to phosphorus ratio (e.g. poultry litter and swine slurry) to crops with a high nitrogen to phosphorus ratio (e.g. alfalfa and bermuda grass). Operators applying unagitated swine lagoon effluent will likely be unaffected by the type of phosphorus rule because of its high nitrogen to phosphorus ratio.

The effluent limitation guideline proposed by the EPA explicitly prohibits phosphorus banking strategies to meet phosphorus application limits ("Multi-year phosphorus applications are prohibited when either the P-index is rated high, the soil phosphorus threshold is between ¾ and 2 times the threshold value, or the soil test phosphorus level is high…"; Federal Register, 1/12/2001, pg. 3142). If the rule is adopted as proposed, the analysis in this chapter will underestimate costs and not address infeasibility issues associated with annual phosphorus limits contemplated by the EPA.

We chose to evaluate the phosphorus rule based on its least restrictive form, the phosphorus rotation approach. We based our analysis on the nitrogen-based phosphorus rotation limit because that is the most feasible and least expensive of the two approaches to a phosphorus rule. If the USEPA chooses to implement the annual phosphorus limit, the total costs of the proposed EPA approach would be the sum of incremental costs developed here for conversion from nitrogen-based applications to nitrogen-based phosphorus rotation approach plus the incremental costs developed in Chapter 3 associated with conversion from a nitrogen-based phosphorus rotation approach to an annual phosphorus limit.

This chapter evaluates removal capacity of selected crops throughout the U.S. and determines anticipated annual phosphorus application rates for selected classes of manure. These application rates were then compared to the technical specifications of selected, currently available land application equipment.

2.4 MATERIALS AND METHODS

The top concentrated livestock producing states (Table 2-1) were identified based on being in the top ten states according to the 1997 Census of Agriculture in at least one of the following six categories of animal feeding operations (NASS, 1997): dairy (*Bos taurus*), cattle fatted on grain, pig (*Sus scrofa*) inventory, layers (*Gallus domesticus*), broilers or turkeys (*Meleagris gallopavo*). States included were Alabama, Arkansas, California, Colorado, Delaware, Georgia, Iowa, Idaho, Illinois, Indiana, Kansas, Maryland, Michigan, Minnesota, Missouri, Mississippi, North Carolina, Nebraska, New York, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Texas, Virginia, Washington and Wisconsin.

We estimated the range of typical yields for the 28 major concentrated livestock states for the crop categories corn (*Zea mays*), corn silage, soybean (*Glycine max*), wheat, alfalfa (*Medicago sativa*) and other hay based on state mean yields between 1990 and 1999 (NASS, 2000). The state with the minimum 10-year mean yield, the state with the maximum 10-year mean yield and the 28-state mean yield and standard deviation of the selected states were identified (Table 2-2). Some crops were not grown in significant quantities in all states (NASS, 2000), so for these crops fewer than 28 states were included in the analysis.

Nitrogen and phosphorus removal capacity of the harvested portion of the crop were developed through literature review for the selected crops (Table 2-3). These were used to calculate nitrogen and phosphorus removal rates for minimum, maximum and mean yields for each crop where:

$$\text{nutrient removal} = \text{yield} \times \text{removal capacity}/\text{yield unit} \qquad \text{Eq. 2-1}$$

Phosphate removal capacity of the other hay category (cool and warm season grasses) was based on 12 lb P_2O_5/ton.

Typical nutrient concentrations for selected types of manure were developed through a literature review (Table 2-4). Manure was divided into two categories, liquid (slurry and lagoon effluent) and solid. Nutrient concentrations in liquids were reported as lbs/1000 gallons and nutrient concentrations in solids were reported as lbs/ton. Nutrient concentration was also reported as percent nutrient concentration where liquid manure was assumed to have a density of 8.3 lb/gal.

Table 2-1. States ranking in top 10 of livestock production.

State	Hogs	Dairy	Cattle on Feed	Broilers	Turkeys	Layers
AL				3		4
AR				2	5	3
CA		1	7	8	6	6
CO			4			
DE				9		
GA				1		1
ID	4					
IN	6				7	7
IA	1		5			10
KS	10		2			
MD				7		
MI		9				
MN	3	5	10		2	
MS				5		
MO	7				3	
NE	5		3			
NM		10				
NY		3				
NC	2			4	1	9
OH	9					2
OK	8		6			
PA		4			10	5
SC					8	
SD			8			
TX		6	1	6	9	8
VA				10	4	
WA		8				
WI		2				

Source: (NASS, 1997)

Note: Values in each column are the ranking of the state in each of the 6 categories; blanks indicate the state is not in the top ten states in that category.

Plant available nitrogen was estimated by assuming 65% of the organic nitrogen (75% for poultry manure) was available to the crop, and 60% (surface applications) or 100% (injected manure) of the NH4-N was available to the crop. Crop need for phosphorus was estimated based on crop removal capacity of the crops in the rotation. Manure phosphorus was assumed to be 100% available. Manure application rates were limited by the lesser of nitrogen requirement of the crop in the year of application or the 4-year phosphorus need of the crop rotation. After the 4-year phosphorus need of the rotation was met with manure applications no additional manure was applied to a field until crop removal had removed the applied phosphorus. This approach was designated as the nitrogen-based phosphorus rotation approach.

Manure application rate of selected land application technologies was calculated using the equation:

$$\text{Application rate} = \frac{\text{discharge rate}}{\text{travel speed} \times \text{effective swath width}} \quad \text{Eq. 2-2}$$

For liquid manures application rate was calculated in gallons/acre; for solid manure it was calculated in tons/acre.

Table 2-2. Mean, standard deviation of the mean, minimum and maximum mean state yields of selected crops among states ranking in the top 10 in livestock production.

Crop	n	Yield Units	Mean Yield	Std. Dev.	Max. Yield	Top 5 States	Min. Yield	Bottom 5 States
Corn grain	28	bu/ac	117	25.0	185	WA, CA, CO, ID, KS	72	SC, AL, NC, SD, GA
Corn silage	28	tons/ac	15	4.2	26	WA, CA, ID, CO,TX	8	SD, AL, SC, MS, MO
Soybean	23	bu/ac	32	6.8	43	IA, IN, IL, WI, NE	22	SC, GA, OK, AL, MS
Wheat	28	bu/ac	49	12.0	78	ID, CA, WA, DE, OH	29	OK, TX, SD, MN, CO
Alfalfa	24	tons/ac	3.6	0.9	6.8	CA, WA, TX, ID, KS	2.3	SD, NY, WI, NC, MO
Other hay	28	tons/ac	2.1	0.4	2.8	CA, DE, WA, GA, IN	1.3	NE, SD, OK, CO, PA

Note: Yield data are based on state mean yields between 1990 and 1999 (NASS, 2000).

Table 2-3. Nutrients removed in the harvested portion of selected crop[1].

Crop	Yield Unit	N (lbs/unit)	P_2O_5 (lbs/unit)	$N:P_2O_5$ Ratio	K_2O (lbs/unit)
Corn grain	bushels	0.9	0.4	2.3	0.3
Corn silage	tons	8.4	3.8	2.2	8.9
Soybean	bushels	3.4	0.8	4.3	1.4
Wheat	bushels	1.3	0.7	1.9	0.4
Bermuda grass hay	tons	49	11	4.5	42
Big bluestem hay	tons	20	11	1.8	26
Tall Fescue hay	tons	39	14	2.8	53
Alfalfa hay	tons	50	12	4.2	50

Note: Values are reported as nitrogen (N), phosphate (P_2O_5) and potash (K_2O).

[1]Sources:

NRCS. 1992. Agricultural waste management handbook. U.S. Department of Agriculture Soil Conservation Service, Washington DC.
Buholtz, D.D. 1992. Soil Test Interpretations and Recommendations Handbook, Department of Agronomy, University of Missouri, Columbia, MO.
Potash Phosphate Institute, Norcross, GA.
Agronomy Guide, The Pennsylvania State University, State College, PA.
North Carolina State University, AG-439-16
General Guide for crop nutrient recommendations. March 1999. Iowa State University, Ames, IA.
Atlas of nutritional data on US and Canadian Feeds. 1971. National Acad. of Sciences, Washington, DC.
Griffith, W.K. and L.S. Murphy. 1996.
Macronutrients in Forage Production. In (R.E. Joost and C.A. Roberts eds.) Nutrient Cycling in Forage Systems. Proc. Of a conference held March 7-8, 1996. Columbia, MO. PPI, Manhattan, KS

Table 2-4. Typical nutrient concentration in selected sources of manure[1].

						PAN:P_2O_5 Ratio	
Manure Source	Units	Total N	NH_4-N	P_2O_5	K_2O	Surface-applied	Injected
Pigs							
Grow finish - deep pit	lb/1000 gal	50	33	42	30	0.73	1.04
Grow finish - wet/dry feeder deep pit	lb/1000 gal	75	50	54	40	0.86	1.23
Grow finish - earthen pit	lb/1000 gal	32	24	22	20	0.89	1.33
Farrow-finish pit	lb/1000 gal	28	16	24	23	0.73	0.99
Nursery pit	lb/1000 gal	25	14	19	22	0.82	1.11
Grow-finish unagitated lagoon	lb/1000 gal	4.0	4.0	2.0	3.0	1.20	2.00
Farrow-finish unagitated lagoon	lb/1000 gal	4.5	4.0	2.9	3.6	0.94	1.49
Grow finish - solid	lb/ton	16	6	9	5	1.12	1.39
Farrow finish - solid	lb/ton	14	6	8	5	1.10	1.40
Nursery - solid	lb/ton	13	5	8	4	1.03	1.27
Dairy cows							
Pit	lb/1000 gal	31	6	15	19	1.32	1.48
Unagitated lagoon	lb/1000 gal	4.1	3.6	1.7	2.9	1.46	2.31
Solid	lb/ton	10	2	3	7	2.13	2.40
Beef cows							
Finish - pit	lb/1000 gal	29	8	18	26	1.03	1.20
Finish - solid	lb/ton	11	4	7	11	0.99	1.22
Feedlot solid	lb/ton	24	-	16	3	-	-
Feedlot lagoon sludge	lb/1000 gal	52	-	18	14	1.88	1.88
Poultry							
Broiler litter	lb/ton	71	12	69	47	0.75	0.82
Broiler breeder litter	lb/ton	37	8	58	35	0.46	0.51
Turkey litter	lb/ton	55	12	63	40	0.63	0.70
Turkey breeder litter	lb/ton	35	8	47	18	0.53	0.60
Layer - solid	lb/ton	34	12	51	26	0.46	0.56
Layer - pit	lb/1000 gal	57	37	52	33	0.72	1.00
Layer lagoon liquid	lb/1000 gal	27	23	7.1	42	2.37	3.66
Layer lagoon sludge	lb/1000 gal	84	26	308	40	0.19	0.23
Layer under cage	lb/ton	28	14	32	20	0.59	0.77

Notes: All values are on an "as-is" or wet basis. Plant available nitrogen (PAN) estimates the fertilizer value of manure when surface applied or injected.

[1]Sources:

MWPS. 2000. Manure Characteristics. Midwest Plan Service, 122 Davidson Hall, ISU, Ames IA.

NRAES-132. 1999. Poultry waste management handbook. Natural Resource, Agriculture, and Engineering Service, Ithaca, NY.

NRCS. 1992. Agricultural waste management handbook. U.S. Department of Agriculture Soil Conservation Service, Washington DC.

2.5 RESULTS AND DISCUSSION

2.5.1 Proportional increase in land requirements

Manure and harvested crop characteristics determine the percent increase in land requirements of a farmer converting from an annual nitrogen-based application rate to a phosphorus-based application rate. The percent increase in acres needed if adopting a phosphorus rule (P_{INC}) is a function of the $N:P_2O_5$ ratio of both the crop fertilizer need and the manure where:

$$P_{inc} = \left(\frac{\text{crop fertilizer } N:P_2O_5 \text{ ratio}}{\text{manure PAN}:P_2O_5 \text{ ratio}} - 1 \right) \times 100\,\% \qquad \text{Eq. 2-3}$$

This calculation assumes that the land currently receiving manure and the additional land have similar crops and fertilizer needs and manure is currently applied based on the nitrogen need of the crop. Alternatively, the percent decrease in manure application rate (R_{DEC}) when transitioning from a nitrogen-based rate to a phosphorus-based rate is:

$$R_{DEC} = \frac{\text{manure PAN}:P_2O_5 \text{ ratio}}{\text{crop fertilizer } N:P_2O_5 \text{ ratio}} \qquad \text{Eq. 2-4}$$

The $N:P_2O_5$ ratio of crops typically is greater than the $PAN:P_2O_5$ ratio of manure (compare Tables 2-3 and 2-4). Harvested crops typically have a $N:P_2O_5$ ratio of 1.8 to 4.2 (Table 2-3). Manure $PAN:P_2O_5$ ratios range from 0.5 to almost 5 although most are below 1.5 (Table 2-4). Farmers adopting a phosphorus limit under typical conditions will need to reduce per acre manure application rate and increase acreage receiving manure. For example, a farmer converting to a phosphorus limit would need to increase acres for manure application by 220% (using Eq. 2-3, ((2.3/.73)-1) x 100) if surface-applying finishing pig slurry to corn. Only injected lagoon effluent consistently exceeded some crop $N:P_2O_5$ ratios. In these situations, nitrogen, not phosphorus, will limit manure application rates, and there will be no increase in land requirements.

The harvested components of all crops have a greater fertilizer nitrogen need or nitrogen removal capacity than phosphorus removal capacity ($N:P_2O_5$ ratio > 1; Table 2-3). Crops with the highest fertilizer nitrogen need compared to phosphorus need (highest $N:P_2O_5$ ratios) will be most affected by conversion to a phosphorus standard. Soybean, bermuda grass and alfalfa hay had the highest reported $N:P_2O_5$ removal ratios for the harvested portion of the crop (Table 2-3). Crops with higher phosphorus need compared to nitrogen, or fields needing phosphorus in excess of crop phosphorus removal, will be less affected by conversion to phosphorus removal-based rates.

Manure types with the lowest $PAN:P_2O_5$ ratio will be more affected by conversion to an phosphorus standard. Manure nitrogen available to the crop (PAN), not total nitrogen content of the manure, is the critical component. Consequently, surface applied manure is more affected by conversion to phosphorus application rates than injected manure because losses during surface application of manure reduce the manure PAN:P_2O_5 ratio.

Adopting phosphorus-based limits on application rates will require increasing land requirements for manure by up to a factor of 10 (Fig. 2-1). Manure has a greater range in PAN:P_2O_5 ratios compared to the N:P_2O_5 of crops (compare Tables 2-3 and 2-4). Therefore, differences among manure types and management cause the greatest range in increased acres required when adopting a phosphorus application rule. The largest increases are associated with solid manure such as poultry litter (e.g. up to a 900% increase acres when applied to soybean or hay). Increased acreage need for surface applications of slurry manure and unagitated lagoon effluent can exceed 350% on the same crops. Phosphorus-based application for some injected lagoon effluents will only require an increase in land of 15% for soybean and hay production.

The N:P_2O_5 ratios of the harvested portion of crops only vary by a factor of approximately 2 (Table 2-3). Consequently, potential increases in land need due to crop factors are less than those due to manure factors. For example, among poultry litter sources, phosphorus rates would require 220 (wheat) to 520% (alfalfa) more land. Similarly, among unagitated pig and dairy lagoon manure sources, phosphorus rates would require increasing land base by 60 to 250% (surface applied) and 0 to 120% (injected), depending on the crop produced.

In summary, phosphorus-based rates will result in increased land requirements for most animal producing farms. The proportional increase in acreage requirements is independent of crop yield or quantity of phosphorus produced by the animals. Phosphorus limits will have the largest impact on producers dependent on crops such as alfalfa and other hays where the harvested portion of the crop has a high N:P_2O_5 ratio. Phosphorus limits also will have the largest impact on manure types that have lower PAN:P_2O_5 ratios such as poultry litter and other solid manure types.

2.5.2 Quantity of additional land required

The additional acres a farmer needs to comply with a phosphorus rule (A_{INC}) is a function the quantity of phosphorus an operation land applies (P_{LA}) and the quantity of phosphorus a crop requires per acre (P_{CR}) where:

$$A_{INC} = \frac{PAN}{P_{CR} \times \left(1 - \left(\frac{manure\ PAN : P_2O_5}{crop\ N : P_2O_5}\right)\right)} \qquad \text{Eq. 2-5}$$

Any operational characteristics that increase phosphorus in the manure will increase the number of acres needed to meet a phosphorus rule (Eq. 2-5). Larger operations will need access to more acres to comply; operations that have slurry systems or agitate lagoons will have a greater increase in required acres when adopting a P rule than operations that apply unagitated lagoon effluent. At least 85% of the phosphorus entering an unagitated lagoon is retained in the sludge that remains in the bottom of the lagoon (MWPS, 2000). Consequently, these systems will require 85% fewer additional acres when converting to a phosphorus rule than a slurry system that applies all excreted phosphorus every year.

The productivity of the cropland receiving manure also has a significant impact on the amount of additional acres a farmer will need to comply with a phosphorus rule (Eq. 2-5). There is a wide range in soil productivity in the top animal feeding states (Table 2-2). States with the highest yields have mean yields that are 2 (soybean) to 3.25 (corn silage) times greater than the lowest yielding states. This means that under a phosphorus rule, the low crop productivity states will require 2 to 3.25 times more land to distribute the same quantity of phosphorus. For example, an average operation in South Carolina has lower yield potential for corn grain than one in Washington State (Table 2-2). The South Carolina operation would require 340 additional acres of land to adopt a phosphorus rule for a 1000-head finish swine operation that annually injects approximately 18,000 lbs of P_2O_5 as slurry. A similar operation in Washington State generating the same quantity of P_2O_5 would only require 130 additional acres of land. Both operations need to increase their land base by 120%, (((2.3/.73)-1) x 100, Eq. 2-3). The less productive soils require nearly 3 times more land to meet the requirements for a phosphorus rule.

Less productive soils also have greater risk for large swings in land requirements than more productive soils. The yields reported in Table 2-2 are 10-year means. In some years, yields can be substantially lower due to poor weather and other conditions. Following these years, farmers will need to access additional land for manure application. The per acre crop yield and phosphorus removal capacity is inversely related to the number of acres required (Eq. 2-5). Small changes in yield goal make a larger impact on the number of acres needed on low yielding sites than on high yielding sites (Fig. 2-2). A 5% drop in crop yield for a 1000-head swine finishing operation would require the owner to locate 70 acres of additional land in the South Carolina example, but only 29 acres in the Washington State example.

Regional cropping patterns, manure management systems and soil productivity will determine the regions of the U.S. most impacted by conversion to a phosphorus rule. The effect of manure type, cropping system and yield capacity of the land can combine to create vastly different impacts on the land requirements of a phosphorus rule for operations handling the same quantity of phosphorus. For example, a poultry operation that has dry litter containing 18,000 lbs of P_2O_5 (approximately 35,000 birds) and a PAN:P_2O_5 ratio of 0.75 applying manure to bermuda grass hay with a yield goal capacity of 2 tons/acre will require 680 acres of additional land to meet the requirements of phosphorus-based land application. A 1000-head swine finishing operation using a pit-slurry system generates a similar amount of P_2O_5. If either operation applies slurry to corn with a yield goal of 185 bu/acre, 70 acres of additional land will be needed. A swine finishing operation injecting unagitated lagoon effluent for wheat production may require no additional land for manure application because nitrogen, not phosphorus, limits land application rates for that manure source on wheat. The areas with the greatest potential impact will be those areas that already grow crops with low capacity to remove phosphorus (e.g. hay, Table 2-2), and those that have soils with limited productivity. These regions already require the most land to meet the current nitrogen requirements for land application and they will also require the largest increase in acreage to meet phosphorus-based acreage requirements for land application of manure.

Unagitated lagoons create a unique situation with respect to the adoption of phosphorus application limits. Until now, we have assumed that conversion from a nitrogen-based to a phosphorus-based rule would require application of the manure currently removed annually from the manure storage. Lagoon systems partition at least 85% of the phosphorus into the sludge, which remains in the lagoon after pumping unagitated effluent from the surface of the lagoon (MWPS, 2000). The lagoon effluent has a relatively high PAN:P_2O_5 ratio if it is injected into the soil, thereby minimizing ammonia nitrogen volatilization. If the phosphorus in the sludge is not accounted for, conversion to a phosphorus rule requires little adjustment for an operation that pumps from an unagitated lagoon. The analysis above addresses this scenario. Operations with anaerobic lagoons will need much larger increases for land application if lagoons must be agitated or other phosphorus accountability is required to meet a phosphorus rule. This topic is dealt with in greater detail in Chapter 4.

In summary, the amount of phosphorus generated by the farm, the productivity of the land, and the nitrogen to phosphorus ratios of the crop and the manure all affect the quantity of additional acres a farm would require to adopt a phosphorus rule. Regions of the country that have low crop productivity, and are dependent upon crops that use relatively high amounts of nitrogen compared to phosphorus (e.g. hay crops) will require the greatest increase in land to meet a phosphorus standard. Operations with manure that has a low PAN:P_2O_5 ratio such as solid and slurry manure will also be required to have greater land application areas to implement phosphorus rules. The effect of these factors can be large. For an operation that generates 18,000 lbs P_2O_5 annually, the added amount of additional land required for a phosphorus rule can range from 0 to more than 650 acres.

2.5.3 Time Effects Model

The objective of this section is to develop and evaluate equations describing the component activities of land application of manure. This analysis assumes that if a phosphorus rule is adopted, producers will be able to use a phosphorus rotation approach. A phosphorus rotation approach means they will be allowed to apply manure to meet the nitrogen needs of a crop and then refrain from additional manure applications on that field until crop removal depletes the excess phosphorus. This will result in an manure application pattern where manure will be applied to one set of fields the first year, a second set the next year and so on until crop removal of phosphorus allows a return to the first set of fields.

An annual phosphorus limit where manure applications cannot exceed the yearly phosphorus need of the crop was proposed by the USEPA (FR, 2001; page 3142). In Chapter 3 and 4, the feasibility and cost issues of the annual approach are addressed. We chose to evaluate phosphorus-based management using the phosphorus rotation approach in this chapter because of the infeasibility and increased cost of adopting the annual approach on many farms.

2.5.3.1 Truck-mounted and tractor-pulled spreaders

Total time needed for land application of manure for tractor-pulled and truck-mounted spreaders (T_{TOT}) is a function of loading time (LT), road travel time to the field (TT_R), in-field travel time to the point where spreading/injection begins and after spreading/injection ceases (TT_F), and discharge time (DT) where:

$$T_{TOT} = LT + TT_R + TT_F + DT \qquad \text{Eq. 2-6}$$

In this analysis, we are assuming that the farmer can apply manure at the same rate under the phosphorus rule as under the nitrogen rule in the years a field receives manure. Consequently, the farmer will be using the same equipment to haul the same number of loads of manure each year under the phosphorus rule as under the nitrogen rule. The primary change will be that the farmer may need to make applications to different fields in different years.

Loading time (LT) should not change because the same equipment is being used to pump similar amounts of manure with both strategies. Discharge time (DT) should not change between nitrogen-based and phosphorus-based land application approaches. Manure is being applied at the nitrogen-based need on all crops receiving manure in a given year under both scenarios. This result assumes additional acres needed for phosphorus-based applications have the same fertilizer needs as acres currently being used.

In-field travel time (from the field gate to the point of application and back) (TT_F) also should remain relatively constant between the nitrogen-based and phosphorus rotation-based approaches. This result also assumes that the additional fields needed to comply with the phosphorus rule are similar to the fields currently used for manure application.

Conversion to a phosphorus rotation-based phosphorus limit can have significant effects on road travel time (TT_R). Road travel time (TT_R) for tanker spreaders is a function of total distance traveled on the road to and from all fields receiving manure (D_{TOT-R}), road travel speed (MTS_R) where:

$$TT_R = D_{TOT-R} \times MTS_R \qquad \text{Eq. 2-7}$$

A convenient way to calculate TT_R is:

$$\mathrm{TT_R} = NOL \times AMDPT \times MTS_R \qquad \text{Eq. 2-8}$$

where NOL is number of loads per year and AMDPT is the annual mean distance per trip. A farmer applying manure to the same fields every year should find that AMDPT remains relatively constant from year to year.

When adoption of the phosphorus rule requires access to additional land for manure application, there is a potential for AMDPT to increase. It is possible that as more land is required for manure application, the farmer will have to travel longer distances to reach that land. However the specific effects of the phosphorus rule on travel time will be highly site specific depending upon the current amount of road time spent reaching fields receiving manure and the location of the additional land used to meet the new requirements of the phosphorus rule. The incremental increase in road travel time ($TT_{R\text{-}INC}$) will be:

$$\mathrm{TT_{R-INC}} = \left(\mathrm{AMDPT_{P-Rule}} - AMDPT_{current}\right) \times NOL \times MTS_R \qquad \text{Eq. 2-9}$$

where $AMDPT_{P\text{-}RULE}$ is the average mean distance per trip under the new rule and $AMDPT_{current}$ is the average mean distance per trip under current conditions.

Note that incremental changes in annual mean distance per trip will be magnified in total road travel time because the changes are multiplied by the number of loads per year. Operations where $AMDPT_{P\text{-}RULE}$ is much larger than the current value and where there is a high annual NOL will see large increases in time required for manure application under a phosphorus rule.

There is a potential for the additional road travel time to make conversion to phosphorus-based application rates infeasible using the current manure application equipment complement. Operations that have a large increase in AMDPT may not have sufficient time to land apply manure during manure application windows and/or may have unrealistic work loads for existing tractors and spreaders. These operations would need to invest in additional or larger applicators or supplemental equipment such as nurse tanks to reduce road travel time.

2.5.3.2 Traveling gun and dragline systems

Total time needed for land application of manure (T_{TOT}) for traveling guns and dragline systems that use an irrigation piping network for transport of manure is a function of irrigation network setup time (INST), between pull setup time (BPST) and discharge time (DT) where:

$$\mathrm{T_{TOT}} = \mathrm{INST} + \mathrm{BPST} + \mathrm{DT} \qquad \text{Eq. 2-10}$$

Note that many operators will do much of the work associated with INST while manure is being applied at another location, thereby reducing the duration of manure application activities but not the total labor and time required to accomplish the task.

This analysis assumes the farmer can apply manure at the same rate under the phosphorus rule as under the nitrogen rule in the years a field receives manure. Consequently, the farmer will be using the same pumping and irrigation equipment to pump the same volume of manure each year under the phosphorus rule as under the nitrogen rule. The primary change will be that the farmer may need to apply on different fields in different years.

Between pull setup time (BPST) should not change because the same equipment is being used to pump similar amounts of effluent with both strategies; the number of pulls should only change if the geometry of the additional fields is significantly different on the additional fields needed for land application. Discharge time (DT) should not change between nitrogen-based and phosphorus-based land application approaches. Manure is being applied at the nitrogen-based need on all crops receiving manure in a given year under both scenarios. This result assumed additional acres needed for phosphorus-based applications have the same fertilizer needs as acres currently are being used.

Irrigation network setup time (INST) is analogous to road travel time in tanker systems; it has the potential to increase with adoption of a rotation-based phosphorus limit. It is possible that as more land is required for manure application, the farmer will have to pump effluent greater distances to reach that land. The specific effects of the phosphorus rule on set-up time will be highly site specific.

Access to additional land is often difficult for irrigation-based systems. Existing pumps and piping have absolute limits on effective pumping distances. Usually additional pipe is required to reach more distant acres and larger pumps or booster pumps are also needed. Piping manure to more distance sites may not be possible due to natural or man-made barriers that block access to additional land application areas. The inability to obtain easement access for piping across non-owned land not controlled by the farmer can also limit the additional acres available for irrigation of manure effluent.

2.6 REFERENCES

ASAE, 1998. Agricultural machinery management data. Std. no. D497.4.

Barrow, N.J. 1980. Evaluation and utilization of residual phosphorus in soils. *In* The Role of Phosphorus in Agriculture. ASA-CSSA-SSSA, Madison, WI.

Edwards, D.R., and T.C. Daniel. 1993. Runoff quality impacts of swine manure applied to fescue plots. Trans. Of the ASAE 36:81-86.

Edwards, D.R., and T.C. Daniel. 1994. Quality of runoff from fescue plots treated with poultry litter and inorganic fertilizer. J. Env. Qual. 23:579-584.

NRCS. 2000. Nutrient management standard 590. United States Department of Agriculture - Natural Resource Conservation Service. www.nrcs.usda.gov.

Pote, D.H., T.C. Daniel, D.J. Nichols, A.N. Sharpley, P.A. Moore, Jr., D.M. Miller and D.R. Edwards. 1999. Relationship between phosphorus levels in three Ultisols and phosphorus concentrations in runoff. J. of Env. Qual. 28:170-175.

Sharpley, A.N., S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Managing agricultural phosphorus for protection of surface waters: issues and options. J. Environ. Qual. 23:437-451.

Shreve, B.R., P.A. Moore Jr., T.C. Daniel, D.R. Edwards and D.M. Miller. 1995. Reduction of phosphorus in runoff from field-applied poultry litter using chemical amendments. J. Environ. Qual. 24:106-111.

2.7 FIGURES

The figures for this chapter are on the following pages.

Figure 2-1. The percent increase in acres needed for adopting a phosphorus-based rule and the percent over-application of phosphorus when manure is applied at a nitrogen rate for selected crops and manure sources. Values of 0% will continue to be restricted by nitrogen limits and have no excess phosphorus applied when applied at nitrogen limited rates.

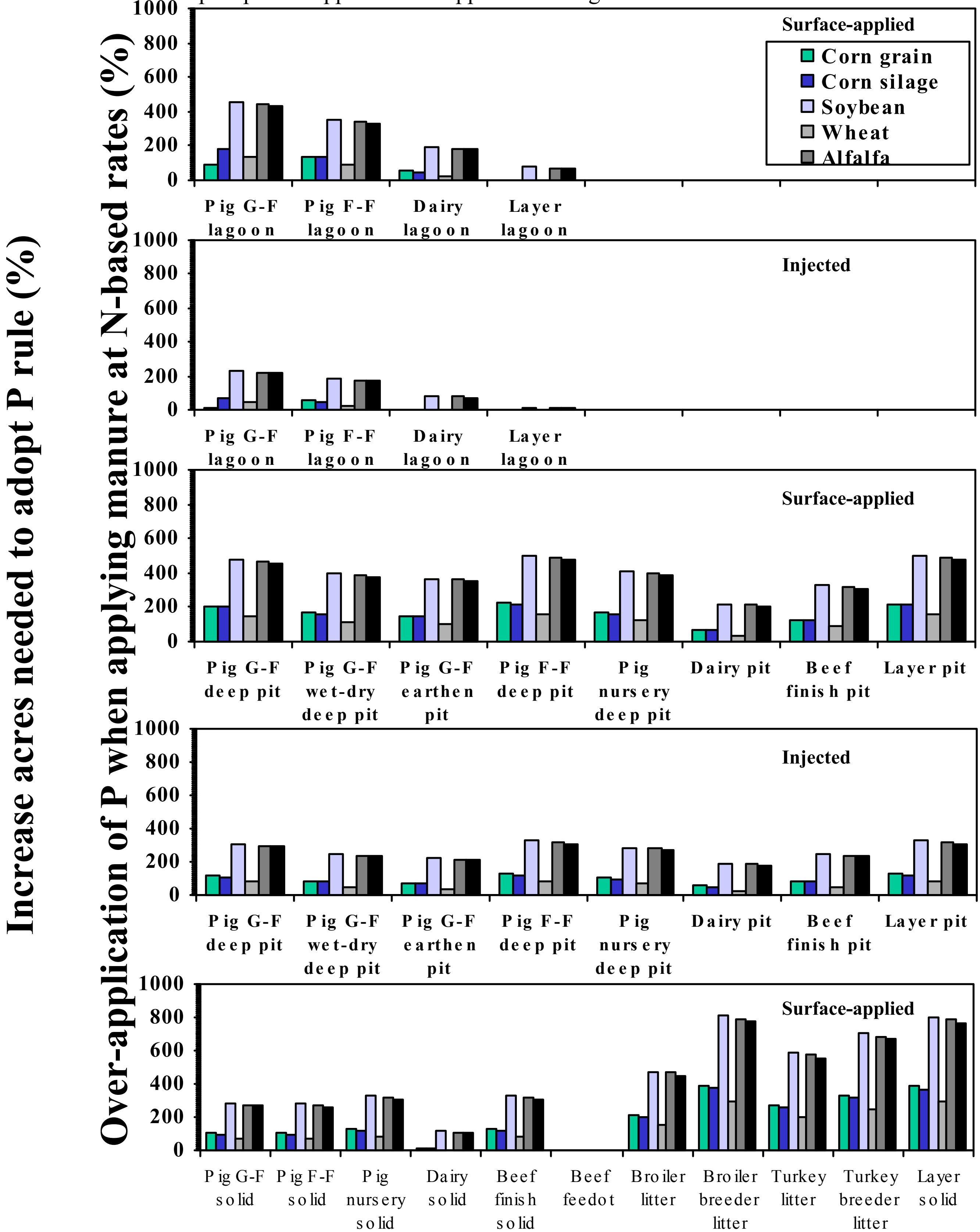
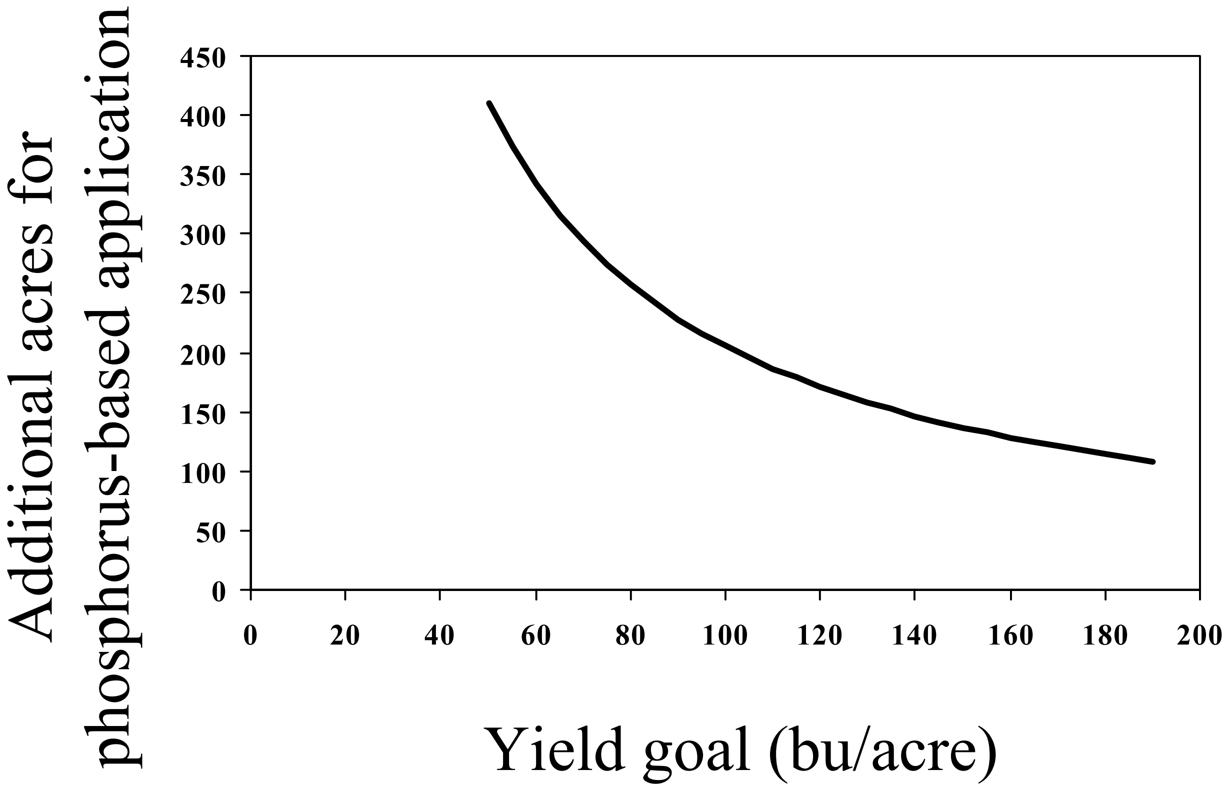


Figure 2-2. The effect of yield goal on the number of additional acres a farm requires to apply manure based on the phosphorus removal capacity of the crop. This example assumes the operation generates 18,000 lbs P_2O_5 per year as slurry from 1000 finish pigs and applies manure to corn grain crops.



Chapter 3
THE FEASIBILITY OF ADOPTING ANNUAL VERSUS ROTATIONAL PHOSPHORUS LIMITS FOR MANURE APPLICATION

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3.1 INDEX

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3.2 EXECUTIVE SUMMARY

The proposed EPA rule requires manure applications on phosphorus restricted fields be limited by the annual phosphorus requirements of the crop (annual phosphorus limits) (Federal Register, p 3142). We propose farmers be allowed to continue to apply manure on phosphorus restricted fields at the nitrogen limited rate and then refrain from further applications until subsequent crops use the applied phosphorus (rotational phosphorus limits).

We conclude that rotational phosphorus limits restrict phosphorus applications while allowing the farmer to:

- Rotate fields receiving manure and target crops that need both nitrogen and phosphorus.
- Continue to apply manure at the same rate and with the same equipment currently used for manure application in the years the field receives manure.
- Use manure to meet all fertilizer needs of the crop in the year manure is applied, eliminating the cost and time required to apply fertilizers other than manure to the crop.

We conclude that annual phosphorus limits will:

- Require farmers to reduce the annual, per acre application rate of manure by up to 90%.
- Result in slurry manure application rates that are infeasible with current manure application technologies and equipment.
- Require farmers with solid manure, slurry manure or other concentrated manure sources to invest in modifying existing, or purchasing new, manure application equipment.
- Require farmers with solid manure, slurry manure or other concentrated manure sources to reduce spreading discharge rate, thereby, increasing the time required for application of manure.
- Promote surface application of manure.
- Have the least impact on farms applying manure sources with high nitrogen to phosphorus ratios such as unagitated lagoon effluent.
- Have the largest impact on farmers who apply manure to crops that have high nitrogen to phosphorus ratios such as hay crops.
- Require farmers to apply supplemental nitrogen to all nitrogen-requiring crops that receive manure, thereby eliminating much of the incentive to use manure as a fertilizer.
- Have little water quality benefit compared to the rotational phosphorus limit.

We propose replacing the existing wording in Federal Register, p 3142, 412.37 (a)(2) *i* and *ii* with the following text:

"Multi-year phosphorus applications are permissible as long as they do not exceed the nitrogen limit for the current crop year. The phosphorus store should not exceed 5 years of crop need if there is a high or very high risk of phosphorus loss."

3.3 INTRODUCTION

Phosphorus is typically the most limiting nutrient in most freshwater aquatic systems (Sharpley et al., 1994). Excessive phosphorus entering a stream or lake will promote growth of aquatic flora and fauna and will degrade water quality through the process of eutrophication. Negative attributes of eutrophic water bodies include reduced water clarity, excessive algal growth, low oxygen content, altered fisheries, increased filtration costs and objectionable taste for drinking water sources, and, in excessively eutrophic waters, water-born toxins from cyanobacteria.

Mismanagement of fertilizers such as manure increases the quantity of phosphorus in runoff from agricultural fields. Increasing soil test phosphorus in a field will increase the concentration of phosphorus in runoff from the field (Pote et al., 1999; Sharpley et al., 1994). Runoff from fields soon after a surface application of phosphorus as chemical fertilizer or manure also results in high phosphorus concentrations in runoff (Edwards and Daniel, 1994; Shreve et al., 1995).

Manure nutrients have been regulated based on the nitrogen content of the manure (Compendium of State Regulations published by EPA.). Manure application rates could not exceed the annual nitrogen need of the crop. Many manure sources contain more phosphorus and other nutrients than the crop requires when manure is applied based on the nitrogen requirement of the crop. Soil test phosphorus and other soil nutrient tests can increase rapidly when these sources of manure are applied every year in accordance with the nitrogen requirement of the crop.

The potential for water quality degradation due to mismanagement of manure phosphorus has resulted in voluntary and regulatory efforts to include phosphorus restrictions on manure application rates for agricultural fields. The NRCS agronomy standard (NRCS, 2000), (Federal Register, 01/12/2001), and the proposed EPA rules governing confined animal feeding operations include provisions that manure be applied based on the phosphorus removal rate of the crop. In both standards, the phosphorus status of the soil is assessed by one of three methods: the phosphorus index, the phosphorus threshold or the soil test phosphorus level. Manure can be applied every year based on the annual nitrogen requirements of the crop to fields with a low or medium phosphorous rating according to the chosen assessment method. Phosphorus and nitrogen application limits must both be observed on fields with a high phosphorus rating by the selected assessment method. No manure applications are allowed or recommended on fields rated very high in phosphorus.

3.4 PHOSPHORUS-BASED STRATEGIES FOR MANURE APPLICATION

There are at least two potential strategies for implementing phosphorus limits for manure application. Phosphorus rotation is the term we use to describe the practice of applying more than one year of phosphorus to a soil and then not applying manure until that amount of phosphorus has been harvested from the field by crops, meat or milk. In a nitrogen-based phosphorus rotation approach, manure is applied to the crop based on the nitrogen needs of the crop. A farmer using a nitrogen-based phosphorus rotation strategy will be able to use the same land-application equipment, pumping rates and application speeds as were previously used for nitrogen-based management. A nitrogen-based phosphorus rotation strategy allows the farmer to apply manure to a field at the same rate as in the past, but requires that the frequency of application to a specific field be reduced.

Alternatively, phosphorus could be limited to the annual crop needs of the crop. In this strategy, crop phosphorus removal capacity will be met each year with a manure application, but the manure will frequently provide insufficient nitrogen to meet crop needs. Additional fertilizer nitrogen may be required each year. Many farmers adopting annual phosphorus limits will likely need to reduce manure application rates.

The same number of acres of land will be needed for a manure plan based on the nitrogen-based phosphorus rotation strategy and the annual phosphorus strategy. Every acre in the plan will receive manure every year with an annual phosphorus-based plan. In contrast, a portion of the acres may receive manure in any given year with the nitrogen-based rotational phosphorus approach. Manure applications will be rotated from field to field until all acres receive manure.

Application rate is the gallons or tons per acre of manure that are applied to land. Manure application equipment is calibrated to provide a specific application rate by setting the rate at which the manure is discharged from the applicator, the equipment travel speed and the effective manure application width. Reducing the manure application rate will require increasing travel speed, increasing effective application width and/or reducing discharge rate.

Implementation of annual phosphorus limits may pose economic disadvantages that are not encountered in nitrogen-based phosphorus rotation strategies. When annual phosphorus limits require reducing manure application rates, the time and cost of land application may increase compared to phosphorus rotation strategies. The reduced manure applications rates may also be below those attainable by equipment available on the farm or currently available for purchase.

The NRCS agronomy standard does not specify how limits on the phosphorus applications are to be implemented. The effluent limitation guideline proposed by EPA explicitly prohibits multi-year phosphorus applications to meet phosphorus application limits (“Multi-year phosphorus applications are prohibited when either the P-index is rated high, the soil phosphorus threshold is between ¾ and 2 times the threshold value, or the soil test phosphorus level is high…” Federal Register, p 3142). However, the proposed rule acknowledges that, in at least some cases, annual phosphorus application strategies may be infeasible (“Manure application equipment designed for dry poultry manure or litter cannot obtain an application rate low enough to meet a phosphorus based application rate as determined by the PNP. In the event a phosphorus application occurs during one year which exceeds the crop removal rate for that given year, no additional manure or process water shall be applied to the same land in subsequent years until all applied phosphorus has been removed from the field via harvest and crop removal;…" Federal Register, p 3142).

Our primary objective was to compare the technical feasibility and cost of an annual phosphorus-based application strategy required by the proposed EPA rule to a phosphorus rotation strategy. This chapter does not assess the feasibility or impact of switching from nitrogen-based land requirements to phosphorus-based land requirements. Converting from a nitrogen land base to a phosphorus land base would be similar for both the phosphorus rotation strategy and annual phosphorus limit strategies. The costs and feasibility of converting from nitrogen to phosphorus-based management are evaluated in chapter 2. We instead evaluate the feasibility of two different phosphorus-based application strategies: annual limits and phosphorus rotation.

Our analysis has two parts. First, we assess the feasibility of applying annual phosphorus rates with currently available equipment. This assessment was done by comparing the annual nutrient content of selected crops with land application equipment technical specifications provided by several commercial equipment companies. The second part of the analysis compared the costs of adopting rotational phosphorus and annual phosphorus limits on 50 farms located throughout the U.S.

3.5 MATERIALS AND METHODS

Typical nutrient concentrations for selected crops and types of manure were developed through a literature review (Tables 3-1 and 3-2). Manure was divided into two categories: liquid (slurry and lagoon effluent) and solid. Nutrient concentrations in liquid manure were reported as lbs/1000 gallons and nutrient concentrations in solid manure were reported as lbs/ton.

Plant available nitrogen (PAN) was estimated by assuming 65% of the organic nitrogen (75% for poultry manure) was available to the crop, and 60% (surface applications) or 100% (injected manure) of the NH_4-N was available to the current crop.

Manure application rate of selected land application technologies was calculated using the equation:

$$\text{Application Rate} = \frac{\text{discharge rate}}{(\text{travel speed} \times \text{effective swath width})} \times c \qquad \text{Eq. 3-1}$$

where c is a constant to adjust application rate to the units used for the specific manure source. For liquid manures, the application rate was calculated in gallons/acre; for solid manure, it was calculated in tons/acre. The phosphorus rule was assessed based on the assumption that the manure application rate would be limited by the capacity of the harvested crop to remove phosphorus on all land receiving manure.

3.6 RESULTS AND DISCUSSION

3.6.1 Plant and manure factors

Manure and the harvested crop characteristics determine the percent reduction in manure application rate if a farmer converts from a nitrogen-based phosphorus rotation application rate to an annual phosphorus-based application rate. The percent reduction in manure application rate required for a adopting an annual P rule (AP_{RED}) is a function of the $N:P_2O_5$ ratio of both the crop fertilizer need and the manure where:

$$AP_{RED} = \left(1 - \frac{\text{manure PAN} : P_2O_5 \text{ ratio}}{\text{crop fertilizer N} : P_2O_5 \text{ ratio}}\right) \times 100\% \qquad \text{Eq. 3-2}$$

Plant available nitrogen (PAN) is the fraction of the total nitrogen in manure that is available to the crop (Table 3-2).

The impact of annual phosphorus limits on the per acre manure rate is independent of the crop yield (Eq. 3-2). The adjustment of manure rates from nitrogen to annual phosphorus basis is purely a function of nitrogen and phosphorus ratios in the crop (removal in harvested portion of the crop or recommended fertilizer rate) and the manure.

An annual phosphorus limit will result in reduced manure rates when the $N:P_2O_5$ ratio of crops is greater than the $PAN:P_2O_5$ ratio of manure (Eq. 3-2). Harvested crops typically have a $N:P_2O_5$ ratio of 1.8 to 4.5 (Table 3-1). Manure $PAN:P_2O_5$ ratio ranges from 0.5 to almost 4 although most are below 1.5 (Table 3-2). Consequently, on most farms and fields, conversion to an annual phosphorus removal strategy will require lower manure application rates than the current nitrogen-based rates. For example, a farmer converting to an annual phosphorus limit would need to reduce broiler litter application rates to corn grain by up to 67% (using Eq.3-2, (1-(0.75/2.3)X100)).

Crops with the highest fertilizer nitrogen need compared to phosphorus need (highest $N:P_2O_5$ ratios) will be most affected by conversion to an annual phosphorus standard. The harvested components of all crops have a greater fertilizer nitrogen need or nitrogen removal capacity than phosphorus removal capacity ($N:P_2O_5$ ratio > 1; Table 3-1). Soybean, bermuda grass and alfalfa hay had the highest reported $N:P_2O_5$ removal ratios for the harvested portion of the crop (Table 3-1). Crops, with higher phosphorus need compared to nitrogen, and fields, with phosphorus need in excess of crop phosphorus removal rate, will be less affected by conversion to an annual phosphorus removal rate.

Manure types with the lowest $PAN:P_2O_5$ ratio will be more affected by conversion to an annual phosphorus standard. Manure nitrogen available to the crop (PAN), rather than the total nitrogen content of the manure, is the critical component. Consequently, surface applied manure is more affected by conversion to annual phosphorus application rates than injected manure because ammonia nitrogen volatilization losses during surface application of manure reduce the manure PAN:P_2O_5 ratio (Table 3-2).

Table 3-1. Nutrients removed in the harvested portion of selected crop[1].

Crop	Yield unit	N lbs/unit	P_2O_5 lbs/unit	N:P_2O_5 ratio	K_2O lbs/unit
Corn grain	bushels	0.9	0.4	2.3	0.3
Corn silage	Tons	8.4	3.8	2.2	8.9
Soybean	bushels	3.4	0.8	4.3	1.4
Wheat	bushels	1.3	0.7	1.9	0.4
Bermuda grass hay	Tons	49	11	4.5	42
Big bluestem hay	Tons	20	11	1.8	26
Tall Fescue hay	Tons	39	14	2.8	53
Alfalfa hay	Tons	50	12	4.2	50

Note: Values are reported as nitrogen (N), phosphate (P2O5) and potash (K2O).
[1]Sources:
NRCS. 1992. Agricultural waste management handbook. U.S. Department of Agriculture Soil Conservation Service, Washington DC.
Buholtz, D.D. 1992. Soil Test Interpretations and Recommendations Handbook, Department of Agronomy, University of Missouri, Columbia, MO.
Potash Phosphate Institute, Norcross, GA.
Agronomy Guide. The Pennsylvania State University, State College, PA.
North Carolina State University, AG-439-16
General Guide for crop nutrient recommendations. March 1999. Iowa State University, Ames, IA.
Atlas of nutritional data on US and Canadian Feeds. 1971. National Acad. of Sciences, Washington, DC.
Griffith, W.K. and L.S. Murphy. 1996.
Macronutrients in Forage Production. In (R.E. Joost and C.A. Roberts eds.) Nutrient Cycling in Forage Systems. Proc. of a conference held March 7-8, 1996. Columbia, MO.
PPI, Manhattan, KS

Only injected lagoon effluent consistently exceeded some crop N:P_2O_5 ratios. For example, injected lagoon effluent from grow-finish pigs has an PAN:P_2O_5 ratio of 2.0 (Table 3-2) which is greater than the N: P_2O_5 ratio of wheat and bermuda grass and almost as high as corn (Table 3-1). In these situations, nitrogen, not phosphorus, will limit manure application rates.

Adopting annual phosphorus application rates will require reducing manure application rates up to 90% (Fig. 3-1). Manure has a greater range in PAN:P_2O_5 ratios than crop N:P_2O_5 ratios (compare Tables 3-1 and 3-2). Therefore, differences among manure sources, collection systems, storage types and application management cause the greatest range of reductions required when adopting an annual phosphorus application rule. Highest reductions due to annual phosphorus application rate are associated with solid manure such as poultry litter (e.g. up to a 90% reduction when applied to soybean or hay). Reductions needed for surface applications of slurry manure and unagitated lagoon effluent can exceed 80% on the same crops. Annual phosphorus application rate for some injected lagoon effluents will only require a reduction in rate of 10 to 15% on soybean and hay ground.

Table 3-2. Typical nutrient concentration in selected sources of manure[1].

Manure Source	Units	Total N	NH_4-N	P_2O_5	K_2O	PAN[2]:P_2O_5 Ratio Surface applied	Injected
Pigs							
Grow finish - deep pit	lb/1000 gal	50	33	42	30	0.73	1.04
Grow finish - wet/dry feeder deep pit	lb/1000 gal	75	50	54	40	0.86	1.23
Grow finish - earthen pit	lb/1000 gal	32	24	22	20	0.89	1.33
Farrow-finish pit	lb/1000 gal	28	16	24	23	0.73	0.99
Nursery pit	lb/1000 gal	25	14	19	22	0.82	1.11
Grow-finish unagitated lagoon	lb/1000 gal	4.0	4.0	2.0	3.0	1.20	2.00
Farrow-finish unagitated lagoon	lb/1000 gal	4.5	4.0	2.9	3.6	0.94	1.49
Grow finish - solid	lb/ton	16	6	9	5	1.12	1.39
Farrow finish - solid	lb/ton	14	6	8	5	1.10	1.40
Nursery - solid	lb/ton	13	5	8	4	1.03	1.27
Dairy cows							
Pit	lb/1000 gal	31	6	15	19	1.32	1.48
Unagitated lagoon	lb/1000 gal	4.1	3.6	1.7	2.9	1.46	2.31
Solid	lb/ton	10	2	3	7	2.13	2.40
Beef cows							
Finish - pit	lb/1000 gal	29	8	18	26	1.03	1.20
Finish - solid	lb/ton	11	4	7	11	0.99	1.22
Feedlot solid	lb/ton	24	-	16	3	-	-
Feedlot lagoon sludge	lb/1000 gal	52	-	18	14	1.88	1.88
Poultry							
Broiler litter	lb/ton	71	12	69	47	0.75	0.82
Broiler breeder litter	lb/ton	37	8	58	35	0.46	0.51
Turkey litter	lb/ton	55	12	63	40	0.63	0.70
Turkey breeder litter	lb/ton	35	8	47	18	0.53	0.60
Layer - solid	lb/ton	34	12	51	26	0.46	0.56
Layer - pit	lb/1000 gal	57	37	52	33	0.72	1.00
Layer lagoon liquid	lb/1000 gal	27	23	7.1	42	2.37	3.66
Layer lagoon sludge	lb/1000 gal	84	26	308	40	0.19	0.23
Layer under cage	lb/ton	28	14	32	20	0.59	0.77

Notes: All values are on an "as-is" or wet basis. Plant available nitrogen (PAN) estimates the fertilizer value of manure when surface applied or injected.

[1]Sources:

MWPS. 2000. Manure Characteristics. Midwest Plan Service, 122 Davidson Hall, ISU, Ames IA.

NRAES-132. 1999. Poultry waste management handbook. Natural Resource, Agriculture, and Engineering Service, Ithaca, NY.

NRCS. 1992. Agricultural waste management handbook. U.S. Department of Agriculture Soil Conservation Service, Washington DC.

[2]PAN – Plant Available Nitrogen.

The N:P_2O_5 ratios of the harvested portion of crops only vary by a factor of approximately 2 (Table 3-1). Consequently, potential application rate reductions from crop factors are less than those from manure factors. For example, among poultry litter sources, annual phosphorus rates would require a mean reduction in manure application rate from 70% (wheat) to 85% (alfalfa). Similarly, among unagitated swine and dairy lagoon manure sources, annual phosphorus rates would require a mean reduction in manure application rate from 43 to 74% (surface applied) and 8 to 59% (injected), depending on the crop.

In summary, annual phosphorus limits will have the largest impact on manure application rates in crops such as bermuda grass, alfalfa and other hays where the harvested portion of the crop has a high $N:P_2O_5$ ratio. Similarly, annual phosphorus limits will have the largest impact on manure types that have lower $PAN:P_2O_5$ ratios such as poultry litter and other solid manure types. Annual phosphorus rates will result in reductions in manure application rate for most types of manure.

3.6.2 Land application equipment factors

3.6.2.1 Travel speed

This section assesses the feasibility of attaining lower application rates for manure with current land application equipment. Manure application rate is controlled by adjusting travel speed, effective swath width and/or manure discharge rate (Eq. 3-1). Increasing travel speed provides one of two opportunities for reducing land application rate without increasing the time associated with land application. The potential for additional reductions in application rate through increasing travel speed (PR_{TS}) is a function of current travel speed (TS_c) and the travel speed at the minimum application rate (TS_{MAR}) where:

$$PR_{TS}(\%) = \frac{\left(\left(\frac{1}{TS_C}\right) - \left(\frac{1}{TS_{MAR}}\right)\right)}{\left(1/TS_C\right)} \times 100\% \qquad \text{Eq. 3-3}$$

The maximum possible reduction of application rate by adjusting travel speed for each piece of equipment is a function of the minimum and maximum travel speeds possible during land application. Typical minimum and maximum speeds and the associated application rate reduction potentials are reported for selected classes of land application equipment in Table 3-3. These represent the potential application rate reductions possible by increasing travel speed assuming the farmer is currently using the minimum travel speed.

Maximum application speeds are a function of equipment capabilities and safety concerns. Tractor-pulled spreaders have a lower maximum travel speed than truck-mounted spreaders because they have no suspension system. Injection requires lower speeds than surface application because of the greater stress and power requirements associated with pulling an implement through the soil. Traveling at higher speeds increases power requirements of the tractor; doubling the travel speed will more than double the power requirements for land application of manure (ASAE, 1998).

Table 3-3. Minimum and maximum travel speeds for selected types of manure application equipment.

Equipment Type	Travel Speed[1] (Min-Max)		Potential Reduction[2]
Tractor-pulled, injected	1 – 5	miles/hour	80%
Tractor-pulled, surface applied	1 – 6	miles/hour	83%
Truck-mounted, injected	2 – 7	miles/hour	71%
Truck-mounted, surface applied	5 – 15	miles/hour	67%
Traveling gun, water drive	1 – 5	feet/min	80%
Traveling gun, engine drive	1 – 10	feet/min	90%

[1]Travel speed can be varied within range given based on the capabilities of the equipment.
[2]Potential reduction is defined as the percentage reduction possible for application rate by reducing travel speed from the maximum speed to the minimum speed.

Travel speed alone will not provide sufficient reduction in application rate to make the change to annual phosphorus application rates for some methods of land application. For example, truck-mounted surface applications used for poultry litter have the potential to reduce application rates up to 67% through travel speed (Table 3-3) but most annual phosphorus application rates for poultry litter will require reducing application rates by 60 to 90% (Figure 3-1).

The maximum potential reduction in manure application rate attainable by increasing travel speed is typically greater than or equal to reductions in manure application rate needed for annual phosphorus application rates (compare Table 3-3, Figure 3-1). Travel speed has the potential to reduce land application rate of tractor-pulled spreaders by 80 to 83% and traveling guns by 90% (Table 3-3). These reductions are equal to or greater than the reductions needed for most crops receiving manure slurry (Figure 3-1).

The maximum attainable reduction based on equipment capability may not be the maximum achievable reduction for an individual farmer. Unless a farmer is presently traveling at the minimum speed, the maximum achievable reduction cannot be attained. Time incentives typically warrant a producer traveling at greater than the minimum speed.

Farmers seeking to minimize the time required to empty a manure storage structure will maximize the discharge rate of the land application equipment. To maximize the discharge rate, farmers will apply manure to the widest possible swath and travel at the maximum safe speed.

For example, a farmer who has a target application rate of 6,600 gallons/acre will reduce application time by purchasing equipment that has a discharge rate of 800 gallons/minute requiring a travel speed of 4 mph and a swath width of 15 ft compared to selecting equipment with a discharge rate of 400 gallons/minute requiring a travel speed of 2 mph. By increasing target application speed, discharge time is reduced 50% as shown in this example. This incentive makes it likely that manure application is being carried out at higher speeds than the specified minimum rate when there is an opportunity to select higher discharge rates.

We estimated travel speed of land application equipment on 15 farms (17 pieces of equipment) based on farmer reported swath width, discharge rate and/or type of equipment, manure characteristics and crop yield (Table 3-4). For slurry-based systems (tractor-pulled or truck-mounted spreaders), predicted travel speeds were near or at the maximum in 6 of 13 cases. Average travel speed was 4.0 miles/hour for tractor-pulled spreaders and 4.7 miles/hour for truck-mounted slurry spreaders (Table 3-4). This implies that most farmers are currently applying manure at speeds well above the minimum. A farmer using a tractor-pulled spreader traveling at 4.0 miles/hour can further reduce land application rate by 20% using travel speed. This is insufficient for converting to annual phosphorus application rates (Fig. 3-1). Consequently, most farmers applying slurries and solid manure will need to change other application rate variables in addition to travel speed to convert to annual phosphorus application rates.

Table 3-4. Discharge rate, swath width and travel speed used to model land application on U.S. swine farms.

Presentation Code	Discharge Rate (gallons/minute)	Swath Width (feet)	Travel Speed (miles/hour)
Tractor-pulled spreader			
IA-1	600	15	4.9
IA-2	1,000	15	2.8
IA-3	800	15	4.3
IA-4	350	15	4.8
IA-5	650	15	4.9
IA-6	800	30	2.7
MO-2	425	12	4.8
PA-4	1,000	40	2.7
PA-5	800	25	4.5
Mean	714	20	4.0
Truck pulled spreader			
PA-1	725	16	6.8
PA-2	1,000	30	3.3
PA-3	850	20	5.4
PA-6	800	40	3.1
Mean	844	27	4.7
Dragline system			
MO-3	520	15	5.0
MO-4	750	12	1.1
MO-6	650	12	1.6
Mean	640	13	2.6
Box spreader			
IA-3	800	15	4.7

Note: Travel speed was estimated from farmer reported swath width and discharge rate.

We estimated travel speed of three operations using dragline-injection systems. Two of these operations were applying manure while traveling near minimum application speeds. These two operations were applying unagitated lagoon effluent through a network of six-inch pipes. Pumping rate was a function of the pump and limited by specifications (diameter, length, elevation change) of their pipe network. These operations have the potential to meet a phosphorus application through travel speed only. The third operation was traveling at maximum speed while applying pit slurry.

Traveling guns and other irrigation-based manure application systems are unique in that many farmers make multiple passes to meet the target manure application rate. Single pass application rates are often a function of soil infiltration rate, not of crop nutrient need. Under these conditions, the viability of annual phosphorus application rates is difficult to assess using the reduction ratio concept.

Using travel speed to reduce land application rate has the benefits of having no effect on land application time and requires no investment for changes in land application equipment. Operations that cannot fully attain the reduced manure application rates required by annual phosphorus application rates will need to adjust swath width and/or manure discharge rate (Equation 3-1).

3.6.2.2 Swath width

Swath width is the effective width of the manure application pattern and equal to the distance between travel lanes across a field. The impact of swath width on application rate is analogous to travel speed; application rate is inversely related to swath width (Equation 3-1). Changing swath width is the second opportunity to reduce application rate without affecting the amount of time required for land application of manure.

Farmers who use manure injection equipment are resistant to reducing application rate by increasing swath width because it is likely to require purchase of a new, wider application tool bar. A wider injector bar will increase power requirements and may also require a larger tractor for land application. Doubling the width and number of injectors will approximately double the power requirements for the tractor for pulling it through the soil (ASAE, 1998). Maximum swath width of injection equipment may also be limited by road width if the manure application equipment needs to travel on public roads. Increasing swath width also may pose a problem for maneuvering in smaller and irregularly shaped fields. Most injection equipment currently is 8 to 15 feet wide.

Swath width for surface application equipment can be more easily adjusted. For example, poultry litter application trucks can change swath width by adjusting the spinner speed that distributes the manure as it is discharged from the conveyer. A typical range in swath width capabilities for this type of equipment is 20 to 45 feet. Surface applications using a slurry tank can be adjusted with the splash plate. Swath width is not as easily adjusted on box spreaders because they use beater paddles rather than spinners to distribute manure out the back of the spreader. Adjusting swath width is difficult in pivot irrigation systems. Swath width in traveling gun systems is a function of pump pressure and nozzle type.

Typical swath widths for land application equipment range from 8 to 15 feet for injection tool bars to several hundred feet for traveling guns. Potential reduction in application rate from increasing swath width is likely to be less than 50% because of the challenges associated with doubling swath width for most pieces of equipment.

3.6.2.3 Discharge rate

Discharge rate in gallons per minute or tons per minute is the rate at which manure is expelled from the land application equipment. Reducing application rate through discharge rate also directly affects the amount of time required for discharging the volume of manure to be spread (Equation 3-1). Maximizing the discharge rate based on the capabilities of the land application equipment will minimize the application time. Adjusting discharge downwards to reduce application rates has the added cost of increasing the time required to apply a set volume of manure.

The potential for additional reductions in application rate through decreased discharge rate (PR_{DR}) is a function of current discharge rate (DR_c) and the discharge rate at the minimum application rate (DR_{MAR}) where:

$$PR_{DR}(\%) = \frac{(DR_C - DR_{MAR})}{DR_C} \times 100\% \qquad \text{Eq. 3-4}$$

The maximum possible reduction through adjusting discharge rate for each piece of equipment is a function of the minimum and maximum discharge rates possible during land application. Typical minimum and maximum discharge rates and the associated application rate reduction ratios are reported for selected classes of land application equipment in Table 3-5. These represent the potential reductions in discharge rates possible assuming current discharge rate is at the maximum.

Engineering characteristics of specific equipment impact the maximum discharge rate and the ability to adjust discharge rate. Many tanker injection spreaders have a set discharge rate that can only be altered by placing restriction devices in the lines. This method of reducing discharge rate increases the potential for clogging of the lines and may not be recommended by the manufacturer. The potential discharge rate for dragline systems is dependent on the pump and the hydraulic characteristics of the distribution network. Factors such as pump size, pipe diameter, distance from source to applicator and elevation differences all impact the maximum discharge rate and the potential for adjusting discharge rate. Dry litter truck-mounted spreaders typically control discharge rate based on the size of the discharge opening (controlled by an adjustable gate), the speed of the conveyer belt that delivers manure to the opening, and the revolutions per minute of the impeller.

3.6.3 Feasibility of annual phosphorus rates

The total potential reduction in application rate (PR_{TOT}) available to a producer for a specific piece of equipment is a function of potential reduction from increasing travel speed (PR_{TS}), potential reduction from increasing swath width (PR_{SW}) and potential reduction from decreasing discharge rate (PR_{DR}) where:

$$PR_{TOT} = \left(1 - \left(\left(1 - \frac{PR_{TS}}{100}\right) \times \left(1 - \frac{PR_{SW}}{100}\right) \times \left(1 - \frac{PR_{DR}}{100}\right)\right)\right) \times 100\% . \qquad \text{Eq. 3-5}$$

All reductions are entered and reported on a percent basis.

3.6.3.1 Slurry with truck or tractor-pulled spreader

Farmers injecting slurry manure with tractor-pulled or truck-mounted spreaders are unlikely to meet the requirements for annual phosphorus application rates using their current equipment. Travel speed often provides limited opportunity to reduce application rate because they often are traveling closer to maximum than minimum travel speed (Table 3-4). Most producers are traveling at the median application speed or faster. This implies PR_{TS} = 0 to 40%. Tankers often have little inherent capacity to adjust discharge rate (Table 3-5); PR_{DR}=0 for many tankers and is unlikely to exceed PR_{DR}=50%. Expanding swath width with injection equipment usually cannot be accomplished without investment in new equipment (PR_{SW}=0). For most producers using a tanker with an adjustable discharge rate, we anticipate PR_{TOT} for their existing equipment will range from 0 to 40%, and 0 to 70%. The best-case scenario (PR_{TOT}=70%) is sufficient if the farmer applies slurry manure to corn, corn silage and wheat land; however, this potential reduction in application rate is likely to be insufficient for soybean and hay crops. This scenario assumes use of the current tractor, although doubling travel speed more than doubles power requirements. All other scenarios require investment to modify or purchase equipment needed for adoption of an annual phosphorus application rate.

Table 3-5. Discharge rates and reduction ratios for an application rate while changing discharge rate from moving from the maximum to minimum.

Equipment Type	Units	Common Discharge Rates (min-max)	Reduction Potential	Comments
Tankers (Tractor-pulled & truck-mounted)	gallons/ minute	530, 650, 800, 1000, 1300, 1700	0 to 50%	Pump speed fixed by PTO resulting in fixed discharge rate. Rates can be reduced using restrictors to other fixed rates. May not be recommended by manufacturer. May increase plugging from fibrous materials.
Dragline & Traveling gun	gallons/ minute	300 - 1000 200 – 800, 100 – 300	70% 75% 66%	Maximum: function of pump capacity and pipe network. Discharge rate adjusted through orifice restrictors or, in some cases, pump rpm.
Truck-mounted litter	tons/ hour	15 - 100	85%	Discharge rate: a function of belt speed and gate opening.

In many cases, annual phosphorus application rates may be difficult to attain or technically infeasible, even with the purchase of new equipment. A farmer who currently injects slurry manure at the median travel speed (PR_{TS}=40%) must increase travel speed, double swath width and halve discharge rate to attain annual phosphorus rates for soybean and hay crops (PR_{TOT}=85%). The farmer will need to invest in a new injection tool bar and will probably need new metering equipment to control the discharge rate of manure from the tanker. A more powerful tractor will be needed because power requirements are estimated to increase by a factor of four for this land application scenario.

All three modifications are required to make the annual phosphorus application rate feasible in the example above. Failure of any modification will result in failure to meet the limit. Many farmers already are applying manure near the maximum travel speed and will be unable to capture any appreciable travel speed reduction. Others farmers will not be able to expand swath width because of an existing wide injection tool bar, restrictions on allowable road width or field maneuverability problems.

Farmers who surface-apply slurry manure from a tractor-pulled or truck-mounted spreader will have the same challenges adopting an annual phosphorus rule as farmers injecting manure. The reductions needed for surface applied manure are greater than those needed for injecting manure (Figure 3-1). Significant increases in swath width may be difficult because farmers already have an incentive to use a wide swath width for surface applications. They face the same challenges as farmers injecting manure for altering travel speed and discharge rate.

Some farmers who are currently injecting slurry manure may choose to adopt surface application techniques. Transitioning from injection to surface application would provide opportunities to reduce the application rate through increased travel speed and swath width. Travel speed can be greater for surface application equipment (Table 3-3) so farmers who are injecting manure at the highest possible speed could obtain a 17% additional application rate reduction from travel speed by moving from the maximum speed for injection to the maximum speed for surface application. Converting from an injection swath width to a surface application swath width also provides an opportunity to at least double swath width.

3.6.3.2 Solid manure with truck-mounted spreaders

Farmers surface applying solid manure using a truck-mounted spreaders may be able to meet the requirements for annual phosphorus application rates using their current equipment by adjusting all three application rate variables. Travel speed alone will provide insufficient opportunity to reduce application rate (Table 3-5) and, as with slurry spreaders, farmers are likely to be traveling closer to maximum than minimum travel speed. If applicators are traveling at the median application speed or faster, PR_{TS} = 0 to 33%. Poultry litter applicators have a large capacity to adjust discharge rate (PR_{DR}=85%, Table 3-5). Litter applicators have an incentive to use the highest possible discharge rate so most farmers will have most of the potential discharge rate reduction available. Lower discharge rates have the liability of greater potential for bridging and clogging, in addition to increased application time compared to standard application rates. Swath width is unlikely to provide much opportunity for reducing application rates because applicators have incentives to use the widest swath width that is technically feasible (PR_{SW}=0). For most producers applying solid manure with truck spreaders we anticipate PR_{TOT} for their existing equipment will approach 90% ((1-((1-0.33)X(1-0.85)X(1-0))X100% from Equation 3-4). However, many crops receiving solid manure require nearly a 90% reduction in application rate (Figure 3-1). Under a best case scenario there is sufficient reduction potential available to the applicator. But if the travel speed is near maximum for the application equipment or, if more stringent discharge rate limits are imposed, the annual phosphorus application rate will be infeasible.

3.6.3.3 Lagoon effluent with irrigation equipment

Farmers land applying lagoon effluent with irrigation equipment (e.g. traveling gun) or dragline systems should be able to attain annual phosphorus rates. The needed reductions are lower for lagoon effluent than for slurry and solid manures (Figure 3-1). At one extreme, nitrogen, not phosphorus controls injected lagoon effluent rate on corn. Either travel speed (Table 3-3) or discharge rate (Table 3-5) can provide sufficient reduction potential to meet annual phosphorus application rates.

Many lagoon effluent distribution systems have limited discharge capacities because of pump, distance, elevation and pipe diameter limitations. Consequently, operators of dragline injection systems must reduce application speed to attain desired discharge rates. They are often traveling at the minimum travel speed (Table 3-4), so they can often attain annual phosphorus rates through increasing travel speed. Traveling guns frequently limit single pass manure rates to soil infiltration rates. Infiltration rate limits require multiple passes with a traveling gun to reach the nitrogen or phosphorus banking effluent application rate. Infiltration limits have thus forced producers to use equipment that is more compatible with an annual phosphorus application rate.

In summary, producers applying anaerobic lagoon effluent can probably achieve annual phosphorus application rates by using irrigation equipment or dragline systems. Applicators using tractor-mounted spreaders to surface apply solid manure are likely to attain annual phosphorus application rates by reducing manure discharge rates. Manure applicators who surface apply litter at travel speeds close to the maximum for their equipment are the most likely to be unable to attain annual phosphorus rates. Most farmers who land apply slurry manure will need to invest in new equipment and will realize an increase in land application time to attain an annual phosphorus application rate.

3.6.4 Time Effects

3.6.4.1 Tractor-pulled and truck-mounted spreaders

Total time needed for land application of manure with tractor-pulled and truck-mounted spreaders (T_{TOT}) is a function of loading time (LT), road travel time to the field (TT_R), in-field travel time to the point where application begins and after application ceases (TT_F), and discharge time (DT) where:

$$T_{TOT} = LT + TT_R + TT_F + DT \qquad \text{Eq. 3-6}$$

Transitioning from a nitrogen-based phosphorus rotation to an annual phosphorus limit will only significantly affect DT of the four variables included in T_{TOT}. Annual phosphorus limits frequently require reducing discharge rate with a corresponding increase in DT (see section 3.5.3).

The same numbers of loads of manure are hauled with the annual phosphorus and nitrogen-based phosphorus rotation strategies so there is no effect on LT. There will be little difference in TT_R between the two approaches to phosphorus limitations. The same number of acres receives manure under both phosphorus strategies. The annual phosphorus strategy requires visiting all fields every year. The nitrogen-based phosphorus rule allows manure application to a fraction of the fields in a given year; however, those fields will require more trips to supply manure nutrients needed in the year of application. Over the course of the manure rotation all fields will receive the same amount of manure and the same number of trips. Consequently, on average over time, TT_R for the two phosphorus strategies will be the same. With the nitrogen-based phosphorus rotation rule, some years TT_R may be lower if application is predominantly close to the manure storage. These years will be offset by years with higher than average TT_R when the manure application area is predominantly on fields further from the manure storage system.

There is likely to be little difference between the two approaches to phosphorus limits on TT_F. Every load of manure will need to be transported from the road to the starting point for manure application in both approaches.

3.6.4.2 Irrigation-based systems

Total time needed for land application of manure (T_{TOT}) for traveling guns and dragline systems that use an irrigation piping network to transport manure is a function of irrigation network setup time (INST), between pull setup time (BPST) and discharge time (DT) where:

$$T_{TOT} = INST + BPST + DT \qquad \text{Eq. 3-7}$$

Many operators will do much of the work associated with INST while manure is being applied at another location to reduce the duration of manure application activities. This does not reduce the total man-hours required to accomplish the task.

There are potential effects of converting to an annual phosphorus limit from a nitrogen-based phosphorus rotation limit on all three variables of T_{TOT}. A prerequisite for time differential time effects among the two phosphorus strategies is that the annual phosphorus rule will usually decrease the per acre manure application rate and increase the number of acres needed for manure application compared to the nitrogen-based phosphorus rotation limits. This is not always the case (see section 3.5.1).

The nitrogen-based phosphorus limit will allow the irrigation network to be assembled to deliver effluent to the subset of fields scheduled to receiving manure in that year. The annual phosphorus limit will require the farmer to setup the irrigation network to all fields in all years. Requiring annual phosphorus limits will likely increase INST because more extensive irrigation networks must be setup every year.

With nitrogen-based phosphorus rotation application rates, fewer acres are irrigated each year, requiring fewer set-ups and reducing BPST. The annual phosphorus limit would require irrigation of all fields maximizing the time required for BPST.

Operations that need to decrease discharge rate to meet annual phosphorus rates will increase DT. Existing irrigation operations applying unagitated lagoon effluent will meet phosphorus application requirements through increased travel speed and/or fewer passes through the field (section 3.5.3). These irrigators will not need to reduce discharge rate to achieve an annual phosphorus application limit. If an annual phosphorus application limit is implemented, operations using traveling gun irrigation will experience an increase in T_{TOT} because both INST and BPST will increase. This contrasts with T_{TOT} increases for road-based systems such as tractor-pulled tanks and truck-mounted applicators where the impact of annual limits is primarily due to changes in discharge rate. This analysis assumes manure is currently being applied with the assumption that the nitrogen requirements of the crop and manure characteristics remain constant among options.

3.6.5 Fertilization Effects

One value of manure is the compete elimination of commercial fertilizer need in the year of manure application. In contrast, annual phosphorus limits ensure that supplemental commercial fertilizer will need to be applied on most acres receiving manure. The nitrogen-based phosphorus rotation limit allows the farmer to meet the nitrogen need of the crop receiving manure in the year manure is applied. Annual phosphorus limits typically reduce manure application rate below the crop nitrogen need (section 3.5.1). Supplemental nitrogen must be applied on all non-legume crop acres receiving manure with an annual phosphorus limit. The need to apply supplemental nitrogen fertilizer increases the cost and time required for crop production if annual phosphorus application limits are implemented. An additional field operation to apply nitrogen on all fields requiring supplemental nitrogen must be performed. This will increase application time (to apply supplemental fertilizer), fuel use, equipment requirements and costs to implement annual phosphorus limits.

Implementing annual phosphorus limits makes it more difficult to extract the nitrogen value from the manure. The nitrogen-based phosphorus rotation allows the farmer to apply manure on phases of the rotation that have a nitrogen need and then not apply manure in years when there is no fertilizer nitrogen need. For example, manure could be applied only to the corn phase of a corn-soybean rotation with a nitrogen-based phosphorus rotation. In the year manure is applied it would supply all the nitrogen needed for corn production and also the phosphorus requirement of the soybeans to be produced the following year. Applying manure to comply with an annual phosphorus limit requires the producer to apply manure to all acres every year. Manure applied to soybeans provides no nitrogen value to the crop. The operation could double its land base to ensure it has sufficient acres to apply manure only to corn at the annual phosphorus rate. No production incentive exists for this approach because the manure will not provide sufficient nitrogen for the corn crop when applied at the annual phosphorus limit.

3.6.6 Water quality effects

Long-term manure application is not dependent on whether a nitrogen-based phosphorus rotation or an annual phosphorus limit strategy is implemented. The difference is that smaller rates of manure are applied to every acre each year with the annual phosphorus limit whereas larger manure application rates are applied less frequently with the phosphorus rotation strategy.

Manure and other surface-applied fertilizer sources initially cause high concentrations in runoff if rainfall occurs soon after application (Edwards and Daniel, 1994; Shreve et al., 1995). Within days the phosphorus reacts with the soil and becomes less vulnerable for loss as water-soluble phosphorus. Injected phosphorus also rapidly reacts with the soil. Factors affecting the reaction rate of phosphorus with soil include temperature and soil type (Barrow, 1986).

The concentration of phosphorus in runoff soon after a surface application of manure is linearly related to the rate of application (e.g. Edwards and Daniels, 1993). Any increase in the amount of manure applied to a field will result in a similar increase in phosphorus concentration in runoff from the field until the phosphorus attaches to the soil.

As a consequence of the linear nature of this relationship, there is little difference in the water quality impact of an annual phosphorus limit versus a nitrogen-based phosphorus rotation limit. For example, if under the annual phosphorus limit, every acre in the watershed would receive phosphorus, when runoff occurred all acres would lose phosphorus in the runoff water. In the nitrogen-based phosphorus rotation, a proportion of the acres would receive manure each year, for example 50%. Runoff concentrations from those acres receiving manure would be double those observed with the annual phosphorus rule but the losses would only be from 50% of the watershed. No difference in phosphorus load to the watershed would exist between the two approaches for the same runoff event.

3.6.7 Summary

Two potential approaches exist for implementing a phosphorus rule. The annual phosphorus limit approach proposed by the USEPA would require the producer to limit manure application rate to the current crop requirement for phosphorus. Alternatively, a nitrogen-based phosphorus rotation approach would permit manure to be applied to meet the nitrogen needs of the crop. Manure would not be applied until subsequent crops utilized the excess phosphorus from the original manure application.

Annual phosphorus limits will force farmers to reduce manure application rates in the year they apply manure for almost all cropping systems and manure types (section 3.5.1). This reduction in application rate will frequently require reducing discharge rates from the manure application equipment, particularly with solid and slurry type manures (section 3.5.2). In some cases, implementing annual phosphorus limits will require the producer to modify existing equipment or purchase new equipment to attain the reduced manure rates (section 3.5.3). Achieving annual phosphorus limit rates with slurry manure may not be feasible with currently available application equipment (section 3.5.3).

Annual phosphorus limits will frequently increase the time required for manure application (section 3.5.4) by mandating that producers reduce discharge rates (which increase discharge time) with road-based systems such as tractor-pulled tankers and truck-mounted spreaders. Land application time is increased for traveling gun and dragline manure application systems because setup time increases as all acres must be irrigated each year to comply with an annual phosphorous limits approach. Time requirements can also be affected by reduced discharge rates in irrigation systems.

Applying manure to achieve annual phosphorus limits also reduces the value of manure to the farmer (section 3.5.5). Annual phosphorus limits compel farmers to use manure as an incomplete fertilizer; non-legume crops receiving manure applied at annual phosphorus rates will require supplemental nitrogen fertilizer in addition to the manure supplied nutrients. This limits the value of manure because the farmer must perform additional field operations on those fields receiving manure to supply supplemental nitrogen.

The two approaches to phosphorus limits will have little difference in their impact on the phosphorus load reaching surface water bodies (section 3.5.6). With annual phosphorus limits, smaller amounts of phosphorus may be lost from more acres; nitrogen-based phosphorus rotations may allow larger amounts of phosphorus to be lost from fewer acres. The estimated total phosphorus loss from a watershed implementing an annual phosphorus limit rule or nitrogen-based phosphorus rotation rule over an extended period of time is expected to be insignificant.

3.6.8 Conclusion

We propose replacing the existing wording in Federal Register, p 3142, 412.37 (a)(2) *i* and *ii* with the following text:

“Multi-year phosphorus applications are permissible as long as they do not exceed the nitrogen limit for the current crop year. The phosphorus store should not exceed 5 years of crop need if there is a high or very high risk of phosphorus loss.”

3.7 REFERENCES

ASAE, 1998. Agricultural machinery management data. Std. no. D497.4.

Barrow, N.J. 1980. Evaluation and utilization of residual phosphorus in soils. *In* The Role of Phosphorus in Agriculture. ASA-CSSA-SSSA, Madison, WI.

Edwards, D.R., and T.C. Daniel. 1993. Runoff quality impacts of swine manure applied to fescue plots. Trans. Of the ASAE 36:81-86.

Edwards, D.R., and T.C. Daniel. 1994. Quality of runoff from fescue plots treated with poultry litter and inorganic fertilizer. J. Env. Qual. 23:579-584.

NRCS. 2000. Nutrient management standard 590. United States Department of Agriculture - Natural Resource Conservation Service. www.nrcs.usda.gov.

Pote, D.H., T.C. Daniel, D.J. Nichols, A.N. Sharpley, P.A. Moore, Jr., D.M. Miller and D.R. Edwards. 1999. Relationship between phosphorus levels in three Ultisols and phosphorus concentrations in runoff. J. of Env. Qual. 28:170-175.

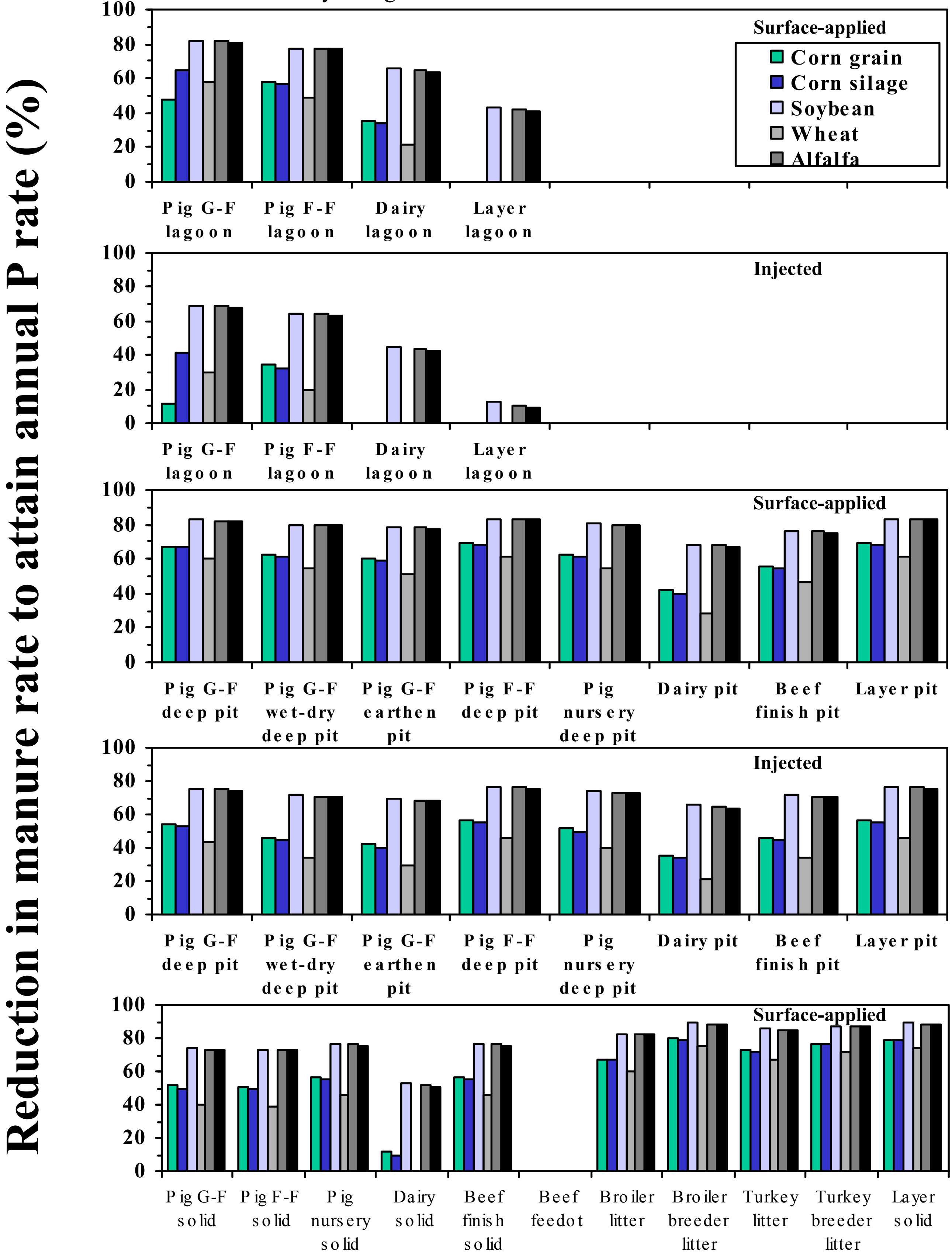
Sharpley, A.N., S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Managing agricultural phosphorus for protection of surface waters: issues and options. J. Environ. Qual. 23:437-451.

Shreve, B.R., P.A. Moore Jr., T.C. Daniel, D.R. Edwards and D.M. Miller. 1995. Reduction of phosphorus in runoff from field-applied poultry litter using chemical amendments. J. Environ. Qual. 24:106-111.

3.8 FIGURES

Figures for Chapter 3 are on the following pages.

Figure 3-1. The percent reduction in manure application rate required if adopting an annual phosphorus rate for manure application for selected crops and manure sources. Values of 0% will continue to be restricted by nitrogen limits.



Chapter 4
ON-FARM EVALUATION OF ADOPTING PHOSPHORUS VERSUS NITROGEN LIMITS FOR MANURE APPLICATION ON U.S. SWINE OPERATIONS

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4.2 EXECUTIVE SUMMARY

- A simulation model containing 7 modules (1) an animal production module, 2) a manure storage design module, 3) a manure nutrient generation module, 4) a nutrient management module, 5) a GIS module, 6) a manure application module and 7) an economic simulation of swine production module) was used to estimate the feasibility and impact of proposed EPA CAFO regulations on 31 farms in 5 states.
- Feasibility was defined as either technically feasible using current land application technology or able to be accomplished within a window of fieldwork days appropriate for manure application.
- Farms using tankers to distribute pit slurry were operating near their maximum travel speed and therefore needed to reduce discharge rate or increase swath width to comply with phosphorus limits. Twenty percent of the operations would be unable to attain annual phosphorus application rates even with totally new equipment purchases. Rotational phosphorus limits was their only method to attain compliance.
- PA and IA will have the most difficultly accommodating a phosphorus rule because they predominately use pits, have increases in application time due to over-the-road tanker transportation and grow row crops that limit when manure can be applied prior to planting.
- The average monthly capacity of pits in IA and PA is 7 months. Any regulations against fall applied manure for spring planted crops will severely affect IA and PA.
- In the short run, producers in MO and IA using lagoons are relatively unaffected by a switch to a phosphorus rule as long as they are not required to agitate lagoons. Producers in NC using lagoons will need to access 25% more acres to implement a phosphorus limit. The predominate use of irrigation technology and the geography of NC could make this difficult. (Note: short run analysis does not take into account cleaning and closing lagoons that have filled with sludge).
- The estimated average cost of land application of manure was $.006/gallon for traveling guns and dragline technologies, $.001/gallon for center pivots, $.003/gallon for stationary sprinklers, $.007/gallon for truck-mounted tankers and $.012/gallon for tractor pulled tankers.
- Independent swine producers currently spend an average of 2% of their gross revenue on land application of manure (does not include storage structure costs); contract producers spend an average of 10% of their gross revenue on manure management.
- Our analysis estimates 6 of the remaining 30 farmers (one farm could not comply) capable of applying manure under a phosphorus rule (20%) would have a greater than 5% increase in the cost:sales ratio. All are contract producers. Five are in PA and one is in IA. All apply pit slurry with a tanker. Forty six percent of contract producers are in the stress category.
- We predict that the EPA's economic assessment of farms in the moderate to stress categories is underestimated. Table 10-6 of the Preamble (Federal Register, p 3090) reports that the EPA estimates that 20% of the hog producers will be in the moderate to stress categories. Their estimate of 20% includes the cost of attaining zero discharge. Our estimate of 20% considers only the cost of implementing a rotational phosphorus limit.

4.3 INTRODUCTION

This chapter seeks to follow the impact of implementing a phosphorus limit through the entire swine production system.

Correctly assessing any regulatory change requires that the impact on production and financial measures of the business be understood. Second, the regulations need to be deemed technically feasible. Third, the rules must be financially feasible for the businesses subject to the rules.

In order to understand the system in which regulations would be implemented, we chose to model the impacts of regulations on real farms rather than hypothetical farms. We went to five states and extensively interviewed over 50 farms. Of those we were able to model 31 farms to determine what they were presently doing for manure management and what the impact of regulations would be on these specific farms.

The results enabled us to evaluate the impact of proposed regulation on land availability for manure application and the differences between farms in different geographic regions and with different business structures.

Technical feasibility requires a thorough understanding of the system within which the rules will be implemented. Environmental regulations on confined animal feeding operations have impact on animal production, engineering designs, cropping systems and financial performance.

We looked at the impact of application rate changes on travel speed, discharge rate and swath width to determine if the farmer could implement the rule with little or no monetary outlay. When current equipment was not capable of implementing a change, we sought to identify and acquire equipment that could accomplish with the application requirements imposed by the proposed regulation. On several occasions it was deemed that no capable equipment currently existed, or that the availability of the equipment was so limited that purchase and operation was not likely to occur. The proposed rule created a change that affected the whole system and not an portion of the system.

Environmental regulations affect the financial performance of businesses seeking to comply with them. Financial performance is composed of profitability, liquidity and solvency. Changes in profitability as measured by return on assets were determined for the different systems. Sales as a percent of gross revenue were evaluated because this was the primary measure used by the USEPA to determine financial impact. We also looked at (but had difficulty reporting) the impact on liquidity by observing the impact of equipment purchases and annual operating cost increases on cash flow.

The result of our analysis of the sample of real farms is that an annual phosphorus limit is unnecessary to achieve the environmental goals of the USEPA. An annual phosphorous limit is either infeasible, or more expensive when feasible, than a rotational phosphorus limit. We also find that regional and business organization differences are significant in understanding the impact of the proposed rule.

4.4 METHODS AND MATERIALS

Farm visits were conducted to gather data on current manure management on farms in IA, OK, MO, NC and PA. These states were chosen to represent the four major pork production regions in the US as defined by EPA. Appendix A describes the farms, their type of manure storage and land application technology. The survey collected information about the location of the farm; the number, production phase and size of swine on the farm; the amount of water use in the buildings; description of the manure handling and storage system; estimates of annual manure volume; nitrogen, phosphorus and potassium concentration in the ration; manure test results; description of crop rotations including yield goals; location of fields receiving manure, streams, wells and other sensitive areas near the land application areas; equipment used for manure application and estimates of the time required for manure application. Farmers were also asked for soil test phosphorus levels for each field. All information was not available on all the farms.

4.4.1 Simulation Model

The collected data was used to develop the input and to validate the results of a simulation model used to estimate time requirements, land requirements and economic ramifications of adopting either an annual phosphorus-based application strategy required by the proposed EPA rule or a phosphorus rotation strategy. The mechanistic simulation model used contains the following seven modules: 1) a swine production module, 2) a manure storage design module, 3) a manure nutrient generation module, 4) a nutrient management module, 5) a GIS module, 6) a manure application module and 7) an economic simulation of swine production module (Massey, et al., 2000).

The animal production model predicts the number of animals at each phase of production based on specific production characteristics including weekly, bi-weekly, or monthly farrowing capacity, farrowing rate, pigs per litter, days pigs are in the nursery, weight leaving the nursery, wean to finish average daily gain, and market weight. Typically, actual animal numbers in each phase of production were clearly reported by the operator and were used in this analysis instead of the predicted animal numbers using the animal production model.

The storage design model estimated volume of manure or effluent pumped annually from the manure storage facility based on county weather data, animal numbers and the geometry and type of the manure storage facility. Nutrients excreted by the animals were estimated in the nutrient generation model based on the quantity of nutrients fed the animals and efficiency of the nutrient retention estimated from a literature review. Typically, we used model estimates of mean volume of manure pumped annually and the farmer manure test result to estimate nutrient generation. Results of the predicted manure volume and nutrient concentration were compared with manure test results and farmer estimates of manure volume as a check on accuracy of volume and manure nutrient concentration estimates used in the analysis. In some cases farmer manure test results were rejected when low manure nutrient concentrations implied improbably high nutrient efficiencies based on model results. Feed-based estimates of nutrient content of the manure were used when no manure test data was available.

Farmers were asked to identify on a map all fields on their farm and on rented farms. A geographical information system (GIS) was used to map fields, calculate field size, determine acres suitable for manure application (field size minus water quality set backs), and measure the distance the manure must be transported from storage to field. The total number of acres, the acres in crop production and the crop acres suitable for manure application were determined for each farm. Farmers were also asked to identify other farms where they currently apply manure and to identify other fields and farms where they anticipated they could apply manure if they needed more land. Neighbors' farms that were designated as potentially receiving manure were also mapped.

Fertilizer need for each field for each year of a 4-year crop rotation was determined based on farmer reported yield goal. Nitrogen need of non-legume crops was calculated based on the state-specific fertilizer recommendations. Phosphorus and potassium fertilizer need of all crops and nitrogen fertilizer rate for legumes was calculated based on crop removal capacity of the crops (Table 4-1).

Fields were prioritized for manure application based on proximity to storage (tanker technology and pivot irrigation) or to minimize additional piping requirements to the next field (irrigation and dragline technology). The fields within a similar distance to storage were further ordered based on nitrogen fertilizer need (e.g. corn preferred to soybean because corn requires fertilizer N whereas soybean has no fertilizer N requirement).

A computer program was used to calculate the application rate and distribute manure to the ordered fields until all manure was distributed. Application rates based on nitrogen need were based on the plant available nitrogen content of the manure. Manure plant available nitrogen (PAN) was estimated by assuming 35% of the total nitrogen is organic nitrogen in slurry pits; 20% in lagoons. Application rates based on phosphorus were based on the total phosphorus content of the manure. Manure phosphorus and potassium was assumed to be 100% equivalent to other phosphorus and potassium fertilizer sources.

Time required to distribute manure was calculated using a mechanistic budgeting approach. Manure distribution time is composed of setup time, transport time and land application time. Farmer supplied data was used, where available, to estimate time parameters such as travel speed and pipe layout time. Where no farmer-supplied data were available, a time motion study performed at the University of Missouri in 1999 (unpublished data) was used to estimate time parameters.

Storage setup time was the positioning of any pumps and pipes used in manure application. Examples of storage setup activities would be setting up pumps for agitating and unloading the storage. A 2-hour setup time was assumed for each storage. If the storage was agitated prior to pumping, agitation time was added to setup time.

Table 4-1. Nutrients removed in the harvested portion of selected crop.

Crop	Yield unit	N lbs/unit	P_2O_5 lbs/unit	$N:P_2O_5$ ratio	K_2O lbs/unit
Corn grain	bushels	0.9	0.4	2.3	0.3
Corn silage	tons	8.4	3.8	2.2	8.9
Soybean	bushels	3.4	0.8	4.3	1.4
Wheat	bushels	1.3	0.7	1.9	0.4
Bermuda grass hay	tons	49	11	4.5	42
Big bluestem hay	tons	20	11	1.8	26
Tall Fescue hay	tons	39	14	2.8	53
Alfalfa hay	tons	50	12	4.2	50

Note: Values are reported as nitrogen (N), phosphate (P_2O_5) and potash (K_2O).

Sources:

NRCS. 1992. Agricultural waste management handbook. U.S. Department of Agriculture Soil Conservation Service, Washington DC.

Buholtz, D.D. 1992. Soil Test Interpretations and Recommendations Handbook, Department of Agronomy, University of Missouri, Columbia, MO.

Potash Phosphate Institute, Norcross, GA.

Agronomy Guide, The Pennsylvania State University, State College, PA.

North Carolina State University, AG-439-16

General Guide for crop nutrient recommendations. March 1999. Iowa State University, Ames, IA.

Atlas of nutritional data on US and Canadian Feeds. 1971. National Acad. of Sciences, Washington, DC.

Griffith, W.K. and L.S. Murphy. 1996.

Macronutrients in Forage Production. In (R.E. Joost and C.A. Roberts eds.) Nutrient Cycling in Forage Systems. Proc. Of a conference held March 7-8, 1996. Columbia, MO.

PPI, Manhattan, KS

Transportation time for tanker technology is a function of the distance from storage to field. Our study used a road travel speed of 10 miles per hour when the tank is pulled by a tractor and 20 miles per hour when mounted on a truck. Within field travel speed (travel from the road to the point within the field where manure is applied) was set at 5 miles per hour.

The time required for setup of distribution pipes for technologies such as irrigation and dragline was viewed as transportation time. Lay down and pickup time for aluminum pipe was assumed to require three persons and was estimated to take 11.6 hours per mile of pipe lain. Lay down and pickup time for flexible hose was assumed to require two persons and was estimated to take two hours per mile. In traveling gun systems, an additional setup time of one hour per pull was included in traveling gun transportation time to move the irrigation to the next pull lane and to extend the traveling gun to the end of the pull lane. In dragline systems, an additional setup time of 30 minutes was added for each additional pull from a pivot point for moving the tractor and hose from the end of the first pull to the beginning of the second.

Application time is a function of discharge rate (gallons/minute) from the land application equipment. The manure-pumping rate was assumed at the highest mechanically attainable discharge rate within the field speed range of the land application equipment. The model was constrained by a permissible range of field speeds for each piece of equipment. For tankers and pivots, swath width was held constant; for traveling guns, swath width occasionally decreased with discharge rate.

Lowering discharge rate often requires equipment modifications such as installing a pinch valves and/or manifold distribution systems. If adjustments in travel speed and discharge rate were insufficient to meet an application rate the application rate was considered not to be feasible for that farm.

Changing application rate (gallons/acre) directly affects the discharge rate. Application time changed when the constrained application rate caused a change in setting on equipment used. The producer's choice of discharge rate, application swath width and field travel speed establishes the application rate. Our analysis assumed that the producer would choose to use their current equipment complement and considered swath width as a pre-determined variable. Most producers modeled currently operate in the upper range of the attainable field speed (Of 14 tankers modeled in our study, the average speed was 4.4 miles per hour. See table 3-4).

Feasibility of calculated application rates was assessed for equipment reported for manure application use. Application rate was met by maximizing discharge rate for the specific piece of equipment. Travel speed was used to adjust equipment application rate. If more adjustment were required to attain the desired application rate, discharge rate would be lowered. Lowering discharge rate often requires equipment modifications such as installing a flow reducer. For tankers and pivots, swath width was held constant; for traveling guns, swath width varies with discharge rate. If adjustments in travel speed and discharge rate were insufficient to meet an application rate, the application rate was considered not feasible for that farm.

Depreciation of power equipment is a function of age and annual hours used. Depreciation of non-power equipment is considered a function of age only. Depreciation was estimated using the remaining value coefficients estimated by Cross et al. [, 1995 #293]. Remaining value was input into other cost estimates of interest (7%/year), taxes and insurance (2%/year), and repair. Standard cost estimation techniques were used.

A labor rate of $10/hour was charged regardless of the season when manure is distributed or the total number of hours needed for manure distribution. Fuel cost was set at $1.00 per gallon.

If the producer used a custom manure applicator rather than personally owned and operated equipment, an hourly custom rate was charged to the number of hours estimated by the model. The hourly rate charged was reported by the producer and varied from producer to producer and by geographic region.

4.4.2 Fieldwork days

The USDA Ag Statistics Services in each state track fieldwork days per week and progress of planting and harvest. Table 4-2 presents the fieldwork hours for OK, IA, MO, and PA (USDA). These reports were used to estimate the number of hours available for manure distribution. Reported field work days were divided into the following categories: 1) pre-planting season, 2) planting season, 3) growing season, 4) harvest season and 5) post-harvest season.

Table 4.2. Fieldwork hours for different cropping seasons

	MO		OK			PA		IA	
Cropping Season	Corn	Soybean	Corn	Soybean	Wheat	Corn	Soybean	Corn	Soybean
Pre-planting	74	225	813	1062	728	239	361	173	300
Planting	275	181	181	447	261	198	278	174	165
Growing Season	1183	1306	1202	813	1347	1319	1117	1407	1232
Harvest	398	219	327	321	246	318	221	246	198
Post-harvest	106	106	688	568	n/a	46	141	207	325

Source: USDA State Ag Statistic Services

When zero or one out of the last five years had no suitable fieldwork days, no fields were assumed suitable for working. MO, PA and IA have weeks with no reported fieldwork days. OK reports suitable fieldwork days every week of the year. When at least two of the last five years have reported fieldwork days, these fieldwork days are averaged and multiplied by the number of hours of sunlight for that week to determine available fieldwork hours for the respective season.

Pre-planting season reports the number of fieldwork hours after the ground thaws and before the “most active planting season” begins. Most active planting season is shorter than usual planting season, allowing a longer period for pre-plant manure application. Pre-planting season is the time most producers can perform activities such as manure distribution, tillage, fertilizer application and seedbed preparation. All injected or incorporated manure application must occur during this season in order to not interfere with crop growth and to utilize the fertilizer value of the manure.

Planting season fieldwork hours are the number of hours available for planting during the “most active planting season.” Usual planting occurs before and after this time but was included in the pre-planting and growing seasons to make conservative time limitation estimates. During the most active planting season the producer is assumed to be planting and have no time for other field activities.

Growing season is the time between planting and harvesting. For most crops, only irrigation of manure effluent can be done at this time. Surface application using tankers can be done in limited situations. For hay crops, manure distribution was assumed possible as surface application of manure for one week after each hay cutting. Harvest season fieldwork hours are the number of hours available for harvest during the "most active harvest season." Usual harvest fieldwork hours occur before and after the "most active" harvest season time. The harvest fieldwork hours occurring before and after the "most active harvest season" were included in the growing and post-harvest seasons to make conservative time limitation estimates. During the harvest season, the producer is assumed to be harvesting and have no time for other field activities.

Post harvest season is the number of hours available after harvest season and before the ground freezes. Field activities such as tillage and fertilizer application can be performed during this season but are discouraged in order to reduce soil and nutrient losses. No manure application was assumed during this season.

The fieldwork time estimates give an impression of the feasibility of manure application during appropriate periods. For example, a typical Iowa farm growing corn and soybeans would be expected to have 173 hours prior to planting corn for manure application. Prior to soybean planting, the farmer has an additional 127 hours available. However, corn planting will be the priority activity during that time and little time may be available for manure application. If the farmer uses tanker technology to inject manure, little opportunity outside of the pre-plant season is appropriate for manure application.

An Oklahoma farmer using irrigation technology to apply lagoon effluent would have a wide range of time to apply during the growing season.

4.4.3 Pumpable Nitrogen and Phosphorus Estimation

Excreted nitrogen and phosphorus were estimated using two methods. One was the feed intake method based on the feed consumed by the pigs and an estimate of the nitrogen and phosphorus use efficiency of the animal. The second was the manure test method based on manure test results, the volume of manure generated on the farm and the percent of excreted manure land applied. The feed intake method was more highly correlated with animal units (r^2=0.87 for nitrogen; r^2=0.89 for phosphorus) but did not reflect possible differences in feed efficiency among operations. The manure test method was more poorly correlated (r^2=0.74 for nitrogen; r^2=0.64 for phosphorus). Errors in manure testing, estimating the volume of manure and the percentage of P land applied all contribute to the variability of this method. Some of the variability may also be due to differences in animal nutrient use efficiencies and diets reflected in the manure test.

4.5 Results and Discussion

Thirty-one swine operations were analyzed in five states: Iowa, Missouri, North Carolina, Oklahoma and Pennsylvania. These operations represented a wide range in number of animals (Figure 4-1), phases of production, methods of manure storage and land application strategies and quantity of manure and nutrients available for land application (Appendix A).

4.5.1 Current Manure Management Practices

The current manure management practices were analyzed for each operation to establish a baseline of information for comparison. Then, various changes in manure management requirements were analyzed and compared to the developed baseline simulation results to show the potential effect of the given management change.

4.5.1.1 Size effects on nutrient production and utilization

The USEPA proposes to continue to regulate animal feeding operations based on the number of animals in the operation. Size of operation was a good predictor of the quantity of nitrogen and phosphorus excreted by animals on the analyzed operations (Figure 4-2). Operation size represented by animal units was highly correlated with the estimated quantity of phosphorus consumed and the nitrogen and phosphorus excreted by animals (Figure 4-2) among swine operations with different phases of production.

USEPA has assumed that larger operations concentrate more manure on less land than smaller operations (Federal Register, 2001; p. 2974). The USEPA's assumption that larger swine operations have less land was weakly supported by our data. Regional differences in land management were more important than size on the analyzed swine operations. On the analyzed farms, the density of animals on controlled acres (acres owned and rented by the animal feeding operation) was positively correlated with the size of operation (Figure 4-3), but the size of operation only explained 18% of the variability in animal density. North Carolina farms had significantly higher animal density per controlled acre than farms in other surveyed states ($P<0.01$). The six farms analyzed in North Carolina had a mean of 22 animal units per acre whereas farms in the other five states had a mean of 3.5 animal units per acre. The high ratio of animal units to owned and rented (controlled) acres implied nutrient production on North Carolina operations was the most intense for their land base.

The ratio of animal units to acres provides an inaccurate picture of the balance between land and animals. The number of acres fails to capture the capacity of the land to utilize nutrients from animal feeding operations. Crops, geographic regions, soil types and site-specific factors all affect the quantity of nutrients removed annually by crops. Mean nitrogen removal varied by a factor of almost two among states, and phosphate removal capacity varied by a factor of over four (Table 4-3). North Carolina and irrigated fields in Oklahoma had higher nitrogen removal capacity than other states. Most analyzed farms in North Carolina grew bermuda grass with, in some cases, an early season rye forage crop, to utilize manure nutrients. Legumes were the most prominent part in nitrogen removal capacity in Iowa (compare nitrogen recommended and nitrogen removed).

A full understanding of the balance of land and animals requires looking at the balance of nutrients produced by the animals and the capacity of the land to use those nutrients for crop or forage production (Table 4-4). North Carolina is only marginally higher than other states when evaluating the ratio of nitrogen excreted by animals to nitrogen removal capacity (Table 4-4). North Carolina operations often have relatively few owned and rented (controlled) acres, but obtain high nitrogen utilization capacity on those acres.

Table 4-3. Mean nitrogen recommended and nitrogen and phosphorus (as P_2O_5) removal capacity on a per acre basis of operations surveyed, by state.

State	n	N recommended lb/ac	N removal lb/ac	P_2O_5 removal lb/ac
Iowa	6	84 b	164 b	55 b
Missouri	6	112 b	147 b	45 b
North Carolina	6	234 a	240 a	64 b
Oklahoma	4	142 b	142 b	23 c
Oklahoma-Irrigated	3	266 a	266 a	95 a
Pennsylvania	6	115 b	145 b	52 b
Prob. > F		<0.01	<0.01	<0.01

Notes: Means in the same column followed by a different letter are significantly different. Recommended nitrogen was 0 for legumes. Operations with irrigation in Oklahoma were listed separately from other operations in Oklahoma.

Table 4-4. Mean ratio of nutrient production and nutrient capacity of swine animal feeding operations.

State	n	Nitrogen Excreted N to N removal capacity ratio lb/ac	Phosphorus (as P_2O_5) Applied PAN[1] to N removal capacity ratio lb/ac	Excreted P to N removal capacity ratio lb/ac	Applied P to N removal capacity ratio lb/ac
Iowa	6	0.5 b	0.2 b	0.9 b	0.9 b
Missouri	6	2.7 ab	0.4 b	6.7 ab	0.7 b
North Carolina	6	3.9 a	0.2 b	17.6 a	0.7 b
Oklahoma	7	1.8 ab	0.1 b	4.9 b	0.5 b
Pennsylvania	6	2.9 ab	1.5 a	5.4 b	5.4 a
Prob. > F		0.03	0.01	0.03	0.01

Notes: Nutrient production calculated as excreted nutrients or as plant available nutrients land applied. Nutrient capacity based on crop removal capacity of acres suitable for manure application on the farm. Means in the same column followed by a different letter are significantly different.
[1] Plant available nitrogen (PAN).

The predominant practice for land application of manure on the analyzed farms was to apply manure on land controlled (owned or rented) by the animal feeding operation. All but five of the analyzed farms had sufficient land for land application of manure on controlled acres for nitrogen-based manure application with the current manure storage and handling system. The five operations without sufficient land for nitrogen application were partially dependent on land not controlled by the operation and all were located in

Pennsylvania. Pennsylvania farms required 1.4 times the land controlled by the operation for nitrogen-based land application. Operations in the other states needed a mean of 28% of their acres suitable for annual manure application based on a nitrogen application.

Costs associated with current land application practices were highest on the smallest operations (Figure 4-4). There is a diminishing benefit of scale associated with manure application costs.

4.5.1.2 Manure storage effects on nutrient utilization and land application costs

Slurry systems land apply a higher proportion of the excreted nutrients resulting in more acres of land being fertilized per animal unit ($P \leq 0.01$). Manure from pits required 0.27 acres per animal unit compared to 0.09 acres per animal unit for unagitated lagoons. The higher need for land with slurry systems reflects the lower losses of nitrogen during storage in slurry systems compared to unagitated lagoons.

Higher nitrogen losses during storage and land application in lagoon systems (predominant in North Carolina and Missouri) eliminate much of the nitrogen excreted by the animals before the manure reaches the crop. North Carolina, Pennsylvania and Missouri had the highest ratio of excreted nutrients to owned or rented (controlled) land capacity (Table 4-4). After manure storage and land application, there is no difference among states, except Pennsylvania, in the ratio of manure nutrients available for the crop to nutrient capacity of the land base (Table 4-4). A similar pattern is found for phosphorus because most of the phosphorus is deposited in sludge retained at the bottom of most lagoon systems.

Costs for land application were similar for lagoon and pit systems (P=0.25) despite the greater land requirements for pit systems. Mean cost per animal unit was $10.17 for lagoons and $13.31 for pit systems. Cost per gallon for land application of lagoon effluent was less than half of that of pit slurry systems ($0.011 vs. $0.004). Lower volume of manure associated with slurry operations offset the higher cost per gallon of applying slurry manure.

Pit systems were consistently able to obtain more fertilizer value from their manure on an animal unit basis ($P \leq 0.01$). The greater fertilizer value of slurry manure was able to offset the added cost of accessing more land. Net costs of manure application (cost of application less fertilizer value of manure) were lower on farms with pit manure. Net manure application costs on farms applying manure from slurry systems was $1.25 per animal unit compared to $6.76 per animal unit for operations applying unagitated lagoon effluent. Compared simulation results show that 6 of 13 operations spreading slurry were able to apply manure profitably on their farm compared to only 3 of 16 applying lagoon effluent (two operations had multiple manure forms (e.g. a pit and a lagoon) on their farm and were not included in this comparison).

This conclusion assumes farmers are capturing the fertilizer value of the manure being applied. To capture manure fertilizer value, farmers need to reduce rates of nitrogen, phosphorus and potassium from other purchased sources on land receiving manure and then harvest a crop with value from the land. Value can be realized as grain or hay from crop ground and meat and milk from pastures. On 88% of the farms, all the manure was being applied to owned or rented ground. The high proportion of the manure being applied to land controlled by the farmer makes it more likely that farmers are capturing at least some of the manure value under the current system.

4.5.1.3 Feasibility of land application equipment

4.5.1.3.1 Pit systems

Characteristics of the 15 operations that handled pit manure are summarized in Table 4-5. Mean minimum application rate for these slurry systems was 4,497 gal/acre with nitrogen-based management. The lowest calculated application rate for slurry operations was 2,390 gal/acre for an Iowa operation (IA-4) with 525-animal units that had a small tractor-pulled spreader with a discharge rate of 350 gal/min. Mean discharge rate among the 14 operations was 728 gallons per minute; mean swath width was 14 feet for injection and 25 feet for surface applications.

Table 4-5. Application parameters for farmers using pit slurry storages and applying on a plant available nitrogen limit.

Presentation Code	Application Technology	Placement	Minimum Application rate (gal/acre)	Discharge Rate (gal/min)	Swath Width (ft)	Travel Speed (mph)
IA-1	Tanker, tractor	injection	4,080	600	15	4.9
IA-3	Tanker, tractor	injection	5,580	800	15	4.7
IA-4	Tanker, tractor	injection	2,390	350	15	4.8
MO-2	Tanker, tractor	injection	3,680	425	12	4.8
IA-2	Tanker, tractor	surface	12,000	1,000	15	2.8
IA-5	Tanker, tractor	surface	4,380	650	15	4.9
IA-6	Tanker, tractor	surface	4,950	800	30	2.7
OK-5	Tanker, tractor	surface	3,000	600	20	5.0
PA-4	Tanker, tractor	surface	4,560	1,000	40	2.7
PA-5	Tanker, tractor	surface	3,550	800	25	4.5
Means			4,817	703	20	4.2
PA-1	Tanker, truck	surface	3,770	725	16	6.0
PA-2	Tanker, truck	surface	5,030	1,000	30	3.3
PA-3	Tanker, truck	surface	3,880	850	20	5.4
PA-6	Tanker, truck	surface	3,160	800	40	3.1
Means			3,960	844	27	4.5
MO-3	Dragline	injection	3,450	520	15	5.0

Most applicators were operating near their maximum application speed (see Chapter 3). Mean travel speed for tractor-pulled spreaders was 4.2 miles/hour; mean travel speed for truck-mounted tankers was 4.5 miles/hr.

Operations using tractor-pulled or truck-mounted tanker spreaders operated their equipment for an average of 118 hours/year doing land application activities (loading the tanker, road travel, in-field travel and application time). The average operation spent 20% of this as road travel time (range 4 to 46%) and 37% of this time discharging manure (range 21 to 53%). The size of the swine operation was a good predictor of the amount of time required for land application of manure utilizing tanker spreaders (Figure 4-5).

4.5.1.3.2 Lagoon systems

Characteristics of the 17 operations that handled lagoon effluent through irrigation systems are summarized in Table 4-6. Mean minimum application rate for these lagoon systems was 27,649 gal/acre using nitrogen-based management. Mean discharge rate among the 17 operations was 383 gallons per minute.

Table 4-6. Application parameters for farmers applying lagoon effluent using irrigation systems and applying based on a plant available nitrogen limit.

Presentation Code	Application Technology	Placement	Minimum Application Rate (gal/acre)	Discharge Rate (gal/min)	Swath Width (ft)	Travel Speed (ft/min)
MO-1	Traveling gun	surface	18,465	200	300	1.6
MO-5	Traveling gun	surface	27,154	400	250	2.6
NC-2	Traveling gun	surface	27,154	300	200	2.4
NC-3	Traveling gun	surface	27,154	300	225	2.1
NC-4	Traveling gun	surface	27,154	250	250	1.6
NC-5	Traveling gun	surface	27,154	295	275	1.7
NC-6	Traveling gun	surface	27,154	350	260	2.2
OK-4	Traveling gun	surface	27,154	325	300	1.7
OK-5	Traveling gun	surface	27,154	320	300	1.7
Mean			26,189	304	262	2.0
NC-1	Stationary sprinkler	surface	27,154	200	90	-
OK-1	Stationary sprinkler	surface	27,154	450	160	-
OK-3	Stationary sprinkler	surface	27,154	225	180	-
Mean			27,154	292	143	-
MO-4	Dragline	injection	27,154	750	12	1.1[1]
MO-6	Dragline	injection	16,564	650	12	1.6[1]
Mean			21,859	700	12	1.4[1]
OK-2	Center Pivot	surface	16,835	500	-	-
OK-6	Center Pivot	surface	14,935	500	-	-
OK-7	Center pivot	surface	77,389	500	-	-
Mean			36,386	500		

[1] Units are mph for these values only.

Most applicators were operating well below their maximum application speed (see Chapter 3). Mean travel speed for traveling guns was 2.0 ft/min; mean travel speed for dragline injection was 1.4 miles/hr.

Operations applying lagoon effluent operate their equipment an average of 142 hours/year doing land application activities (setting up irrigation pipe, setting up pull of traveling gun (when applicable) and application time). The average operation spent 6% of this time setting up the pipe network (range 0 to 23%) and 84% as application time (range 53 to 100%). No correlation existed between operation size and application time for lagoons (Figure 4-5).

4.5.1.4 Travel distance and time of application effects

Time required to land apply manure is a major component of the feasibility of any manure management strategy. Pit slurry is difficult to apply during the growing season so farmers tend to apply it before planting and after harvesting row crops and as a surface application on hay during the summer.

At least two seasonal constraints are possible under the proposed EPA rule. First, the 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… (Federal Register p. 3039)." Second, post-harvest (e.g. fall) application may be restricted or prohibited because "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 (Federal Register p. 3039)."

4.5.1.4.1 Pit systems

Mean travel distance between manure storage and the field for manure application was increased with operation size (Figure 4-6). Pennsylvania farms had greater travel distance than Iowa farms (*P=0.1)*, in part because analyzed Pennsylvania farms were larger than analyzed Iowa farms. Operations currently spend an average of 20% (range of 4 to 46%), or 26 hours (range 3 to 116 hours), of their manure application time in road travel from manure storage to field.

Iowa has a restrictive manure application window. The predominate crop system of corn/soybean rotation requires applying slurry before planting in the spring and after harvesting in the fall. Fieldwork hours prior to corn planting are estimated at 173 hours (Table 4-2). The maximum application time for the Iowa farms modeled was 132 hours, sufficient for pre-plant application. Two of the six Iowa farms used multiple tankers to reduce the amount of time that would actually be spent land applying manure.

Only two of the six Iowa farms had 12-month storage capacity; the remaining four had 4- to 6-month storage capacities. Short storage capacity requires application of manure during the growing season or after harvest in the fall. If the USEPA permit writers do not permit fall application, these farms would need to make significant investments to increase their manure storage capacity.

Pennsylvania farms had the largest annual application time of 121 hours. This allowed application prior to planting corn. The average size manure storage in PA was a 7-month capacity; with none of our modeled farms having 12-month capacity. PA farmers applied manure to hay during the summer and several applied manure after wheat harvest in the summer to keep the pit storage from over-flowing. The proposed regulations may prohibit application of manure after wheat harvest in mid- to late-summer because the land is not planted to a crop for several months and manure nitrogen may volatilize before it can be used for crop production.

4.5.1.4.2 Lagoon systems

None of the lagoon systems experienced time constraints applying lagoon effluent within the appropriate application time windows. All producers in North Carolina and Oklahoma and two producers in Missouri with lagoons used irrigation technologies (spray fields, center pivots and traveling guns) to apply effluent to growing crops. The long growing season in these states permits long application windows.

Two of the four Missouri producers with lagoons used dragline and tanker technology to apply lagoon effluent. This requires application prior to planting corn. MO-6 is estimated to take 119 hours to apply effluent. Only 74 hours are estimated to be fieldwork hours according to the USDA statistics (Table 4-1). This person already applies effluent to land in the spring and fall. Limits on fall application would impact this producer’s management.

4.5.1.5 Land Application Technology Effects On Manure Application Cost

Table 4-7 presents the types of application technologies used and their prevalence by state on the analyzed farms. The irrigation technologies (traveling gun, center pivot and stationary sprinklers) were used exclusively to distribute lagoon effluent. Dragline technology is used to distribute both lagoon effluent and pit slurry. Tanker technology is used predominately to distribute pit slurry but also was used to apply lagoon effluent, particularly when the producer had both lagoon and pit storages.

Traveling gun systems are the most common system for land applying anaerobic lagoon effluent. The average cost was $.006/gallon of effluent applied. Traveling guns are the most expensive irrigation technology used but are less labor intensive than stationary sprinklers and provide more flexibility to irrigate additional land areas than center pivots.

Center pivots are the least expensive manure distribution system ($.001/gallon) where producers use irrigation equipment designed for water application on crops to also distribute manure effluent. Application of lagoon effluent will not, especially in arid regions, provide adequate moisture for maximum crop production without the application of additional water through the irrigation system.

Stationary sprinklers are inexpensive manure distribution systems ($.003/gallon) that are very labor intensive. Stationary sprinklers are appropriate to distribute effluent on small acreages but become labor prohibitive when many acres are needed to appropriately distribute effluent.

Table 4-7. Frequency for different types of manure application technology used on the analyzed operations.

Type of application	IA	MO	NC	OK	PA	Grand Total
Traveling gun		2	5	2		9
Center Pivot				3		3
Stationary sprinkler			1	2		3
Dragline		3				3
Tanker, tractor	5	1			2	8
Tanker, truck	1				4	5
Grand Total	6	6	6	7	6	31

Dragline systems use 4-inch to 6-inch hoses that transport manure from the manure storage to the fields. The hoses are dragged behind a tractor equipped with a tool bar injector that distributes the manure over a 12- to 18-foot swath. Dragline systems had an average application cost of $.006/gallon. Dragline systems typically injected or incorporated manure during land application.

Tractor-pulled tankers were most commonly used to apply pit slurry in the Midwest (IA and MO). The average cost of $.012/gallon was the most expensive application system but permitted hauling of manure greater distances and allowed access to land areas not available with other technologies. Tractor-pulled tankers are frequently used to inject manure.

Truck-mounted tankers were more common in PA and were used when surface application was practiced. Wider swath widths of 25 to 40 feet allow low application rates. Using a truck as power unit for the tanker allows increased transportation speed but limits the power available to incorporate the manure. Truck-mounted tankers had an average cost of $.007/gallon of slurry applied.

The reported costs of manure application are based on the current management technologies used by the producer. Some producers own their equipment and apply their manure; while others producers custom hired their manure application. Five of the seven producers who used custom applicators hired ones who used more than one tank to apply the effluent. This reduced the amount of time spent applying manure on that particular farm. Two producers owned more than one traveling gun to manage their effluent application.

Tractors used to pull manure application tankers were used for other activities on the farm. Their equipment complements were sized to fit the needs of the whole farm. Farms with significant cropping activities had larger tractors and tankers. Small farms tended to have small tractors pulling small tankers (OK-5 and IA-3).

Producers who use traveling guns and solid set sprinkler systems tended to have smaller tractors that are used to assist in operating the manure distribution equipment.

4.5.1.6 Indicators of economic viability of current management practices

The USEPA uses as its primary criteria for determining financial impact of the proposed regulations the Sales Test. The sales test is defined as the cost of compliance (incremental) as a percent of gross revenue. Presumably the cost:sales ratio gives an idea of profitability and the ability of producers to pay for certain activities. Cost:sales ratios for current nitrogen-based management on the 31 farms analyzed are reported in Table 4-8.

Table 4-8: Cost:sales ratios for farms applying manure on a plant available nitrogen basis.

Cost:sales	All farms		Contract growers		Independent producers	
Ratio	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Less than 1%	9	29%	0	0%	9	50%
Less than 2%	6	19%	0	0%	6	33%
Less than 3%	5	16%	2	15%	3	17%
Less than 5%	5	16%	5	38%	0	0%
Less than 10%	5	16%	5	38%	0	0%
More than 10%	1	3%	1	8%	0	0%
Total	31	100%	13	100%	18	100%

Those farms with cost:sales ratio higher than 5% are all contract producers. The average cost:sales ratio was 6.1% for contract producers (minimum of 2% and maximum of 10%) and 1.3% for independent producers. This significant difference demonstrates that manure management is a larger part of the contract producer's total responsibility than it is for independent growers. Whereas independent growers are responsible for all activities associated with pork production, and must be compensated for performing those activities, contract growers have a more limited set of responsibilities for which they are compensated. Contract producers have been contracted to provide facilities, utilities, labor and manure disposal.

The high cost:sales ratio for manure management of contract producers reveals an oversight in the EPA economic analysis. The EPA assumed gross sales for all modeled operations to be the combined grain and livestock sales of the farm and assumed that all livestock were sold at market price. Contract producers do not get market price for the animals they raise and thus have less cash flow flexibility than an independent producer to implement management changes.

The other criteria the EPA uses for financial impact is the cash flow test and the debt to asset ratio. Presumably, the cash flow test would be a measure of liquidity and the debt to asset ratio a measure of solvency. However, the cash flow test as used by the USEPA is a second test of profitability and gives little information regarding the ability of a farm to pay expenses (liquidity).

Our model could estimate a discounted cash flow for each operation; however, we chose not to do this because discounted cash flow is a measure of profitability rather than liquidity – the ability to pay for expenses. Balance sheet information was not collected on the farms modeled and no estimate of the solvency of the farms is made in this economic analysis.

According to traditional economic analysis, we chose to use return on assets (ROA) as a measure of profitability and cash flow analysis to evaluate liquidity.

The appropriate measure of profitability is the ROA because it standardizes income for the amount of assets invested to obtain the return. Over a 10-year planning horizon, we estimate that the 31 modeled farms had an average return on assets of 21%, a minimum of 6% and a maximum of 46%. Independent producers had an average ROA of 26%; contractors, 12%. This indicates that the farms are generally profitable but it does not tell whether they have liquidity.

Liquidity is measured by cash flow of the 31 modeled farms and is difficult to summarize statistically. All farms had a small positive annual cash flow while paying loans on their buildings and equipment. After paying off investments, cash flows tended to rise. Our model used 10-year average prices for feedstuffs purchased and animals sold so it does not account for the wide fluctuations that occur in the market prices of agricultural commodities.

One of the major impacts of the proposed rule is the requirement for nutrient management planning consisting of manure and soil sampling and the record keeping requirements to be in compliance with a permit. Using state-specific university recommendations we estimated the expense of nutrient management planning. Our analysis of costs indicated an average of 10% of manure management costs currently are attributable to nutrient management planning activities.

4.5.2 Phosphorus-based manure applications

The ultimate impact of phosphorus-based application rates is entirely dependent on how they are imposed on the operation. Within the proposed USEPA rules are a large number of options and proposals that would have implications on the costs and feasibility of phosphorus-based manure management. Will USEPA insist on annual phosphorus limits or allow rotational phosphorus limits? Will lagoon operations be required to agitate their lagoons to insure land application of all excreted phosphorus? The many potential outcomes of the phosphorus rule make a straightforward, concise analysis difficult.

In this section we address the effect of potential phosphorus-based rules on the feasibility of manure application rates, land requirements, time requirements and costs.

USEPA in their analysis of the proposed rule focused primarily on the costs associated with the proposed rule. In our analysis of the rule we determined that feasibility issues, not costs, were the most obvious barriers to a farmer implementing the rule.

The three types of manure handling systems discussed in this report are: pit systems, unagitated lagoons and agitated lagoons.

The feasibility of phosphorus application rates for lagoon systems is dependent on how the proposed rule is implemented. All lagoon operations analyzed applied unagitated lagoon effluent. One possible scenario is lagoons will continue to be regulated based on the nutrients that are land applied from an unagitated lagoon. Under this scenario much of the phosphorus (possibly as high as 95%) remains in the lagoon sludge layer. A second scenario is that anaerobic lagoons will be agitated on a scheduled basis to mix the nutrients in the sludge with the effluent that is land applied.

4.5.2.1 Feasibility of manure application rate

4.5.2.1.1 Pit systems

The impact of phosphorous-based application rates on swine operations that store manure in pits and apply slurry depends on how the phosphorous rate limits are imposed. Phosphorus rates restricted by the annual phosphorus requirement of the crop create significant feasibility issues on the majority of farms analyzed. A four-year phosphorus rotation application rate was not feasible when applied to low productivity, low phosphorus removal crops (dryland range).

4.5.2.1.1.1 Annual phosphorus limits

Annual phosphorus rates required reducing manure application rate an average of 73% on slurry-based operations. Mean minimum application rate was 1,416 gal/acre for the 15 operations that predominantly stored manure as slurry (Table 4-9). The mean minimum application rate was reduced to 946 gal/acre if data from one Iowa operation with low uncharacteristically manure phosphorus concentrations were not included.

Application rates as technologically feasible with current equipment if they could be attained by decreasing discharge rate to 400 gal/min and increasing travel speed to five mph for tractor-pulled spreaders and six mph for truck-mounted spreaders. These modifications to existing equipment and equipment operation reduced application rate an average of 50% compared to a needed mean reduction of 71%.

Annual phosphorus-based application rates were feasible for four of the 15 operations. Reducing discharge rate was necessary for three of these four operations to meet this requirement. Reducing discharge rate required a financial investment to modify the manure application equipment(see Chapter 3). Most tanker-type applicators do not have a recommended method for reducing discharge rate for slurries. The remaining 11 slurry-based operations cannot apply manure at annual phosphorus rates with their current equipment.

There is no equipment currently on the market capable of injecting manure to meet annual phosphorus limits on these operations. The lower extreme limit for injection of manure is currently near 2000 gal/acre (400 gal/min discharge rate, 20-foot swath width and five mph travel speed). This is above the required annual phosphorus application rate of these 11 operations (Table 4-9). Injection of swine manure slurry is not a feasible technology with currently available manure application equipment if application rates are dictated by annual phosphorous limits.

Table 4-9. Mean minimum application rate of manure slurry from 15 swine operations for three strategies for determining application rate.

Operation	Nitrogen	Annual Phosphorus	Rotational Phosphorus
IA-4	2,390	630 I,T	2,390
OK-5	3,000	220 I,T	890 I, T
PA-6	3,160	1,420	3,160
MO-3	3,450	830 I	3,450
PA-5	3,550	640 I,T	3,550
MO-2	3,680	1,040 I	3,680
PA-1	3,770	1,050 I	3,770
PA-3	3,880	1,020 I	3,880
IA-1	4,080	1,500 I	4,070
IA-5	4,380	750 I,T	4,260
PA-4	4,560	1,030	4,560
IA-6	4,950	700 I,T	3,570
PA-2	5,030	1,180	5,030
IA-3	5,580	1,240 I	5,600
IA-2	12,000	8,000	12,000
Mean	4,497	1,417	4,257

Notes: Current requirements are for nitrogen-based rates; USEPA is proposing annual phosphorus limits; rotational phosphorus limits allow application of up to 4 years of phosphorus in one year and then no further applications until crop removal has utilized the excess manure phosphorus. Values followed by an "I" were determined to be not feasible for equipment currently owned by the farmer but feasible if the operation switched to surface application and bought equipment capable of discharging a 40-foot swath at 400 gallons/minute;. Values followed by a "T" were determined to be not feasible for most equipment currently on the market.

Application rates are defined as technologically possible if they were greater than 990 gal/acre for tractor-pulled spreaders and 825 gal/acre for truck pulled spreaders. To attain this low rate of application, manure would need to be surface applied at a discharge rate of 400 gal/min, swath width of 40 feet and travel speed at the maximum attainable (5 mph for tractors, 6 mph for trucks). These modifications reduced application rate an average of 77% compared to a needed mean reduction of 71%. One fifth of the operations (3 of 15); however, would not be capable of achieving annual phosphorus application rates after implementing discharge rate reductions and travel speed increases (Table 4-9).

In summary, adopting a higher travel speed, wider swath width, and/or lower discharge rate strategies would require changes in current land application practices for most of the 10 operations to meet annual phosphorus limits. Injection operations would need to convert or purchase new equipment capable of surface application. Surface application of manure increases the potential for odor generation. Eight of the 10 operations would need to modify equipment to increase the width of application, by a factor of almost three. Reducing discharge rate also increases time required for land application of manure. Most operations would be required to increase travel speed during manure application to comply with annual phosphorous application limits.

All these changes are within the technical performance standards of existing equipment, implementation may not be feasible in all operations. Increased travel speed may not be safe or feasible on some sloped or rough fields. A 40-foot swath width may not be compatible on some fields or make areas of some fields inaccessible.

Forcing operations to surface apply manure contradicts other best management practices for manure. Many operations are currently adopting injection of manure to reduce odor and minimize ammonia losses from manure. The USEPA is advocating the concentration of nutrients in manure by reducing water inputs. This further concentrating of manure nutrients and will make it more difficult for operations to attain annual phosphorus rates. Feeding strategies to reduce phosphorus excretion will improve the feasibility of annual phosphorus limits.

Reduced discharge rates will increase the time required to land apply manure. Thirteen of the 15 operations would need to reduce manure discharge rate to meet annual phosphorus limits. Mean reduction was 46% with eight operations requiring a reduction in discharge rate of 50% or more. Reducing discharge rate to 400 gal/min would increase time required for manure application by an average of 42 hours/year (range 3 to 82 hours/year). Reducing discharge rate to 400 gal/min would increase land application time by 33% (range 3 to 65%) compared to current management practices. These estimates of reduced application rate and time effects may underestimate true values because reducing manure discharge rate to 400 gal/min was insufficient to meet annual phosphorus limits in five of the 13 farms.

Increased time for land application, as required for implementing an annual phosphorus rule, may hinder the farmer’s ability to apply manure in a timely manner for crop utilization. The increased time associated with decreasing discharge rate to 400 gal/min was equal to 12% of the pre-plant work hours in Iowa and Pennsylvania (range 0 to 23%).

Increased time for land application was not affected by operation size (*P*=0.36). Mean increase in application time due to reducing discharge rate to 400 gal/min was 0.06 hours/animal unit.

Implementing an annual phosphorus rule, where feasible, increases costs of application by requiring equipment modifications and increasing hours that tractors or truck are used. The initial cost of modifying tanker pumps to discharge at a 400 gal/min rate is estimated to be $10,000 to $12,000 per tank. This modification increases the cost of a new tank 25% to 30%. Tractors rental is approximately $50/hour and labor is $10/hour so it could be expected that applying manure an annual phosphorus rate would increase application costs by at least $60 for every hour increase over the nitrogen based application rate.

Annual phosphorus application rates were not feasible for slurry-based swine operations. One-fifth of the analyzed operations could not meet the standard because current equipment cannot apply the low rates required by the annual phosphorous application limit. Injection of slurry manure would be infeasible for any of the operations studied because of the low manure application rate. The remaining 80% of the swine operations capable of attaining an annual phosphorus limit application rate with slurry would need to surface apply manure at the maximum application speed, increase to 40-foot swath width and reduce discharge rate by nearly 50%. Reduced discharge rate alone will increase land application time at least 33% and use 12% of the pre-plant field time available to farmers in Iowa and Pennsylvania. Forcing farmers to adopt high travel speeds, low discharge rates, and surface application strategies may result in safety concerns, and increase odor and ammonia emissions because injection of manure is not feasible with existing application equipment.

4.5.2.1.1.2 Rotation phosphorus limits

Adopting rotation-based phosphorus limits had little effect on the feasibility of manure application rates relative to nitrogen application rates for slurry operations. We evaluated a four-year rotation phosphorus limit that allowed farmers to apply up to four years of phosphorus when manure was applied. No additional manure applications are made until the phosphorus has been utilized by crops grown on the land. Manure application could not exceed the annual nitrogen requirement of the crop grown during the application year.

Rotation phosphorus application rates allowed all but four operations to continue to land apply manure at the same rate as the nitrogen-based rate in the years that fields receive manure (Table 4-9). Mean minimum application rate was 4,257 gal/acre for the 15 operations that applied manure predominantly as a slurry. This mean minimum application rate is 2% less than the application rate required by nitrogen-based management (Table 4-9). All but one operation could adjust application rate from nitrogen-based rates to phosphorus-based rates by adjusting travel speed.

Consequently, rotational phosphorus rates have no effect on discharge time and costs of manure applicator operation when compared to current nitrogen-based application rates.

The exception was an operation applying manure to dryland range in Oklahoma (OK-5). Forage productivity was low (2 tons/acre). The combination of low forage yield and crops with a high nitrogen to phosphorus ratio resulted in limited phosphorus removal on this pasture-based operation. This case study emphasizes that continued slurry application on low productivity pasture land may not be feasible under any form of phosphorus application rule.

This analysis assumes that rotation phosphorus limits allow up to four years of phosphorus to be applied to fields in the years that manure is applied. Longer phosphorous application rotations (more than four years) may make low productivity soil locations feasible. Mandating shorter phosphorous rotations (less four years) increase the potential that other operations will encounter manure application rates that are not feasible. Slurry manure application rates required by a strict interpretation of the annual phosphorus limits resulted in manure injection applications not being feasible for all operations and surface applications not being feasible on at least 20% of the slurry operations studied.

4.5.2.1.2 Unagitated Lagoon systems

All phosphorus limited application rates were feasible for all operations applying unagitated anaerobic lagoon effluent.

All analyzed lagoon operations currently apply unagitated lagoon effluent. These operations were able to meet annual and rotation phosphorus limits by implementing changes in application speed and/or adjusting the number of effluent applications to the field. No operations had to change discharge rate or swath width. Consequently, there was no effect of phosphorus rules on the length of time needed to pump unagitated anaerobic lagoon effluent from the storage.

Average discharge rate of the 16 operations was 367 gal/min and average swath width was 193 feet.

Nitrogen, rather than phosphorus, limited manure application rates in five of the 16 analyzed unagitated lagoon operations. These operations would make no changes in manure application rates based on phosphorus limit rules. Three of the 13 operations capable of adjusting travel speed had to make adjustments in travel speed. The solid set and hand-carry irrigation systems were able to meet the application requirements of phosphorus limits by reducing the duration of the irrigation period.

4.5.2.1.3 Agitated Lagoon systems

Lagoon agitation would pose major feasibility issues for operators using irrigation systems for land application of manure. Annual phosphorus application rates of agitated lagoon effluent would not be feasible for all sprinkler-based or traveling gun type systems. These operations would be required to modify or convert to a different system of manure application.

Agitation of anaerobic lagoon effluent based on annual phosphorous limits resulted in low manure application rates not feasible for at least five of the 16 irrigation-based systems. These operations would be required to convert to a new manure handling system such as tanker spreader or dragline injection. Pivot irrigators may have problems handling agitated lagoon effluent because of increased solids content.

4.5.2.2 Land requirements

In this section we address the effect of phosphorus limits on the amount of land required for manure application and the distance needed to travel to reach that land.

4.5.2.2.1 Pit systems

Pit systems converting from a nitrogen-based to a phosphorus-based land application system require significantly more land ($P \leq 0.01$). The 14 operations that handled all their manure in slurry form required more than three times more land for phosphorus-based manure management: 0.3 acres/animal unit for nitrogen-based application, 1.0 acres/animal unit for phosphorus-based application.

Operations owned or rented (controlled) sufficient land to address 40% of the additional land needed for implementing a phosphorus rule. Only three of these 14 operations had sufficient owned or rented land (controlled acres) for phosphorus-based management (0% additional land needed). Under nitrogen-based management 9 of the operations had sufficient land available for manure application. Five operations need to find 100% of the additional land needed because they were presently applying manure on non-owned or non-rented land. Smaller operations were more likely to have sufficient land to meet the additional requirements of a phosphorus rule (Figure 4-7) but operation size only explained 35% of the relationship between animal units and additional land need. All the farms that needed to locate100% of the additional land needed for manure application from currently uncontrolled acres were in Pennsylvania.

The 11 land-deficient operations needed to locate an average of 512 additional acres for phosphorus-based application in addition to the land they currently own or rent (range 75 to 1369 acres) or 0.6 more acres/animal unit.

An annual phosphorus rule would require the farmer to access all of these extra acres every year. Using a nitrogen-based phosphorus rotation limited by four-year phosphorus need would allow applying manure on a fraction of the total acres each year and then rotating to different acres in the following years. The average number of acres receiving manure in any given year was only 18 acres more for a phosphorus rotation than for the current nitrogen-based approach among the 14 operations applying slurry.

Tanker- and truck-mounted slurry spreaders increased road travel distance and time to reach the additional fields needed for phosphorus based manure applications by an average of 0.5 miles ($P \leq 0.01$). Operation size is positively correlated with mean travel distance to the field for manure application ($y = 0.41 + 0.0012\,x$, $r^2 = 0.35$).

Traveling the extra distance increased the proportion of land application time spent in road travel from 20 to 34% of the time spent applying manure. Operations spent between 0 to 139 additional hours transporting manure to more distant fields (mean=38 hours). Operations with multiple pieces of manure application equipment can reduce the impact of the added time by using two or more pieces of equipment simultaneously. Five of the slurry-based operations used more than one tanker to apply manure. Use of multiple applicators reduced mean travel time from 38 to 27 hours (range 0 to 66 hours).

The additional road travel time associated with phosphorus limits on slurry operations will create a significant challenge to farmers using manure to fertilize corn on some operations. The proposed rules emphasize timely application of manure as a fertilizer. For operations applying slurry manure for corn this implies application during the spring pre-plant period. Additional road travel time averages 15% of the pre-plant hours available for corn planting. For four of the operations, the additional road travel time represents 50 to 65 additional hours of work or an average of 26% of the available fieldwork time during the spring pre-plant period for corn (see Table 4-2).

Manure application will be made on all acres every year with annual phosphorus limits so average road time should remain relatively constant from year to year. With rotation phosphorus limits, the mean travel time over the rotation will be the same as for annual phosphorus limits because the same volume of manure will be applied. In specific years, the average travel time may be above or below the average, depending on which fields receive manure application that year. The farmer will need a system with the capacity to transport the volume of manure in a timely manner for those years with the most road travel time.

Our analysis is a conservative estimate of the additional road travel time a producer may require to meet phosphorus application limits. We assumed all owned and rented land was available for manure application. It was also assumed that neighboring farms would be willing and able to accept manure from the CAFO. We estimated the mean travel distance from the swine production operation to eight contiguous neighboring farms based on the presence of roads and agricultural land shown in aerial photos. Mean travel distance to neighboring farms was two miles (range 0.8 to 5.2 miles) for tanker operations. PA producers in our study currently transport manure an estimated average of 1.9 miles each year. IA producers are estimated to transport manure an average of 1.5 miles each year. Farmers that need to travel farther than neighboring farms will spend additional time transporting manure.

Greater travel distances will increase the transport time and cost. Using custom rates from our survey of PA farms and equation 4-1 below we estimate the cost to transport 1000 gallons 1 mile to be $.51. The 5 PA farms produce an average of 1,248,446 gallons of manure annually. On average costs increase about $640/year or

$0.58/animal unit for each additional mile the manure must be transported. Each additional mile adds about 7% to the cost of manure application.

$$Cost\ per\,1000\,gallons\ per\ mile = \frac{Custom\ charge\,(\$/hr)}{\dfrac{1000\,gallons}{load} \times \dfrac{miles}{hour}} \qquad \text{Eq. 4-1}$$

In summary, phosphorus limits tripled land requirements for slurry-based operations. This reduced the number of operations able to apply only to owned and/or rented land (controlled acres) from 65 to 35%. On average, operations applying manure based on a phosphorus rule applied 40% of the manure to controlled acres. The increased land requirements forced farmers to increase manure transport distances for access to land that can receive manure. The slurry-based operations in this analysis would increase average distance traveled to fields by at least 0.5 miles. The mean increased travel time was equivalent to 15% of corn pre-plant work time and averaged 25% on the 30% of operations most affected by the increased land requirements.

4.5.2.2.2 Unagitated lagoon systems

All lagoon based operations currently spread unagitated effluent on land owned or rented by the farm. Operations used 18% of their owned and rented (controlled) acres for effluent application (range 2 to 66%). The mean acreage needed per animal unit on these operations was 0.09.

Phosphorus limits increased land requirements on 11 of the 16 farms that stored manure in unagitated anaerobic lagoons. Annual phosphorous limits increase the mean current land requirements of 60 acres up to 80 acres. Annual phosphorus limits increased land required per animal unit to 0.13. One operation had insufficient land to meet the requirements of a phosphorus rule and a second operation had only the needed acres with no land available for contingencies such as high manure volumes or low crop yields. Swine operations applying unagitated lagoon effluent use an average of 55% of their owned and controlled acres.

Rotation phosphorus limits resulted in similar land requirements as annual phosphorus limits with unagitated lagoon effluent.

4.5.2.2.3 Agitated lagoon systems

Any requirement to agitate anaerobic lagoons combined with a requirement to apply effluent based on phosphorus content of the manure will result in higher land application area requirements. These operations would experience average land area requirement increases per animal unit from 0.09 to 1.3. These operations would require about ten times the land area they currently own or rent.

North Carolina operations would experience the greatest impact and would require more than 16 times their current land base. Oklahoma farms would be significantly less impacted (P=0.08) needing to locate four times their current land base. Only two operations, both in Oklahoma, had sufficient land to switch to an agitated lagoon system on a phosphorus limit basis and be able to continue applying manure to land they currently own or rent.

4.5.2.3 Time effects

4.5.2.3.1 Pit systems

The annual phosphorus rule increased both road travel time and land application time. Average total increase in manure handling time was at least 77 hours/year (range 7 to 228 hours). Operations with multiple pieces of manure application equipment can reduce the impact of the added time by using multiple pieces of equipment simultaneously. Five of the slurry-based operations used more than one tanker to apply manure. Use of multiple applicators reduced mean handling time from 77 to 54 hours (range 7 to 147 hours). It should be noted that even with these changes in manure management, 33% of the operations still were unable to attain annual phosphorus limits.

The additional time associated with annual phosphorus limits on slurry operations will create a significant challenge to many farmers using manure to fertilizer corn. The proposed rules emphasize timely application of manure as a fertilizer. For operations applying slurry manure for corn this implies application during the spring pre-plant period. The additional time represents an average of 28% of the pre-plant hours of work for corn, but is over 50% of the pre-plant hours on three case study farms.

Farmers faced with such a significant increase in workload during the busy spring season will need to adopt strategies to limit manure application time. Possible options include purchasing additional land application equipment so more manure can be applied in a shorter period of time. This option would reduce the duration of manure application but not the total labor needs during the land application period. Satellite storage cell, nurse tanks and larger and faster tankers will shift road transport time from the busy period or reduce manure transport time. The costs of these strategies were not evaluated but it is anticipated that many slurry based operations will need to change current practices because of these time constraints.

An alternative to annual phosphorus limits is the four-year phosphorus rotation approach. This approach allows manure application to meet the four-year phosphorus need with out exceeding the annual nitrogen requirement of the crop in the year of manure application. No additional manure is applied until crops remove the applied phosphorus. Using this strategy, all but one operation was able to meet rotation phosphorus limits without increasing application time (see section 4.5.2.2.1). On this operation, phosphorus limits of either type are infeasible with currently available equipment and so time effects could not be calculated (see section 4.5.2.1.1.1)

Using the rotation phosphorus limits, the primary increase in manure handling time from the phosphorus limit is from increased road travel time from the manure storage to the field for application. The added acre requirements resulted in farmers traveling greater distances to apply manure (see section 4.5.2.2.1).

Average total increase in manure handling time was at least 38 hours/year (range 0 to 147 hours) with a four-year rotation phosphorus limit. Operations with multiple pieces of manure application equipment can reduce the impact of the added time by using these multiple pieces of equipment simultaneously. Five of the slurry-based operations used more than one tanker to apply manure. Use of multiple applicators reduced mean handling time from 38 to 27 hours (range 0 to 66 hours). Further discussion of increased road time associated with rotation phosphorus limits is presented in section 4.5.2.2.1.

Rotation phosphorus limits increase application time requirements 24% compared to 58% for annual phosphorus limits. Rotation phosphorus limits have no impact on discharge rate and land application time whereas annual limits have the potential to increase manure discharge time an average of 42 hours/year. Mean manure handling time was 93 hours per year for nitrogen-based management, 117 hours per year for rotation phosphorus limits and 147 hours per year for annual phosphorus rates. Adopting rotation phosphorus rates will present time management challenges for some farmers; adopting annual phosphorus limits will present time management problems for most farmers.

Table 4-10. Mean effect of three methods of limiting manure application on selected measurements of related to manure application time (31 swine operations).

Parameter	Units	Nitrogen Limit	Annual Phosphorus	4-year Phosphorus Rotation Limit
Equipment operation duration[1]	hours	127	201	162
Manure handling time[2]	hours	93	147	117
Percent of pre-plant field work time for corn	%	51	79	65

[1]Total equipment operation time.
[2]Total equipment time adjusted for operations that have more than one piece of manure application equipment operating simultaneously.

Iowa has one of the most restrictive manure application windows. Manure slurry application in a corn/soybean rotation requires applying slurry before planting corn in the spring and after soybean harvest in the fall. Spring fieldwork hours prior to corn planting are estimated at 173 hours (Table 4-2). Producer IA-6 needs an estimated 194 hours to land apply manure on a rotational phosphorus limit. Manure application hours exceed the hours available prior to spring planting. This producer would need to purchase additional equipment (not included in our analysis) or hire custom applicators to come in with multiple pieces of equipment or change his cropping system to allow for application during the summer months (e.g. grow wheat in his cropping system). One other IA farmer is able to apply all manure prior to planting because he does have multiple pieces of application equipment. The other IA farmers in the study do not have a significant increase in time needed to apply manure.

Pennsylvania farms had the largest average annual application time of 153 hours. Three of the six modeled farms used multiple pieces of application equipment to reduce the duration of application time. One farm currently does not use multiple pieces of equipment (PA-5) but is estimated to need 309 hours for application. This does not permit application prior to planting corn. Applying manure to fields following wheat harvest may be prohibited because the land is not planted to a crop for several months and nitrogen may volatilize before it can be used. This producer would need to get additional manure application equipment.

4.5.2.3.2 Unagitated Lagoon systems

Agitated lagoon systems are less affected than slurry pit systems by windows of appropriate application time because they often apply effluent via irrigation systems that can apply prior to planting or on top of growing crops. The type of irrigation system is designed for the type of crops that will receive effluent. For example, traveling guns can apply to hays and soybeans with little trouble but are not appropriate for irrigating corn. Pivots would be used if corn is the crop that will receive effluent.

Eighty eight percent of the operations that use lagoons exclusively used irrigation systems (traveling guns, center pivots, spray fields and solid set sprinklers). The two operations that did not use irrigation used dragline systems and were located in Missouri.

For operations using irrigation systems, the switch from a nitrogen rule to a rotational phosphorus rule resulted in an average increase of 18 hours (from 103 to 121), or 17%. The increase was due primarily to the increased time of laying pipe to the irrigation system as the producer irrigated acres further from the lagoon. The increase did not exhaust the number of hours available for applying to growing crops (Table 4-2).

Moving to a rotational phosphorus limit decreased setup time for application for three operations that switched or added traveling gun technology to their existing irrigation system. Two OK farms switched from solid set sprinklers to traveling guns; 1 NC farm added a traveling gun to his spray field in order to reach distant acres. It is safe to say that moving to a phosphorus rule will require most solid set sprinkler systems and spray fields to switch or add a traveling gun to their irrigation equipment.

Twelve percent (2 of 17) of the operations that use lagoons exclusively used dragline systems to land apply effluent. Switching to a rotational phosphorus rule increased application time 90%. One farm (MO-6) now needs 316 hours to apply effluent. According to estimates of field work hours in table 4-2 MO-6 could not apply all his effluent prior to planting corn or soybeans. He would need to apply to wheat stubble in the summer (if permitted) or switch to some other application method.

4.5.2.3.3 Agitated Lagoon systems

We did not model time effects of adopting a phosphorus limit in combination with a requirement to agitate lagoons. The resulting changes in land needs and accessibility and land application feasibility would require a totally different manure application strategy, methodology and equipment on almost all farms. This potential required change was beyond the scope of this study to estimate.

4.5.2.4 Nutrient management planning

We predict a large increase in nutrient management planning time and costs to implement the proposed rules. Nutrient management costs included soil and manure testing, developing a certified nutrient management plan, maintaining records and updating the nutrient management plan. The USEPA clearly intends to have nutrient management plans, including an evaluation of the phosphorus status of the soil, on all land receiving manure from a concentrated animal feeding operation (see Chapter 1). Consequently, we assumed that all land receiving manure would require a nutrient management plan. It is also assumed that the animal feeding operation would incur all the additional cost of nutrient management planning, even on acres not owned or rented by the animal operation. Few farmers will accept manure if they must incur the costs inherent to increased sampling and record keeping. Farmers producing manure will benefit from maintaining complete records on all land areas where they apply manure.

Average nutrient management planning time spent by the farmer was estimated at 104 hours. This is approximately a three-fold increase from the 36 hours currently spent on nutrient management planning.

4.5.2.5 Impact on economics Indicators of Economic Viability After Adopting Phosphorus Limits

The analysis of 31 farms resulted in sales tests (e.g. cost:sales ratio) reported in Table 4-11.

Table 4-11. Cost:sales ratio for nitrogen limit, rotational phosphorus limit and the incremental costs between the nitrogen and rotational phosphorus limits.

Cost:sales Ratio	PAN limits		Rotational Phosphorus Limit		Incremental costs	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Less than 1%	9	29%	7	23%	17	57%
Less than 2%	6	19%	2	7%	6	20%
Less than 3%	5	16%	5	17%	0	0%
Less than 5%	5	16%	7	23%	1	3%
Less than 10%	5	16%	2	7%	6	20%
More than 10%	1	3%	7	23%	0	0%
Total	31	100%	30	100%	30	100%

The percent of farmers that had cost:sales ratio greater than 5% (defined as moderate impact or financial stress in the USEPA rule) rose from 6 of the 31 farmers (19%) when plant available nitrogen limits were used for manure application to 9 of 30 farmers (30%) when rotational phosphorous limits were implemented. One farm (OK-5) was unable to apply manure under the rotational phosphorus rule (limited to 4 years of phosphorus removal). This farmer raises hogs in the arid southwest and applies pit slurry to hay ground. Under a phosphorus rule, this farmer would not be able to land apply manure. This farmer's dilemma is not included in the cost:sales ratio estimate (i.e. his financial stress is not included in the analysis).

Considering only the incremental costs, as the USEPA does, our analysis estimates six of the remaining 30 farmers are capable of applying manure under a phosphorus rule (20%) with a greater than 5% increase in the sales test. All six are contract producers. Five are in PA and one is in IA. All apply pit slurry with a tanker. Forty-six percent of contract producers are in the stress category.

We predict that the EPA's economic assessment of farms in the moderate to stress categories is underestimated. Table 10-6 of the Preamble (Federal Register, p. 3090) reports that the EPA estimates that 20% of the hog producers will be in the moderate to stress categories. Their estimate of 20% includes the cost of attaining zero discharge. Our estimate of 20% considers only the cost of implementing a rotational phosphorus limit.

We find only producers with pits to be in the moderate and stress categories as defined by the EPA. Chapter 5 will establish that covered, agitated lagoons will have nutrient content similar to pit slurry. Chapter 6 will establish that all farms who adopt covers to meet a "zero discharge" requirement will be in a financial stress category.

We predict that the compliance cost associated with a phosphorus rule (independent from a zero discharge requirement) may have regional implications. PA operations are predominately slurry and need to access an average of six times more acres than they control (own and rent) to apply manure on a P basis. Pit manure distribution via tankers is the most expensive method of land application. All adjacent land was assumed willing to accept the pit slurry. Estimates will be low to the degree that tankers must travel past adjoining land to access more distant land area for manure application.

In the short run, contract farmers with pit slurry will be unable to pay for increased costs of complying with a rotational phosphorus limit from contract payments. Undoubtedly, contracts will be revised to reflect the increased costs of contract producers. However, the multi-year characteristic of production contracts will make the transition difficult for contractors who still have several years remaining on an existing contract.

Additionally, as integrators revise contracts they will seek to minimize costs. One way to minimize costs is to select regions of the country, or even locales within a region, that have low manure management costs. The possibility exists that contractors who built expecting to have contracts for 15 or 20 years will lose their contract due to excessive manure management costs.

Land requirements for applying anaerobic lagoon effluent that were based on nitrogen application require additional acres for phosphorous application, Irrigation systems are difficult to expand on additional land because of topographic and property boundary barriers. Our analysis assumed that additional land for irrigation could be accessed by installing above-ground piping. The additional expense of purchased piping and traveling gun irrigators was factored in to our estimate of the cost of compliance. This estimate is low because it does not consider the expense of clearing a right of way. If a right of way or easement can not be obtained, the producer would probably need to use tankers to transport manure and the expense would be considerably greater than is estimated.

4.5.2.5.1 ROA Analysis

Return on assets (ROA) gives an indication on the impact of regulations on profitability. Our analysis shows that adopting a rotational phosphorus limit reduces average ROA one percentage point – from 20% to 19%. The decrease for contract producers was 1.5 percentage points from 12% to 10.5%.

Adopting a rotational phosphorus rule resulted in an average decrease of manure fertilizer value to the producer of $373/year. The maximum decrease was $17,046 and the maximum increase was $7,409. The largest decreases in value occurred in PA on farms where manure was exported to neighbors' fields. The largest increases in fertilizer value was on farms in IA and NC where additional phosphorus benefit was credited to more controlled acres. Under a phosphorus rule, all nitrogen applied to non-legume crops will be under-supplied and therefore valued. Under a nitrogen rule, phosphorus supplied in excess of crop need is not valued.

4.5.2.5.2 Nutrient Management Planning Costs

One of the major impacts of the proposed rule is the requirement for nutrient management planning consisting of manure and soil sampling and the record keeping requirements to be in compliance with a permit. Using the assumptions published by the EPA for permit nutrient plans we estimated the expense of nutrient management planning (see Section 4.5.2.4).

Nutrient management costs among analyzed operations also increased from an average of $655 to $4,481. Average costs were substantially higher on slurry operations compared to lagoon operations (pits $7,173, lagoon $2,265). Higher land requirements resulted in more acres included in a nutrient management plan. Nutrient management planning costs were a major source of increased cost associated with the proposed rules.

In the short run, our estimate of record keeping cost will be high. We assumed the farm would spread all manure based on phosphorus removal capacity of the crops. Initially many farms may have land capable of using nitrogen-based rates. However, that is likely to change rapidly as phosphorus levels build, particularly on slurry-based operations.

Our analysis of costs indicated an average of 34% of total manure management costs were attributable to nutrient management planning activities. North Carolina had the highest PNP costs per acre of $35/acre because so few acres are used to spread the fixed cost of writing a plan. Iowa and Pennsylvania are able to spread the fixed costs over more acres and have an average PNP cost of $9.50/acre.

4.6 References

Cross, T. L. a. G. M. P. "Depreciation Patterns for Agricultural Machinery." *American Journal Agricultural Economics* 77, no. February(1995): 194-204.

Massey, R. E., et al. (2000) Comprehensive Software for Manure Management Planning, ed. J. A. Moore. Des Moines, IA, American Society of Agricultural Engineers, pp. 468-475.

4.7 FIGURES

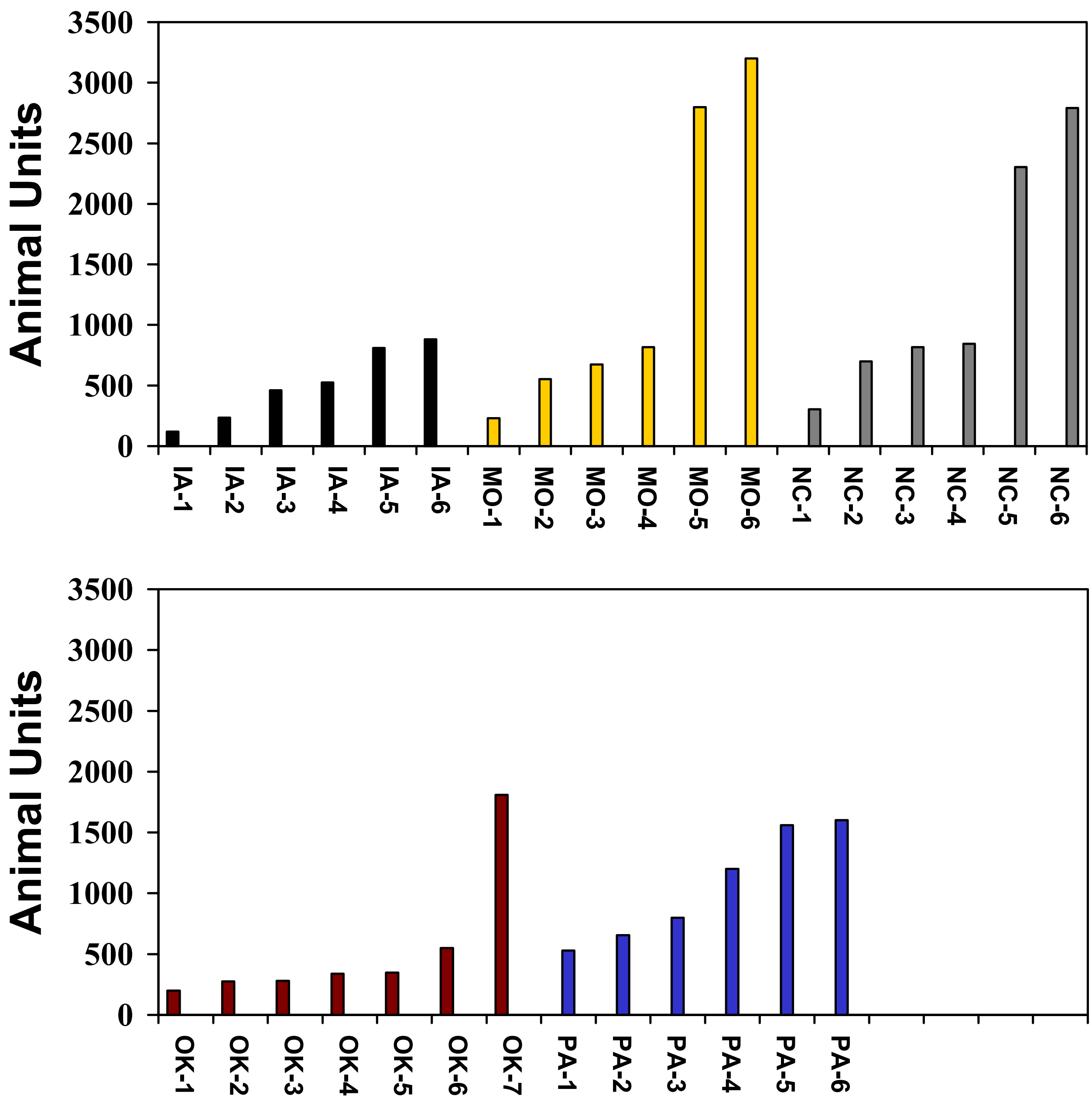
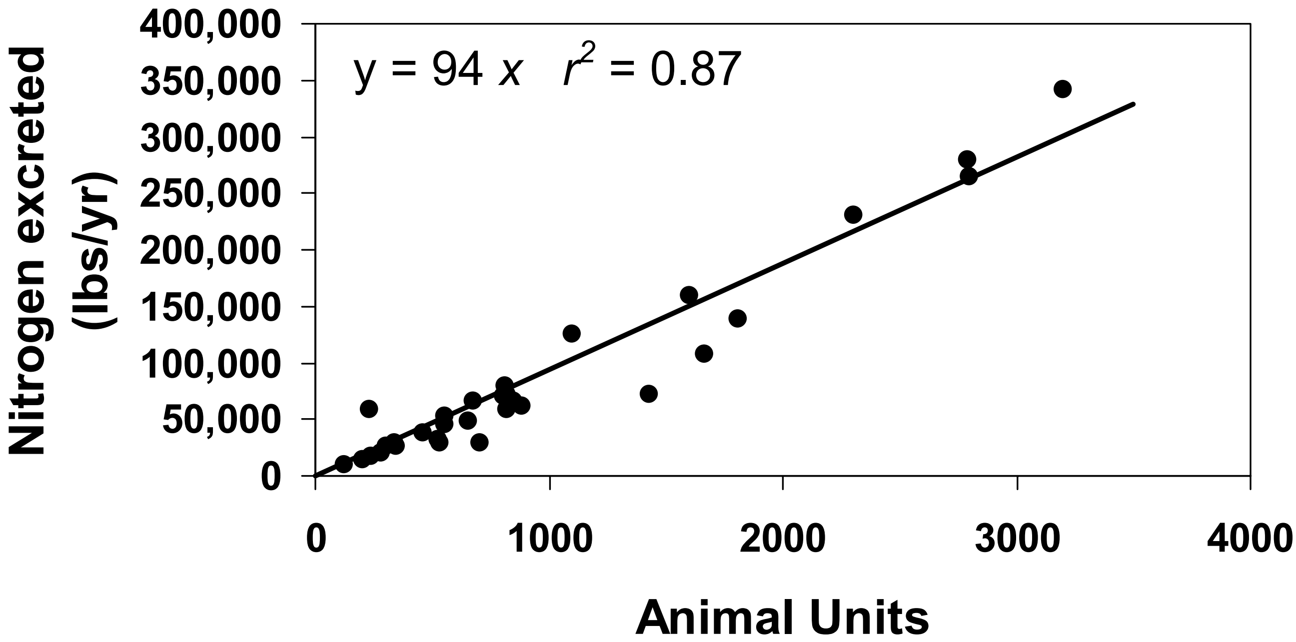


Figure 4-1. Animal units from pigs for 31 operations used in this analysis.

Note: One animal unit was equal to 2.5 pigs greater than 55 pounds or 10 pigs less than 55 pounds.



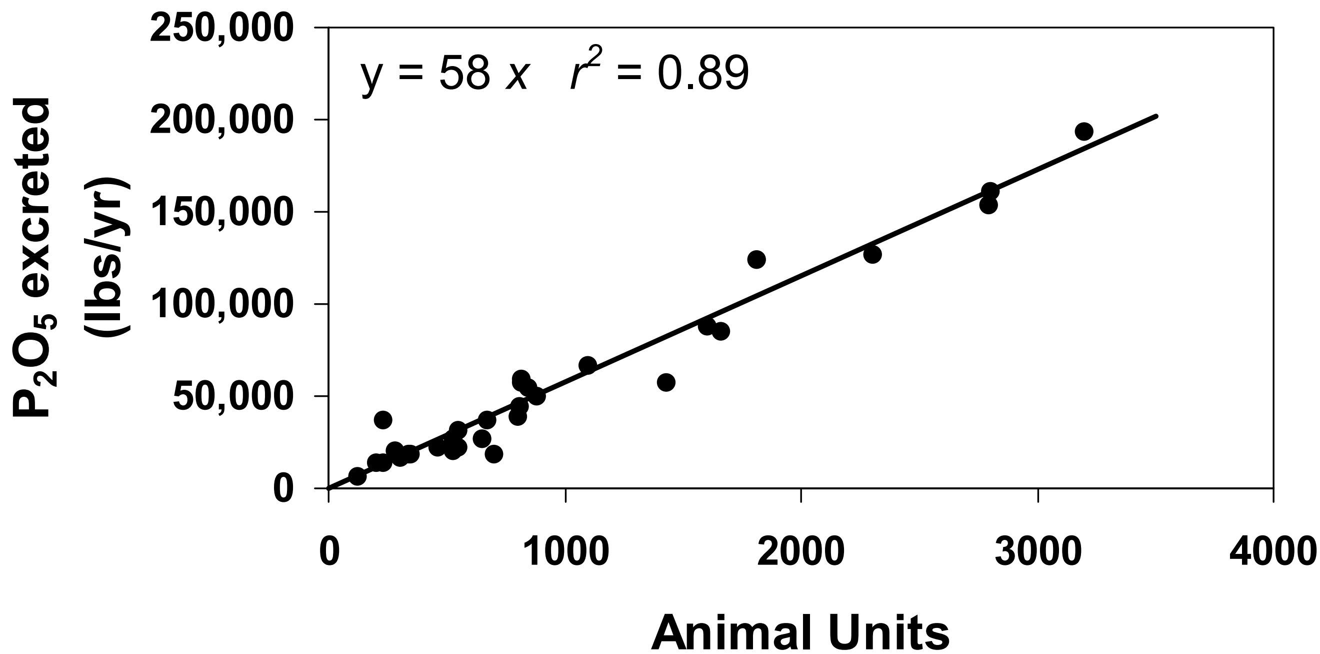


Figure 4-2. The relationship of animal units and estimated nitrogen and phosphorus (as P_2O_5) excreted by pigs on 31 swine operations.

Note: Excreted nutrients were based on estimated feed intake.

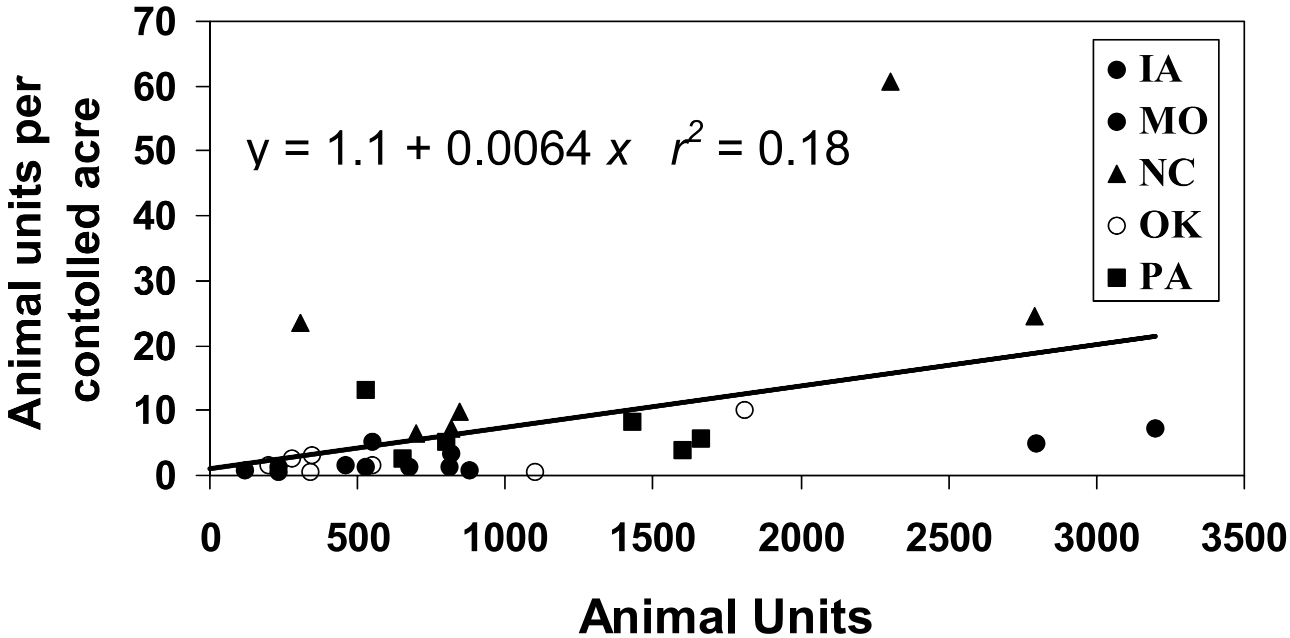


Figure 4-3. Animal units per controlled acre as a function of farm size in animal units.

Notes: Animal units are for pigs on the operation calculated as one animal unit equal 2.5 pigs greater than 55 pounds or 10 pigs less than or equal to 55 pounds. Controlled acres are owned or rented by the animal feeding operation.

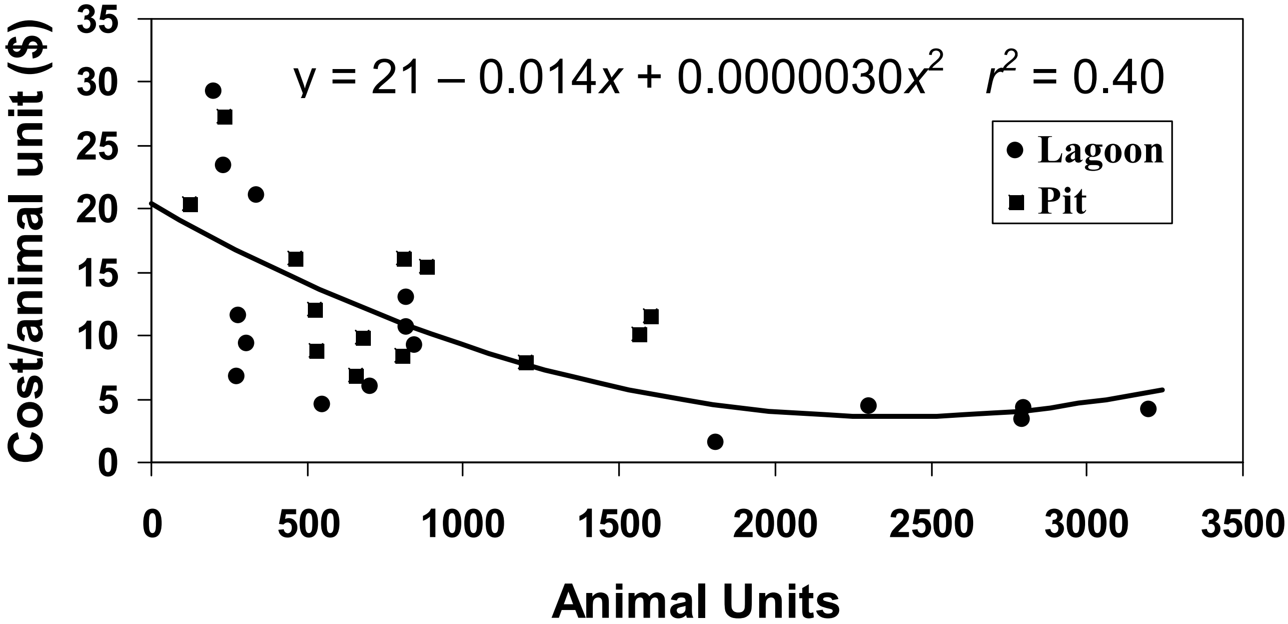


Figure 4-4. Cost of land applying manure per animal unit as affected by size of operation.

Note: Animal units are for pigs on the operation calculated as one animal unit equal 2.5 pigs greater than 55 pounds or 10 pigs less than or equal to 55 pounds.

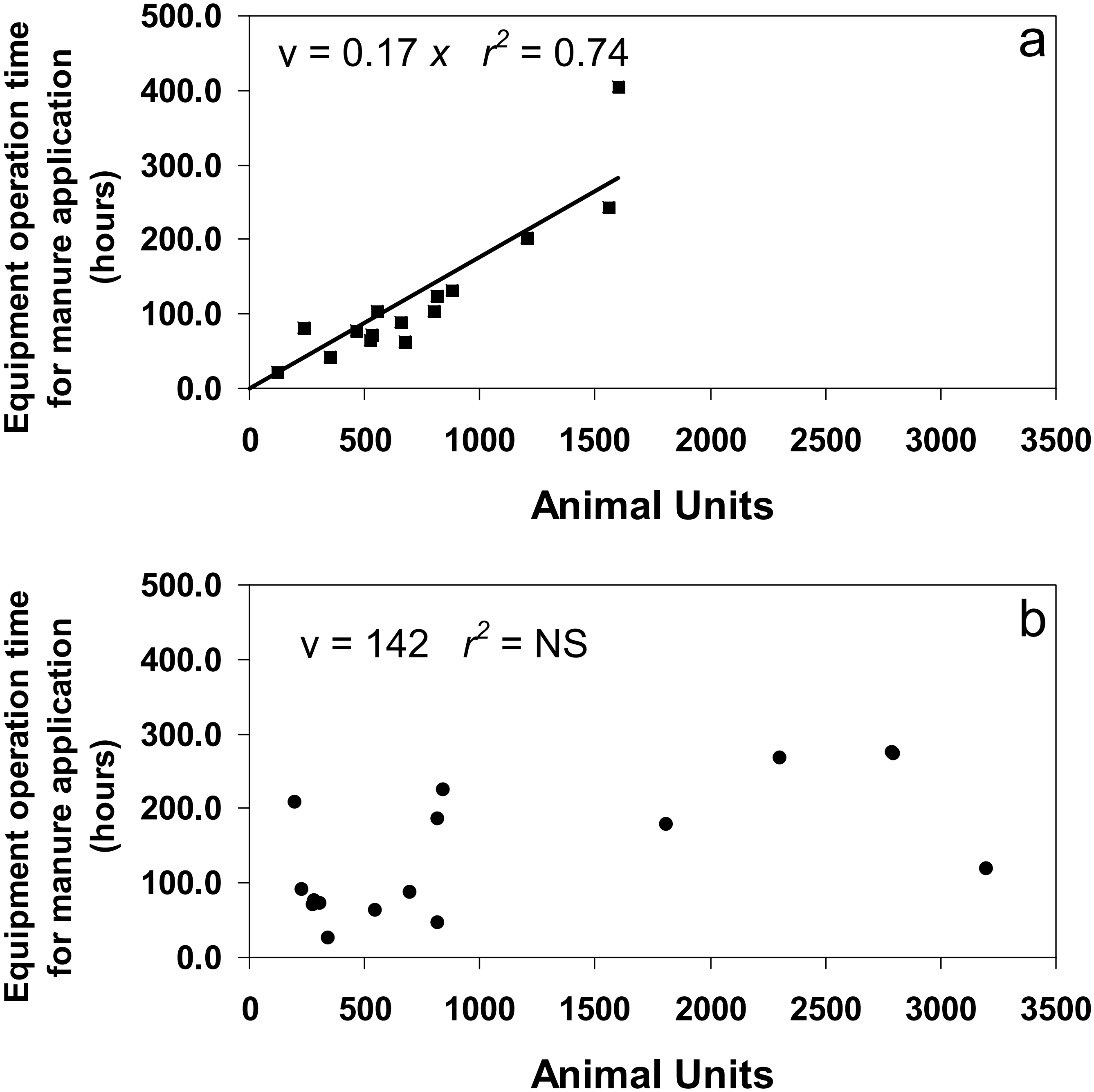


Figure 4-5. Effect of operation size (based on animal units) on total operation time of equipment for manure application. Panel A is for tanker based systems; Panel B is for irrigation based systems.

Notes: Setup, transport and application time included. Animal units are for pigs on the operation calculated as one animal unit equal 2.5 pigs greater than 55 pounds or 10 pigs less than or equal to 55 pounds.

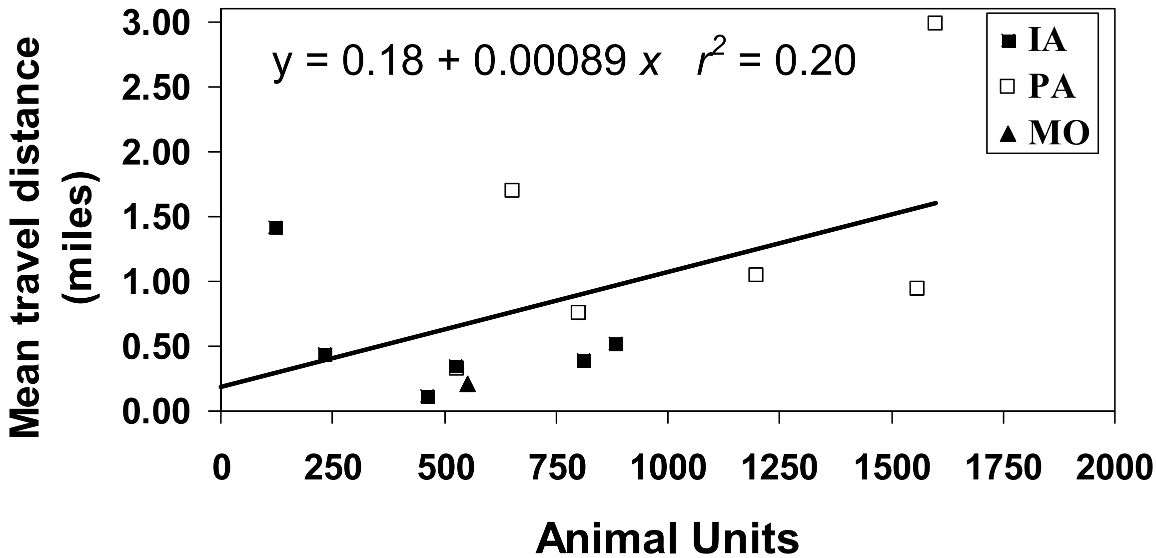


Figure 4-6. Mean travel distance from manure storage to field for nitrogen based manure management as affected by animal units.

Note: Animal units are for pigs on the operation calculated as one animal unit equal 2.5 pigs greater than 55 pounds or 10 pigs less than or equal to 55 pounds.

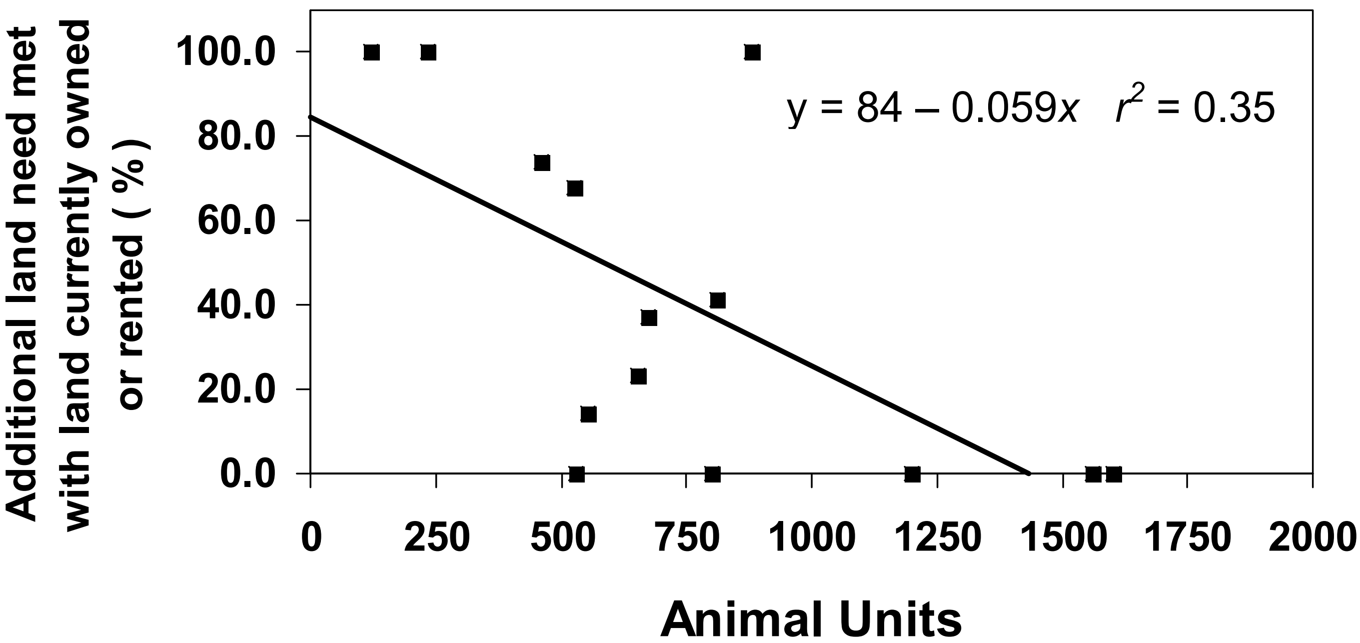


Figure 4-7. For slurry-based operations, the effect of operation size (as animal units) on the additional land need for a phosphorus rule met by land already under control of the animal feeding operation.

Notes: Controlled land is owned or rented by the animal feeding operation. Data is reported as a percent of the total additional acres needed to meet the needs of a phosphorus-based rule. Animal units are for pigs on the operation calculated as one animal unit equal 2.5 pigs greater than 55 pounds or 10 pigs less than or equal to 55 pounds.

4.8 Appendices

4.8.1 Characteristics of Iowa and Missouri Operations

Selected characteristics of 12 swine farms used in this analysis from Iowa and Missouri. Animal units based on 1 animal unit equals 10 pigs less than or equal to 55 pounds or 2.5 pigs greater than 55 pounds. Numbers in parentheses are the number of storage structures of that type on the operation.

ID	Predominant Phases of Production	EPA Animal Units for Pigs	Manure Storage Structures	Application Methodology	Mean Annual Manure Volume (gallons)	Mean Annual Total Nitrogen Available for Land Application (pounds)	Mean Annual Total Phosphorus (as P_2O_5) Available for Land Application (pounds)
IA-1	Nursery	120	Pit, detached	Tanker, tractor; injection	299,715	10,297	6,397
IA-2	Farrow to Wean	234	Earthen storage Pit, attached	Tanker, tractor; surface	1,068,444	21,729	5,928
IA-3	Farrow to finish	461	Pit, detached (2) Solid	Tanker, tractor; injection Box spreader	599,565	37,328	23,523
IA-4	Wean to finish	525	Pit, detached (2) Pit, attached	Tanker, tractor; injection	282,472	32,410	20,009
IA-5	Wean to finish	810	Pit, attached (7)	Tanker, tractor; surface	874,646	79,827	44,353
IA-6	Wean to finish	881	Pit, attached (6) Pit, detached	Tanker, tractor; surface	1,259,616	49,690	43,094
MO-1	Nursery	690	Lagoon, single stage (3)	Traveling gun	1,028,748	55,308	28,413
MO-2	Farrow to finish	552	Lagoon, single stage Pit, attached	Tanker, tractor; injection	898,545	53,148	31,258
MO-3	Wean to finish	675	Earthen storage Pit, attached	Dragline; injection	920,608	66,523	36,962
MO-4	Farrow to wean	818	Lagoon, single stage	Dragline; injection	1,787,886	71,915	58,879
MO-5	Farrow to finish	2798	Lagoon, single stage (2) Lagoon, multi stage	Traveling gun	5,034,473	213,792	161,033
MO-6	Feeder to finish	3200	Lagoon, multi stage	Dragline; injection	3,564,137	341,242	282,181

4.8.2 Characteristics of North Carolina and Oklahoma Operations

Selected characteristics of 13 swine farms used in this analysis from North Carolina and Oklahoma. Animal units based on 1 animal unit equals 10 pigs less than or equal to 55 pounds or 2.5 pigs greater than 55 pounds. Numbers in parentheses are the number of storage structures of that type on the operation.

ID	Predominant Phases of Production	EPA Animal Units for Pigs	Manure Storage Structures	Application Methodology	Mean Annual Manure Volume (gallons)	Mean Annual Total Nitrogen Available for Land Application (pounds)	Mean Annual Total Phosphorus (as P2O5) Available for Land Application (pounds)
NC-1	Nursery	304	Lagoon, single stage	Stationary sprinkler	851,444	12,698	12,542
NC-2	Nursery	700	Lagoon, single stage (2)	Traveling gun	1,236,928	9,884	14,803
NC-3	Farrow to wean	816	Lagoon, single stage	Traveling gun	2,833,339	36,517	39,126
NC-4	Farrow to feeder	844	Lagoon, single stage	Traveling gun	3,076,788	29,458	48,153
NC-5	Feeder to finish	2304	Lagoon, single stage (2)	Traveling gun	4,176,314	83,508	146,100
NC-6	Feeder to finish	2791	Lagoon, single stage	Traveling gun	4,680,769	279,528	153,349
OK-1	Farrow to wean	200	Lagoon, single stage	Stationary sprinkler	2,988,239	14,611	14,122
OK-2	Feeder to finish	275	Lagoon, single stage	Center pivot	2,081,130	82,767	28,739
OK-3	Farrow to wean	280	Lagoon, single stage	Stationary sprinkler	800,507	39,206	26,530
OK-4	Nursery	340	Lagoon, single stage	Traveling gun	318,511	25,217	5,864
OK-5	Farrow to finish	347	Lagoon, single stage (2) Lagoon, multi stage (2)	Traveling gun	444,673	26,517	18,188
OK-6	Nursery	550	Lagoon, single stage	Center pivot	1,797,356	80,085	13,237
OK-7	Farrow to wean	1810	Lagoon, multi stage	Center pivot	4,924,327	257,495	68,001
OK-8[1]	Nursery	600	Lagoon, single stage	Traveling gun	604,033	55,685	28,211

[1]OK-8 used only on zero discharge study.

4.8.3 Characteristics of Pennsylvania Operations

Selected characteristics of six swine farms used in this analysis from Pennsylvania. Animal units based on 1 animal unit equals 10 pigs less than or equal to 55 pounds or 2.5 pigs greater than 55 pounds. Numbers in parentheses are the number of storage structures of that type on the operation.

ID	Predominant Phases of Production	EPA Animal Units for Pigs	Manure Storage Structures	Application Methodology	Mean Annual Manure Volume (gallons)	Mean Annual Total Nitrogen Available for Land Application (pounds)	Mean Annual Total Phosphorus (as P_2O_5) Available for Land Application (pounds)
PA-1	Farrow to finish	528	Pit, attached (2)	Tanker, tractor; surface Tanker, truck, surface	672,434	26,706	29,611
PA-2	Wean to finish	654	Pit, attached	Tanker, truck; surface	804,738	27,248	48,949
PA-3	Feeder to finish	800	Pit, attached	Tanker, truck; surface	854,690	35,042	62,270
PA-4	Feeder to finish	1200	Pit, attached	Tanker, tractor; surface	1,439,615	38,852	58,905
PA-5	Wean to finish	1560	Pit, attached (2)	Tanker, tractor; surface	1,950,710	85,431	107,628
PA-6	Feeder to finish	1600	Pit, attached (2)	Tanker, truck; surface	1,954,808	87,901	160,231

Chapter 5
THE TECHNICAL FEASIBILITY OF THE SWINE INDUSTRY MEETING A "ZERO DISCHARGE" REQUIREMENT

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5.1 INDEX

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5.2 EXECUTIVE SUMMARY

This chapter addresses issues related to complying with the proposed rule of "*a zero discharge requirement from the production area that does not allow for an overflow under any circumstances*" as presented as "*Option 5*" on page 3060 of the Federal Register (Vol. 66, No. 9, Friday, January 12, 2001). In the proposed rule, EPA suggested the strategies of improved water management, covered storage or additional storage to meet the "zero discharge" criteria. The potential feasibility and limitations of the proposed strategies have been evaluated and discussed for operations that currently use anaerobic lagoon systems. Brief summaries of the various conclusions are presented below.

Improved Water Management: Water reduction strategies in most operational swine production units will not reduce the effluent volumes that flow to earthen manure storages and anaerobic lagoons enough to provide any appreciable increase in the storage period. Only swine operations located in arid regions (where evaporation significantly exceeds rainfall) that are currently using fresh water to remove manure from buildings can benefit from improved water management to meet a "zero discharge" rule by recycling lagoon effluent for manure removal when the earthen storage is becoming full. Many swine operations currently using a slurry manure system are already using appropriate water reduction strategies to minimize the volume of manure to apply.

Covered Storage: Installing floating, impermeable covers on anaerobic lagoons to meet the "zero discharge" criteria has very limited potential due to a number of technical feasibility issues. Some of the main technical issues limiting the feasibility of floating impermeable covers are:

- Floating cover design and installation must allow for varying liquid surface levels in the lagoon. This results in excess cover material which wind can destroy when the lagoon liquid level is near the full level.
- Gas collection and/or removal must be achieved or the cover will "balloon" above the liquid surface and be subject to wind damage.
- Rainwater, sand, soil, ice and snow must be removed regularly from cover surfaces to keep the cover from sinking. Solid materials like sand, soil and snow are typically not easily removed from lagoon covers.
- Freezing weather or a frozen lagoon surface can destroy gas collection equipment, surface water removal equipment, or floatation support structures inherent to lagoon covers.
- Wind speeds below the design wind speeds required for insurance coverage can destroy covers on large lagoons.
- A small hole or rip in the cover will allow rainwater to enter the lagoon or cause the operation to land apply contaminated rainwater collected on surface of cover. If rainwater on the surface of the cover is contaminated, the animal production operation probably cannot maintain a "zero discharge" criterion.
- Worker safety during cover repair, especially near the center of the lagoon, can be difficult to ensure.

- Access for land application equipment, agitator and pump, compromises the integrity of the continuous impermeable lagoon cover.

Additional Storage: The concept of “zero discharge” presents a dilemma for design engineers because design parameters and limits are required to develop satisfactory designs. The suggested scenarios have been developed using defined storms with designated lengths and return frequencies. These, or other reasonable design storms, can be used to develop and design additional earthen manure storage basins and anaerobic lagoon cells. The suggested scenarios do not guarantee a “zero discharge” because the storage may overflow when a rainfall event occurs that is greater than the design storm used to size the structure. The only structures that can be assured to meet a “zero discharge” criterion due to rainfall are covered structures that do not have rainfall or runoff entering the storage structure.

Two additional storage options are evaluated to minimize the frequency of a discharge event due to rainfall. These options are a second storage cell and an emergency storage basin.

A second storage cell is designed with a compacted clay liner to provide long-term storage of effluent. The second cell would provide the extra storage capacity required by the longer storage period. During years when no additional storage capacity was required, the rainwater collected in the second cell would be land applied because the residual effluent that protects the liner would not meet discharge standards.

An emergency cell would have a compacted clay liner; however, the emergency storage cell would not be used for long-term storage. During years when no additional storage was required, any rainwater collected would be discharged unless tests indicated nutrient content levels that would require land application.

Some key conclusions regarding additional storage options of a second storage cell or emergency storage basin are as follows:

- Operations will incur additional costs for constructing the additional storage volumes.
- Operations will not be guaranteed of “zero discharge” from rainfall events that exceed the design storm used to determine the volume of the added earthen cell.
- Operations with additional storage will be more environmentally friendly because the frequency of a discharge event due to rainfall will be reduced.
- Operations will incur added spreading costs from pumping collected rainwater during wet weather periods when above normal rainfall occurs.
- No additional manure nutrients are available to offset the added spreading costs during wet weather.
- The design of the emergency storage cell was based on a 10-year, 10-day storm plus 30 days of manure and wash water.

5.3 UNDERSTANDING OF "ZERO DISCHARGE" REQUIREMENT

This chapter addresses issues related to complying with the proposed rule of "*a zero discharge requirement from the production area that does not allow for an overflow under any circumstances*" as presented as "*Option 5*" on page 3060 of the Federal Register (Vol. 66, No. 9, Friday, January 12, 2001). In the proposed rule, the EPA suggested the strategies of improved water management, covered storage or additional storage to meet the no discharge criteria. The potential feasibility and limitations of the proposed strategies have been evaluated and discussed for operations that currently use anaerobic lagoon systems.

The implementation of the proposed "zero discharge" rule has resulted in a design dilemma. The design dilemma, from an engineering perspective, is how to design for conditions that essentially have no limits. The proposed "zero discharge" rule implies that storm water (rainwater) entering a manure storage and/or treatment structure cannot result in a discharge from the structure. A structure can be designed to store the amount of rainwater that would enter the given structure for a given design storm or rainfall event. However, the return frequency and duration of the design storm event for a given location must be known in order to determine the volume of rainwater that will enter a structure at the given location. The EPA does not provide the return frequency and duration for a design storm in the proposed rule. This design volume is essential for an engineer to determine the size of the structure. The other option is a design that assures that no rainwater will enter the manure storage structure. Rainwater can be excluded from the manure storage structure or system by constructing the entire swine production system under roof. This includes the swine housing and all manure storage and treatment structures to be buildings with roofs. By not defining the return frequency and duration of design storms, and by explicitly stating no "upset and bypass" in the permit for swine operations, the EPA implies that the entire swine production system must be placed under roof in order to comply with the proposed "zero discharge" rule.

The proposed "zero discharge" rule makes it clear that all lagoons would require some technology modification to be in compliance. First, the requirement that existing lagoons comply with the "zero discharge" rule indicates that no "grand fathering" is envisioned. Existing lagoons would need to have technology added to guarantee zero discharge. Any lagoons built after the Rule goes into effect would need added technology to guarantee "zero discharge."

Secondly, the fact that the frequency factor for lagoon compliance with "zero discharge" is set at 0% (Cost Methodology p 61) and that no specific characteristics warrant a cover (as sandy soils, high ground water table and karst topography are factors that are said to warrant lagoon liners), it can be implied that the EPA considers all lagoons in need of covering or some type of compliance effort. While the EPA might not mandate covers, the fact that all lagoons require some compliance cost in their cost analysis implies that all lagoons (including those designed to contain 12 months of manure storage, a 25-year, 24-hour storm event plus one foot of freeboard) currently do not comply with the proposed rule.

Other technologies, such as secondary containment, may satisfy permit requirements, but it is clear that current lagoon standards, even 12-month storage lagoons, are insufficient to obtain a permit. However, without the return frequency and duration for a design storm, no open structures can be designed to assure, without exception, that a "zero discharge" criterion can be met. If the EPA sets the return frequency and duration for a design storm, an "upset and bypass" provision in a permit must be allowed for any systems with open structures as a rainfall event that will exceed the design storm rainfall is possible for almost any location. Otherwise, all portions of the swine production and manure storage system must be "under roof" to comply with an absolute "zero discharge" rule. Later sections in this chapter provide examples and additional discussion related to rainfall amounts and absolute "zero discharge" compliance.

5.4 SELECTED MODIFICATION STRATEGIES FOR ANAEROBIC LAGOONS AND EARTHEN SLURRY STORAGES

The selected strategies discussed in this section are three strategies expressed by the EPA as potential methods for swine operations to meet the proposed "zero discharge" requirement. The EPA discusses these selected strategies on page 3060 of the Federal Register (Vol. 66, No. 9, Friday, January 12, 2001). The potential of the swine industry to adopt the strategies and implication of adopting the strategies are presented below.

5.4.1 Improved Water Management

The EPA indicates in the "Option 5 section" that fresh water reduction strategies can be implemented to help swine operations comply with a "zero discharge" criterion. The EPA implies that reducing the amount of fresh water used as part of the manure handling activities on swine operations will result in significant reduction in the amount of effluent to be stored and then land-applied.

Water reduction strategies in most operational swine production units will not reduce the effluent volumes that flow to earthen manure storage and anaerobic lagoons enough to provide any appreciable increase in the storage period. Anaerobic lagoon effluent is presently recycled in most flush and pit-recharge manure collection units. Swine operations exist in arid areas of the country where groundwater is used for manure collection without recycling. Swine operations using fresh water for manure handling have irrigated cropland and have found an economic advantage to pumping groundwater at lower flow rates and storing the water, rather than directly pumping the groundwater at the high flow rates needed to supply adequate flow to a center pivot irrigation system. These swine operations use the pumped groundwater to remove manure from their swine facilities to an earthen storage, and then to irrigate the water containing manure nutrients on crops at rates needed by crops. Additional groundwater is typically pumped directly to irrigation systems to provide the total water needs of the growing crop. When the earthen storage structures on swine operations in arid areas are close to full liquid level, the operation will switch to using recycled water from the storage to remove manure from the swine facilities.

Wet-dry feeders and several cup or bowl type drinking water systems will reduce wastewater flows. These devices can make an appreciable difference in manure volume in manure tank storages that have limited or no rainfall volume contributions. These more concentrated manure nutrients are often transported and land applied with tank wagons or trucks. Because of the additional effluent volumes that are the result of rainfall and runoff that flow to earthen manure storage basins and anaerobic lagoons, adopting these water reducing systems will not significantly increase the storage volume period for these types of structures. The major portions of the annual pumping volume for anaerobic lagoon systems include the manure volume and added rainwater unless the lagoon is located in an arid region. Table 5.1 gives the annual pumpdown volume, manure volume, added water and rainwater for anaerobic lagoons from surveyed farms. The added water portion, which an operation can control, is typically the smallest portion of the annual pumpdown volume.

Table 5-1. Liquid volumes composing annual average pumpdown volume of anaerobic lagoons on surveyed farms.

Presentation Code	Annual Pumpdown Volume (gallons)	Annual Manure Volume (gallons)	Added Water[1] (gallons)	Average Rainwater Added (gallons)
MO-1	342,916	207,222	41,969	93,725
MO-4	1,787,886	1,352,444	186,125	249,317
MO-5	1,324,556	758,699	231,885	333,982
MO-6	3,564,137	2,498,263	39,032	1,026,842
NC-1	851,444	273,894	273,754	303,796
NC-2	1,236,928	630,676	56,932	549,320
NC-3	2,833,339	1,177,808	602,170	1,053,361
NC-4	3,076,788	1,115,708	99,996	1,861,084
NC-5	4,176,314	2,710,104	218,972	1,247,238
NC-6	4,680,769	3,283,180	219,701	1,177,888
OK-1	2,988,239	366,178	2,481,688	140,393
OK-2	2,081,130	1,569,182	9,671,208	-7,749,260
OK-3	800,507	469,586	564,214	-233,293
OK-4	318,511	255,274	912,378	-849,141
OK-5	378,977	432,314	929,397	-982,734
OK-6	1,797,356	495,532	3,831,988	-2,530,164
OK-7	4,924,327	2,807,198	5,693,239	-3,576,110
OK-8	604,033	558,599	1,094,854	-1,079,420
PA-8	697,437	464,258	75,180	157,999

[1] Added water includes any runoff from open lots.
Note: OK farms are in an arid region where evaporation significantly exceeds rainfall.

5.4.2 Impermeable Covers

The use of impermeable covers is recommended as a method by the EPA (page 3060, bottom of 2nd column) to meet "Option 5, zero discharge" from swine lagoons. Impermeable covers are promoted as having the ability to keep rainwater from entering the anaerobic lagoon or the earthen manure storage structure. However, in order to implement the use of impermeable covers for lagoons or earthen manure storage structures, several operational issues must be addressed to assure the cover will function correctly. The comments below include the challenges that impermeable cover manufactures and suppliers will need to fully address in order for the swine industry to widely adopt impermeable cover technology. Cited examples of the successful application of impermeable cover technology may not have needed to address all challenges presented below because of their geographic location or may have yet to experience or be exposed to any one of the challenges presented below. Some background information is initially presented to better understand the importance of the challenges that minimize the technical feasibility of implementing impermeable covers.

5.4.2.1 General Operation of an Anaerobic Lagoon with an Impermeable Cover

An anaerobic lagoon, by design, will produce bubbles containing biogas (about 70% methane and 30% carbon dioxide). As the bubbles are created, an impermeable cover will trap the gas under the cover. The trapped gas must be removed from under the cover and be either flared or collected and used as an energy source. When the biogas is used as an energy source, the gas collection system, in conjunction with the cover, must collect and remove gas from anywhere on the lagoon surface. The collection system must be gas tight to avoid diluting the biogas with air from the atmosphere.

The liquid surface level in an anaerobic lagoon will vary from a lower level at the treatment volume to an upper level when pumping should begin. The variation in depth will depend upon the specific design of the system. This variation in depth is typically three to four feet but can easily be six feet or more at specific sites.

The impermeable cover is located on the lagoon surface and inside the berms completely covering the lagoon. As a result, all storm water that falls on the surface of the lagoon and within the berms that slope to the lagoon surface will collect on the surface of the cover. This storm water must be removed from the surface of the cover. The system to remove the trapped water must be able to collect and remove ponded water from anywhere on the surface of the lagoon without compromising the integrity of the cover.

Figure 5-1 shows a picture of an impermeable cover on a swine anaerobic lagoon. Both storm water removal and gas collection challenges exist. If the storm water challenge is not addressed satisfactorily, the cover may sink. If the gas collection challenge is not addressed, wind will damage the cover and may result in total failure of the cover. These challenges are discussed in greater detail later in this chapter.

Figure 5-1. Picture of an impermeable cover showing trapped gas “bubbling” the cover and pools of storm water not pumped from surface.

5.4.2.2 Technical Feasibility of Implementing Impermeable Lagoon Covers

This section addresses the challenges that currently exist with the implementation of impermeable covers. If the current challenges cannot be fully addressed, the number of locations able to implement impermeable lagoon covers will be very limited due to technical feasibility challenges.

5.4.2.2.1 General Feasibility Issues for All Impermeable Lagoon Covers

This section addresses the general feasibility issues for all impermeable lagoon covers installed anywhere in the country. The general feasibility issues discussed in this section are for anaerobic lagoon structures (either single cell or multi-cell systems) that include both manure storage and treatment volumes and that must be accessed with pumping and agitation equipment to transport effluent to cropland. Satisfactorily addressing the challenges listed in this section does not insure the technical feasibility of impermeable lagoon covers for a given location. Other site specific, technical issues can render an impermeable lagoon cover infeasible and will be discussed in section 5.4.2.2.2 of this chapter.

5.4.2.2.1.1 Lagoon Accessibility for Land Application and Agitation

Lagoon effluent is typically pumped from an anaerobic lagoon using a pump placed on the berm of the lagoon with an intake hose suspended below the liquid surface by a float. Pumping access to a lagoon that is covered with an impermeable cover will require a portion of the cover to be removed. Removing a portion of the cover for access to the effluent may lead to contamination of storm water collected on the cover surface. This scenario would require the storm water to be handled as a manure product. Further discussion of this issue can be found in section 5.4.2.2.1.3 of this chapter.

Accessing the lagoon for agitation prior to pumping is another issue relating to land application of effluent from a covered lagoon. Many producers choose to agitate their lagoon prior to land application of lagoon liquids in order to reduce solids build-up in the lagoon. In order to properly agitate some lagoons, the lagoon must be accessed at several points around the lagoon perimeter. Use of an impermeable lagoon cover will limit access to the lagoon for agitation. The proposed rule (Federal Register, page 3061) states that the EPA considers agitation of lagoons every three years to be appropriate management. Lagoons covers are incompatible with this agitation management recommendation.

Any opening provided in the lagoon cover for access of land application activities must be maintained watertight. An underlying assumption of impermeable lagoon covers is defined as “a structural addition to earthen storages and anaerobic lagoons that is capable of keeping storm water out of the effluent stored in the structure.” If the access provided is not watertight, storm water will enter the structure. This storm water issue is discussed further in section 5.4.2.2.1.3 of this chapter.

5.4.2.2.1.2 Gas Generation and Collection

Gaseous emissions from a properly operated anaerobic lagoon can provide for buoyancy of an impermeable lagoon cover. The gas production capability of a lagoon is highly dependent upon the temperature of the lagoon liquids. During cooler months (November through May each year in some regions), lagoon liquid temperature can drop a significant number of degrees compared to liquid temperatures during warmer months. This reduced seasonal liquid temperature results in less microbial activity in the lagoon and, consequently, in reduced gas production. This minimal gas production could contribute to problems with cover buoyancy, and may be of particular concern since snow and ice loads on the cover’s surface are greater during this period. Foam blocks or some other type of flotation aid can be used to provide for buoyancy. However, other problems with freezing can occur and will be discussed later. The effluent under the cover can support the cover by allowing the cover to sink down an amount equal to the weight of the water or material on the cover. Uneven loading of the cover will result and lead to gas bubbles trapped under the cover. This uneven loading and resulting trapped gas bubbles are visible in the picture of Figure 5-1.

The gas generated by the anaerobic lagoon must be collected from under the cover. The gas will constantly be generated and must be removed from underneath the cover, or the cover will “bubble-up” as can be seen in Figure 5-1. When the cover is “bubbled up” from trapped gas, wind forces can easily damage the cover, as opposed to when the cover is on the lagoon surface. Anaerobic lagoons with larger surface areas will have greater challenges than those with smaller surface areas when addressing gas collection.

5.4.2.2.1.3 Storm Water Collection and Disposal

A key underlying assumption of the proposed “zero discharge” rule is that storm water will not enter manure storage and treatment systems used for swine operations. The collection and removal of storm water from the surface of an impermeable cover must be implemented in order to meet the objective assumption of the proposed rule.

5.4.2.2.1.3.1 Collection of storm water (rainwater) to pump

The collection and removal of storm water from the surface on an impermeable cover must be successfully accomplished in order to meet the objective of the “zero discharge” rule. As shown in Figure 5-1, collecting storm water from the surface of a large cover is not automatic and may not be a simple task. Water must be collected from the entire surface by allowing the water to pool in one or several locations and then be pumped from the cover surface. To facilitate pooling of surface water, the cover must be systematically sloped to form water pools at pre-determined locations. If surface water is not systematically pooled, a pump or a pump intake will have to be moved to different locations around the lagoon cover to pump water from the cover surface. Multiple pump locations can be used to remove storm water from covers surfaces, but they increase the time and cost of sampling the water for nutrient content.

5.4.2.2.1.3.2 Sampling of collected storm water for possible contamination

Storm water that is collected from the surface of the impermeable cover will need to be disposed of once it is pumped off of the cover. The collected storm water will likely have to be tested for nitrogen in the same fashion as storm water collected in secondary containments before it can be discharged to waters of the state. In some states, ammonia-nitrogen concentrations greater than 2.5 ppm in the storm water require that the water be land-applied at agronomic rates or pumped into the manure storage system. If lagoon effluent collects on the cover due to a hole in the cover, spillage during access to the lagoon liquid, or other means; then all water on top of the cover becomes contaminated and must be managed as a manure effluent. If water on the cover is treated as effluent, the cover serves no purpose as related to the “zero discharge” issue because the volume of water entering the manure management system has not been reduced.

5.4.2.2.1.4 Challenges Related to Size of Cover

Single cell and two cell anaerobic lagoons used by swine operations can be large compared to most treatment lagoons or structures for municipal systems. Table 5-2 gives example lagoon surface areas for different sizes of swine operations. Since the lagoon surfaces are relatively large, the cover needed to keep storm water from entering the lagoon will be relatively large.

Earthen manure storages can also be large as seen in Table 5-3. Many of the same challenges will exist for earthen manure storage basins as exist for anaerobic lagoons. The challenges include but are not limited to: 1) storm water collection, removal, and disposal issues, 2) access for agitation and pumping, 3) removal of trapped gas (although the generation rate will be significantly lower than for anaerobic lagoons).

5.4.2.2.1.4.1 Variable Storage Depth

Because an impermeable cover is relatively inelastic, the cover must be sized to cover the lagoon liquid surface and exposed inside berms during maximum pump down of the lagoon (when the liquid level is lowest). Covers sized for this condition will have excess material present when the lagoon liquid level is at its maximum. A typical lagoon, with a 3:1 inside slope, will have a 0.17-foot per foot of depth variation in coverable surface area on each side between the minimum and maximum pump down levels. This excess material that is present when the lagoon is near maximum liquid level will make the cover more susceptible to lifting during high winds. In addition, this is the time when the lagoon berms protect the liquid surface from wind the least.

Earthen manure storages will usually have greater variation in liquid depth than lagoons. Excess cover material will be greater for earthen manure storage basins than for anaerobic lagoons. The greatest danger for wind damage to the cover on an earthen basin occurs when the earthen manure storage is almost full because the amount of extra material will be greatest when storage is almost full.

Table 5-2. Geometric characteristics of anaerobic lagoons on surveyed farms.

Presentation Code	Area for Berm Centerlines (ft^2)[1]	Full Water Surface Area (ft^2)[2]	Length:Width Ratio	Inside Slope
MO-1	44,967	37,828	2.5:1	3:1
MO-4	86,933	77,254	2:1	3:1
MO-5	132,653	120,100	2.5:1	3:1
MO-6	319,790	301,949	1:1	3:1
NC-1	39,933	33,600	1.7:1	3:1
NC-2	62,546	50,600	1.9:1	2.5:1
NC-3	165,150	147,900	1.76:1	3:1
NC-4	186,624	160,000	1:1	3:1
NC-5	142,848	126,888	1.6:1	3:1
NC-6	192,219	179,010	1.5:1	3:1
OK-1	45,579	38,844	1.6:1	2:1
OK-2	350,529	320,420	2.3:1	3.5:1
OK-3	36,481	28,561	1:1	3:1
OK-4	48,054	37,950	2.1:1	3:1
OK-5	66,764	55,672	2.78:1	3:1
OK-6	105,779	89,543	1.02:1	4:1
OK-7	161,122	142,129	1:1	3:1
OK-8	76,388	62,376	1.6:1	4:1
PA-8	21,881	16,744	1.7:1	2:1

[1]This area has the perimeter of the centerline of the berms surrounding the lagoon.
[2]This area is the area of the water surface when lagoon is filled to design depth.

Table 5-3. Geometric characteristics of earthen slurry storages on surveyed farms.

Presentation Code	Area for Berm Centerlines (ft^2)[1]	Full Water Surface Area (ft^2)[2]	Length:Width Ratio	Inside Slope
IA-2	90,699	80,000	1.5:1	2:1
MO-3	14,654	10,731	2.5:1	3:1
PA-7	110,400	96,800	2:1	2.5:1

[1]This area has the perimeter of the centerline of the berms surrounding the storage.
[2]This area is the area of the water surface when storage is filled to design depth.

5.4.2.2.1.4.2 Surface Area of Lagoon and Resulting Cover

Design criterion for permitted lagoons in some states require a 3:1 inside slope on the lagoon berm. The EPA's proposed regulations reference 2:1 inside slopes for lagoon berms. The increase in side slopes to 3:1 results in the need for an extra foot of cover material along each side of the lagoon berm for each foot of lagoon depth. Table 5-4 shows several examples of the increased surface area resulting from the flatter inside slope of lagoon. Flatter inside slopes as very common as seen from the survey data in Table 5-2. The EPA's proposed regulations reference length:width ratios of 1:1. As seen in Table 5.2, larger length:width ratios are more common indicting a more rectangular shape. Increased length:width ratios results in increased surface areas as seen in Tables 5-4 and 5-5. The EPA's selection of a 2:1 inside slope and a 1:1 length:width ratio actually minimizes lagoon surface area. The larger actual surface areas will result in an increase (over the EPA's estimates) in material needed to cover a given lagoon. The increased material need will increase the cost for covering lagoons and affect the economic analysis conducted.

Table 5-4. Surface areas of a five million gallon anaerobic lagoon designed using different geometric characteristics.

Example Configuration	Length:Width Ratio	Inside Slope	Full Water Surface Area (ft^2)
1	1:1	3:1	64,778
2	2:1	3:1	66,479
3	1:1	2:1	57,791
4	2:1	2:1	58,792

Table 5-5. Surface area and volume of an anaerobic lagoon for a given operation using different geometric characteristics.

Example Configuration	Length:Width Ratio	Inside Slope	Liquid Volume (gallons)	Full Water Surface Area (ft^2)
1	1:1	3:1	5,000,946	64,778
2	1.5:1	3:1	5,012,102	65,475
3	2:1	3:1	5,034,061	66,848
4	1:1	2:1	4,905,029	56,819
5	1.5:1	2:1	4,912,816	57,237
6	2:1	2:1	4,928,085	58,056

5.4.2.2.1.5 Cover Repair Issues

The watertight integrity of the impermeable cover must be maintained to meet the objective of the "zero discharge" proposed rule. Storm water that enters the lagoon through the cover or becomes contaminated with lagoon effluent will have to be land applied. In these cases, no storm water management benefit has been gained from the use of an impermeable cover. The cover must be maintained watertight to realize a storm water management benefit.

Damage to an impermeable cover can occur along the berm of the lagoon where the cover is attached. Locating and repairing this type of damage along the perimeter of the lagoon can be accomplished with relative ease. The worker doing the repairs can probably remain on the berm of the lagoon and be safe.

Finding and repairing cover damage located away from the berm is a more challenging repair activity. Repairs implemented while the lagoon cover is kept in place require the workers to be on the cover. If a worker were to fall into a lagoon due to cover failure, the danger from drowning would be similar to someone falling through the ice-covered surface of a water body. The damaged cover could be removed and repaired while the cover was temporarily located on the berm. For small lagoons, removing the cover may not be a significant issue. However, for larger lagoons, removing, repairing and replacing the cover without causing additional damage would present a significant challenge and additional cost to the producer.

Repairing damage located away from the berm remains a significant challenge regardless of whether the repair is done on the lagoon surface or on the berm. If portions of the cover have sunk due to holes in the cover, the cover must be cut into strips to be removed because of the water weight on top of the cover. In these cases, a small tear or hole in the cover will require total replacement of the cover.

5.4.2.2.1.6 Old or Damaged Cover Disposal

Disposal of old and damaged covers can be a significant problem for some locations. The disposal challenges of old cover material are similar to challenges for old plastic silage and hay bags and old tires. Present technology limits disposal options to either sanitary landfills or recycling the material for some other use. If sanitary landfills do accept old cover material, charges can range from $12 per ton to over $100 per ton of material. Many sanitary landfills will not accept tires, plastic silage and hay bags. This would indicate non-acceptance of used lagoon cover material. A recycling program or reuse effort will be needed. Some existing recycling programs require that used plastic silage and hay bags be cleaned before the material will be accepted for recycling. Cleaning an old lagoon cover before recycling may be required in certain locations and result in additional expense for disposal of the old cover material. If impermeable lagoon covers are to be implemented on an industry-wide basis, the disposal of old cover material will need to be addressed and the cost of cover disposal incorporated into the overall cost analyses.

5.4.2.2.1.7 Problems with Decreased Quality of Recycled Effluent

The EPA recommends the use of recycled lagoon effluent rather than fresh water for barn flushing purposes to reduce the volume of effluent that ultimately must be land applied. Many production systems are currently using recycled lagoon water (effluent from approximately 12-24" below the lagoon surface) for flushing in production barns. With properly operating uncovered anaerobic lagoons, odor is minimal during flushing with the recycled water. When an impermeable lagoon cover is installed, the recycled flush water will have elevated dissolved gas concentration levels because the cover will reduce the emissions from the anaerobic lagoon. Higher dissolved gas concentrations can result in elevated gas concentrations within the production facilities. Higher gas concentrations might be irritating for animals and production workers in the barns, and might result in increased odor emissions from the production facilities.

Recycled water from a covered anaerobic lagoon will tend to contain a higher level of dissolved and suspended solids due to a decrease in dilution of the effluent from storm water. The increased level of dissolved and suspended solids in the recycled flush water may cause solids to build up in the recycle system within the production units and result in less effective manure removal.

5.4.2.2.2 Site Specific or Regional Issues Challenging the General Feasibility of Impermeable Lagoon Covers

The technical challenges presented in this section may only affect the technical feasibility of an impermeable cover installed at a specific location for a given operation. However, depending upon the location of the swine operation, one or more of the following technical challenges may cause installation of an impermeable lagoon cover to be infeasible.

5.4.2.2.2.1 Challenges Related to Structural Issues

Impermeable covers, as installed, will have to withstand various structural loads. The two types of structural loads discussed in this section include gravity live loads and wind loads. Other types of structural loads may be exposed to impermeable covers; however, if a lagoon cover system can withstand the two load conditions discussed in this section, the cover probably will not fail due to structural loads.

A structure that can repeatedly withstand various loads is considered to be reliable. Two important concepts related to structural loads and structural failures must be understood when evaluating the reliability of a structure. First, the concept of design loads must be understood when evaluating structural reliability. Design loads are defined as the required largest loads that a structure will be expected to withstand. Design loads are determined either from engineering calculations and judgment or from minimum requirements specified by code or regulatory authorities. Second, an understanding of the concept of exposure when evaluating structural reliability is also necessary. Exposure is defined as whether, or how often, a structural load near or equal to the design load is actually experienced by a given structure. A structure never exposed to a design load will not fail due to the design load. A structure is considered reliable when it withstands a given design load or when the structure is shown capable of withstanding the required design load.

When a structural failure occurs, the load the structure experienced is estimated. If the structural failure was caused by exposure to a load that exceeded the design load, no fault is assessed. Insurance coverage from the financial losses possible from a structural failure due to “acts of God” is collected. Loads less than those specified by code causing a structural failure usually negate the owner’s insurance protection. Owners may attempt financial loss recovery from the material manufacturer(s), the engineer or the builder of the structure when structural failures occur at loads less than specified by code. Structures must be designed and constructed to withstand at least the minimum design loads specified by codes in order to obtain insurance protection from a structural failure.

5.4.2.2.2.1.1 Structural Challenges Due to Gravity Live Loads

Gravity live loads are defined herein as the weight experienced by a cover due to any storm water, snow, ice, sand or soil that collects on the surface of the cover. Gravity loads will cause the cover to be displaced downward into the effluent. Equilibrium is reached when the amount of load above the cover is equal to the weight of water displaced under the cover.

One of the problems of gravity loads on covers relates to the displacement of the cover material when a load occurs on the top of the cover. As indicated earlier in this chapter, excess cover material usually exists. However, when the lagoon liquid level is at its lowest point, no excess cover material will be available to sink into the liquid when a gravity load occurs on the top of the cover. The cover may be strong enough to support the material on top of the cover without significant displacement into the lagoon liquid if the gravity load is small. A heavy gravity load will tear the cover resulting in cover failure. Lagoon management recommends pumping the effluent level down to provide a winter storage volume. Gravity loads resulting from winter snow and ice can result in a failed cover unless the snow and ice load is removed in a timely manner.

The distribution of gravity live loads on top of impermeable lagoon covers causes a second problem. Gravity loads, particularly storm water, will be unevenly spread over the top of the cover. Storm water will usually pool in different areas of the cover. The pooling of storm water on an impermeable lagoon cover is seen in Figure 5-1. The uneven distribution of storm water on the cover contributes to the formation of trapped gas that “balloons” the excess cover material. Removal of the pooled storm water presents challenges. Wind forces, discussed later in this report, can easily damage the “bubbled up” cover. Figure 5-2, contributed by a cover vendor, shows installation details that minimize storm water pooling on lagoon cover surfaces. If storm water pools between the foam logs, similar problems as described above can arise.

Soil and sand that is blown onto the cover surface results in a live gravity load. These solid materials are usually unevenly distributed over the cover surface. Gravity live loads introduce by workers removing sand, soil, snow or ice from the cover must be addressed prior to at most potential lagoon cover installations. The impermeable lagoon cover will require the structural load capabilities to support workers doing cover maintenance and repair. The same worker safety issues exist for debris removal as exist for repairing damaged covers.

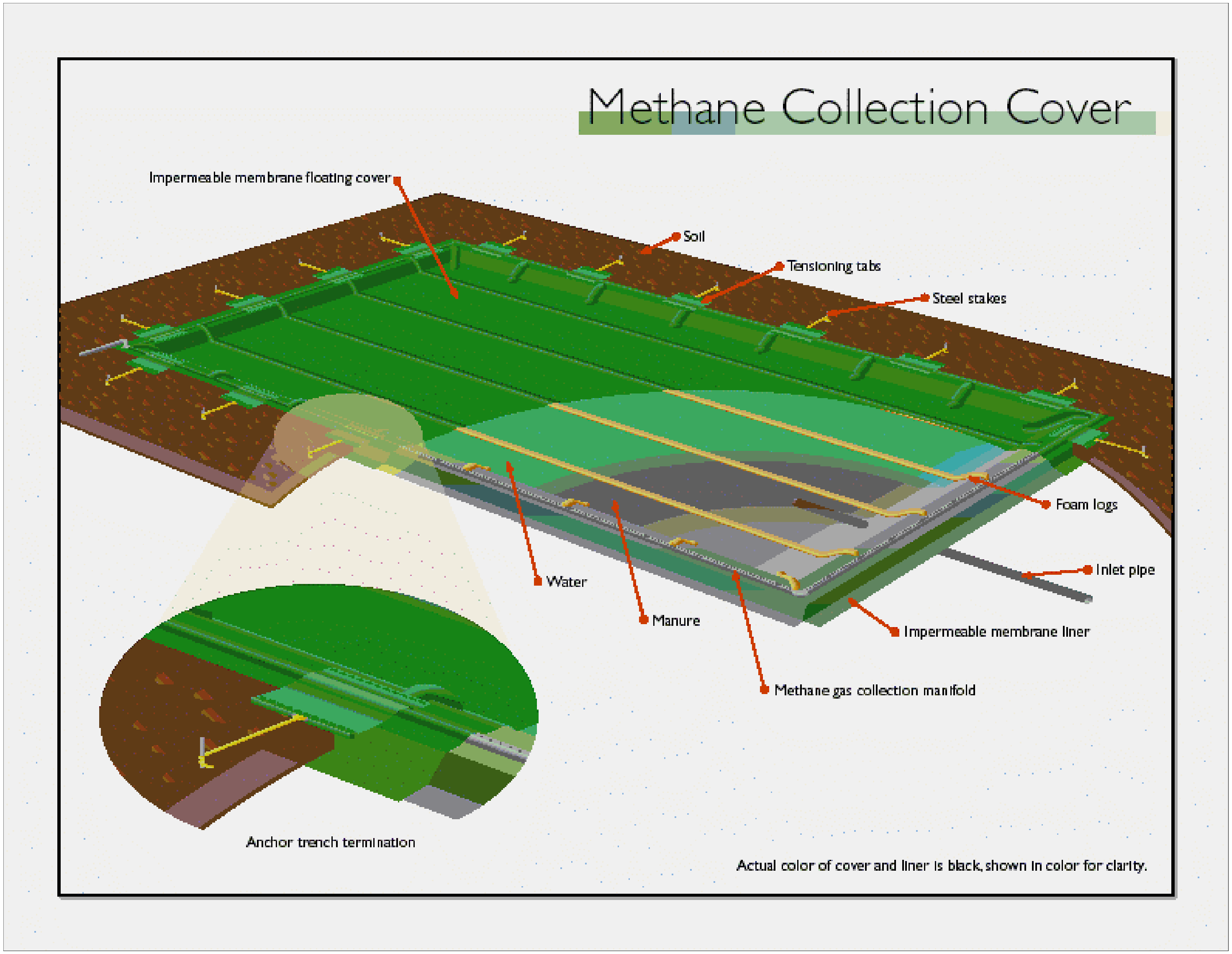

Figure 5-2 Diagram showing installation details for an impermeable cover.
Source: Colorado Lining International. www.coloradolining.com

5.4.2.2.2.1.2 Structural Challenges Due to Wind Loads

Wind loads will damage impermeable covers. The reliability of a given cover with respect to wind loads should be evaluated based on a minimum design wind load for the geographic location utilizing those design parameters that affect the entire surface of the cover. Wind exposure factors on covers can be quite variable. Understanding wind exposure factors and how these factors change between specific sites is critical in the evaluation of wind load design. Impermeable lagoon covers have to be capable of withstanding the wind forces to which the cover is exposed. Lagoon cover reliability is determined by evaluating whether the cover can withstand a given design wind load.

Design wind loads for various structures can be determined by using procedures presented in the design standard ANSI/ASCE 7-98 entitled Minimum Design Loads for Buildings and Other Structures. This Standard specifies how to calculate various design loads for buildings and building components and documents the minimum design loads that buildings or components must be capable of withstanding. Wind load calculation methods and the minimum wind load recommendation are presented in Standard ANSI/ASCE 7-98. The minimum wind load recommendation given in Section 6.1.4.2 of ANSI/ASEC 7-98 states the following: "*The design wind pressure for components and cladding of buildings shall be not less than a net pressure of 10 lb/ft^2 (0.48 kN/m^2) acting in either direction normal to the surface.*" Based on this minimum load recommendation, an impermeable cover on an anaerobic lagoon or earthen manure storage should be capable of withstanding 10 lb/ft^2 of uplift force acting over the entire surface of the cover. Resulting tensile forces the edge of a cover must withstand are tabulated for various cover sizes and geometric configurations in Table 5-6. The force that the cover material must withstand increases as the cover size increases. The largest size of cover for a given cover material is determined by finding the largest tensile force the cover material can withstand from Table 5-6. If the required tensile force is equal to or less than the strength of the cover material, that cover will withstand the specified minimum wind load. If the required tensile force is greater than the strength of the cover material, the cover is too large for the given material. Insurance coverage to protect against the financial losses resulting from a cover failure due to wind damage is usually dependent on accurate wind design of the lagoon cover. A reliable cover should be capable of withstanding the minimum design wind load acting over the entire surface of the cover.

The exposure of wind forces greater than a cover will withstand will result in the failure of the cover due to wind. If, or how frequently, such wind forces occur at a given location defines the foundation for understanding wind force exposure. Using calculation methods presented in Standard ANSI/ASCE 7-98 for various scenarios, the wind load forces acting upon a cover can be estimated. The minimum design wind load of 10 lb/ft^2 can result from approximately a 70 mile per hour (mph) wind speed. Whether an entire cover will be exposed to forces resulting winds greater than 70 mph is the basic exposure question. Some geographic locations in the country may never experience 70 mph wind speeds. Structures in these locations will not be damaged by wind regardless of whether they were designed to withstand design wind loads or not. Other geographic locations experience winds speeds significantly greater than 70 mph, and structures must be designed to withstand the increased design wind forces associated with the greater wind speeds. Structures not designed or constructed to withstand design wind loads will probably be denied insurance coverage for the structure. Insurance coverage is usually available at locations where documented tornado damage has occurred. Lagoon covers should be designed to withstand design wind loads to minimize the potential for cover failure from wind. Covers that are not capable of withstanding design wind loads as specified by code may never fail if the cover is not exposed to design wind loads due to geographic location or local site conditions. These covers should not be considered reliable or structurally adequate for other specific sites. Recommending the use of structures not capable of withstanding minimum design loads is a questionable, if not unethical, engineering practice.

5.4.2.2.2.2 Challenges Related to Freezing Conditions

Freezing conditions will create significant challenges for the implementation of impermeable lagoon covers. These challenges include the potential formation of ice and snow loads, freezing of the lagoon surface, and damage to the cover from storm water collection, gas collection and/or floatation systems used with the cover. Freezing problems will become significant when winter design temperatures reach 25 °F or less. Areas of the country where winter design temperatures can reach 25 °F or less can be seen in Figure 5-3. Minor damage to storm water collection components and gas collection equipment can be expected when temperatures reach 25 °F for short time periods.

The formation of ice and snow loads will create the same challenges as the sand and soil gravity live loads discussed in section 5.4.2.2.2.1.1. The formation of ice and snow loads on the surface will often coincide with pumped down storages going into the winter. The challenge of the ice or snow load is from the deflection of the cover to compensate for the load. Loads that cause large cover material deflections may tear the cover. Physical removal of the ice and snow from the cover has the same worker safety issues as previously discussed.

Freezing of the lagoon surface can be expected to occur in areas where frost penetration exceeds five inches. The areas of the country where frost penetration exceeds five inches can be seen in Figure 5-4. Ice formation will probably damage any floatation aids, as shown in Figure 5-2, along with any other components floating or penetrating the effluent surface when the lagoon surface freezes. Storm water collection components, such as pipes and pumps, not drained between freezing weather uses will be significantly damaged at locations where frost penetration exceeds five inches.

Table 5-6. Tensile force[1] on edge of impermeable cover to withstand minimum design wind load.

	Lagoon Length											
Lagoon Width	50 ft	75 ft	100 ft	125 ft	150 ft	175 ft	200 ft	225 ft	250 ft	300 ft	400 ft	500 ft
50 ft	42	42	42	42	42	42	42	42	42	42	42	42
75 ft		63	63	63	63	63	63	63	63	63	63	63
100 ft			83	83	83	83	83	83	83	83	83	83
125 ft				104	104	104	104	104	104	104	104	104
150 ft					125	125	125	125	125	125	125	125
175 ft						146	146	146	146	146	146	146
200 ft							167	167	167	167	167	167
225 ft								188	188	188	188	188
250 ft									208	208	208	208

[1] Tensile force has units of pounds per inch of cover perimeter length.

Note: Minimum design wind load used is 10 pounds per ft^2.

Example: If cover material has tensile tear strength of 100 lbs per inch of cover width, cover size is limited to lagoons with a width less than 125 feet.

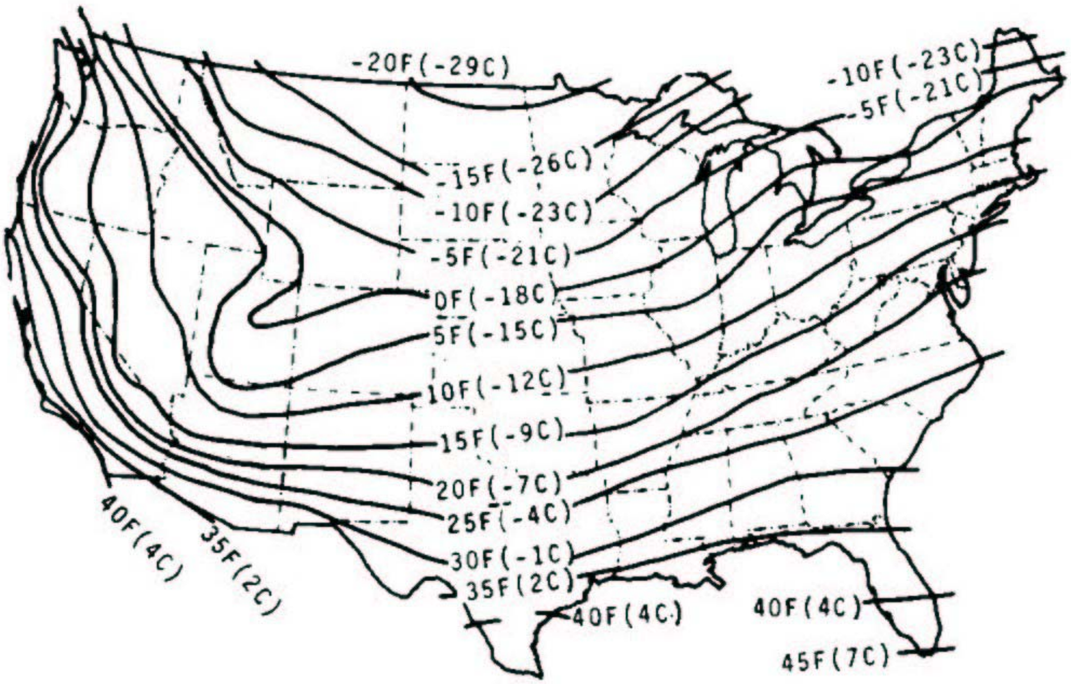

Figure 5-3. Map showing winter design temperatures for US. Source: ASAE EP270.5.

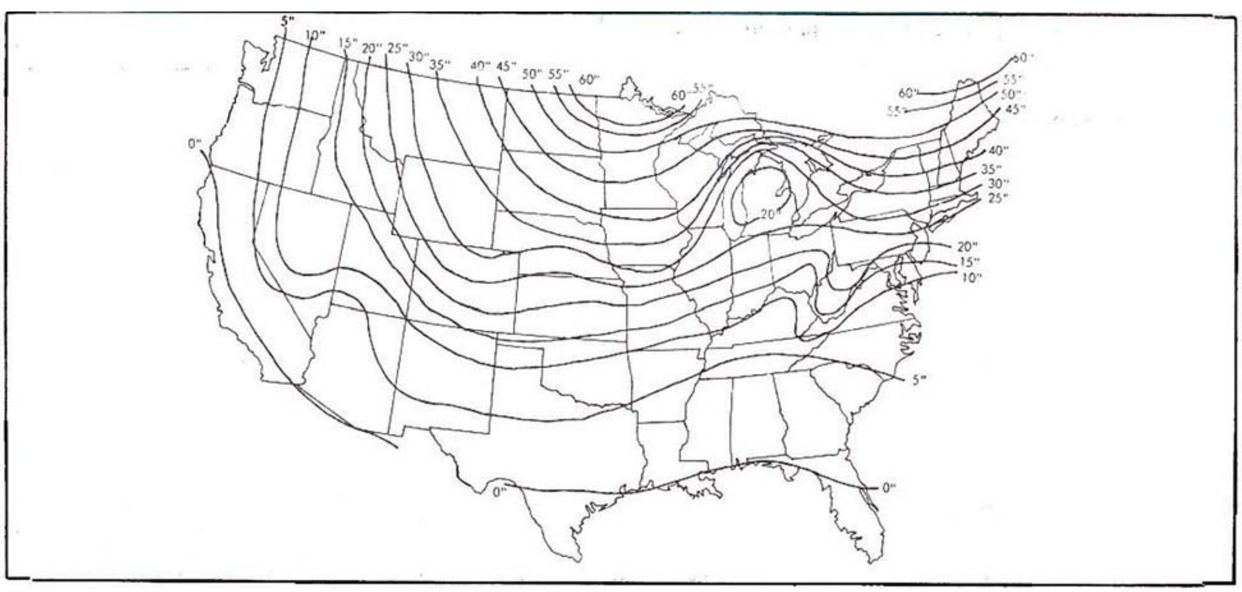

Figure 5-4. Map showing average frost penetration for US. Source: MWPS-1

5.4.3 Additional Storage

The concept of "zero discharge" presents a dilemma for design engineers because design parameters and limits are required to develop satisfactory designs. The scenarios suggested by the EPA are presented below, and have defined storms with designated lengths and return frequencies. These, or other reasonable design storms, can be used to develop and design additional earthen manure storage basins and anaerobic lagoon cells.

The construction of additional manure and wastewater storage is proposed as one alternative to attain "zero discharge" from open earthen manure storage basins and anaerobic lagoons that provide manure storage for Concentrated Animal Feeding Operations (CAFOs). Several concepts may be used to set the design criteria for the added storage. Two concepts presented in this analysis are:

1. Select a longer storage period and construct additional earthen storage to provide storage for manure produced, wastewater, additional lot and berm runoff, and rainfall minus evaporation volumes that occur on the liquid surface during the selected storage period. (Second Storage Cell)

2. Select some frequency and duration of storm and construct an earthen containment basin that would provide secondary storage for manure produced, wastewater, additional lot and berm runoff, and rainfall volumes that would overflow the full primary manure storage during the selected storm. Rainfall collected in the secondary containment basin during periods when manure and wastewater were contained in the primary manure storage would be tested to ensure non-contamination and discharged. (Emergency Storage Cell)

These approaches provide additional manure and wastewater storage for periods when weather related events do not allow scheduled land application of effluent or when rainfall events exceed the present 25-year, 24-hour design storm (catastrophic event) or a 10-year, 10-day design storm (chronic storm). Events that occur in nature are somewhat predictable; however, criteria that specify design limits are required to complete a design. Natural "Acts of God" occasionally exceed design limits. Selection of rainfall frequencies and durations are necessary to design manure storages that will effectively comply with the "zero discharge" concept.

5.4.3.1 Second Storage Cell

A second lagoon storage cell is defined as an earthen structure that is constructed according to federal, state and local regulations, and which can serve as a long-term manure effluent storage basin. The second lagoon storage cell can be located near the primary cell or be sited at a remote location to allow easier effluent pumping access to land application areas. When the second cell is located near the primary cell, effluent from primary cell can usually flow by gravity into the second cell. When the second cell is sited at a remote location, effluent will probably have to be pumped from the primary cell to the second cell. Pumping capacity and operational management design is needed so that the primary cell will not overflow except when design rainfall frequency and/or duration conditions are exceeded. Effluent from the second storage cell would be land applied each year regardless of whether the second cell had received effluent from the primary cell or whether only rainwater had entered the second cell. Annual pumping is required to maintain the designed additional storage capacity. In years when evaporation exceeds rainfall (drought), fresh water may need to be added to the second cell to maintain the volume required by the operating permit to maintain a water cover over the clay liner.

5.4.3.1.1 Second Storage Cell Design Criteria

Selection of a longer storage period is the initial step in the design of a second earthen manure storage cell that has the capacity to collect and store all inflow for the selected storage period. Construction and operational management of second cells must provide additional storage volume. The second cell cannot be used as a substitute for incompetent pumping and land application management of effluent. Design criteria studied are:

- Increase effluent storage periods to 12 and 18 months depending on the length of the present storage period design.
- Design the second cell to store net rainfall amounts from both cells that would be expected during the wettest year in 10 years.
- The second cell would have volume available to store the 25-year, 24-hour frequency storm at anytime during the increased storage period.

5.4.3.1.2 Second Storage Cell Examples

For this study, swine operations located in Missouri, Oklahoma, and North Carolina were examined since anaerobic lagoons are the predominant manure storage systems used in these states. Secondary storage cell structures were designed based on the above criteria. Using the secondary cell designs, additional pumpdown volumes were calculated for 12 or 18-month periods based on the above criteria. Construction costs were estimated for the second cell. Results for secondary cell analysis are presented in Tables 5-7 and 5-8.

Table 5-7. Existing lagoon volumes and additional storage sizes needed to expand storage capability to 12 and 18 months.

		Existing Lagoon		Increasing to 12 Month Capability		Increasing to 18 Month Capability	
Presentation Code	Existing Storage Period	Liquid Lagoon Volume (gallons)	Total Lagoon Volume (gallons)	Liquid Volume (gallons)	Total Volume (gallons)	Liquid Volume (gallons)	Total Volume (gallons)
MO-4	12 mo.	5,993,847	6,585,025	NA	NA	4,356,175	4,925,249
MO-6	12 mo.	19,136,028	21,419,358	NA	NA	9,850,238	11,032,456
NC-1	6 mo.	1,769,144	2,029,079	1,816,003	2,086,150	6,205,693	6,995,115
NC-4	6 mo.	6,718,302	9,184,428	6,320,165	7,111,524	24,320,612	27,058,489
OK-1	6 mo.	2,728,419	3,025,072	3,321,651	3,771,414	10,112,580	11,372,611
OK-8	12 mo.	4,158,310	5,154,171	NA	NA	1,596,921	1,845,410

Table 5-8. Pumpdown volumes and costs associated with adding additional storage to existing operations.

	Increasing to 12 Month Capability		Increasing to 18 Month Capability	
Presentation Code	Average Annual Additional Pumpdown Volume (gallons)	Construction Cost	Average Annual Additional Pumpdown Volume (gallons)	Construction Cost
MO-4	NA	NA	242,955	$36,581
MO-6	NA	NA	472,847	$81,940
NC-1	316,088	$15,494	726,243	$51,954
NC-4	1,030,199	$52,819	3,073,420	$200,969
OK-1	132,298	$28,011	96,193	$84,467
OK-8	NA	NA	(-508,196)[1]	$13,706

[1]Note: This negative annual pumpdown is assumed to be zero for analysis. This operation is located in an arid region. If this operation was to build a second storage cell, the cell should be lined with a synthetic liner instead of a clay liner because keeping water in the cell to protect a clay liner will be difficult.

5.4.3.1.3 Second Storage Cell Implications

Construction of additional earthen cells to store manure and wastewater for longer storage periods also requires added storage volumes to be constructed to contain the additional rainfall and runoff volumes. Especially in humid areas, these additional effluent volumes may cause hydraulic loading problems during land application. Effluent pumping management problems will increase and application of the increased effluent volume may not be feasible on the existing land application area or with the irrigation equipment that is presently used.

Second storage cell volume calculations were based on local rainfall data and the stocking rate of the case study farm. Construction costs were estimated by assuming that 75% of total volume of the cell required soil excavation. The excavation yardage or cut yards were assumed to cost of $2.00 per cut yard.

5.4.3.2 Emergency Storage Cell

Emergency storage is defined as an earthen structure that is constructed to serve only as a short-term earthen manure storage basin. An emergency storage basin is assumed to be located down stream from the primary lagoon structure. The emergency storage would be designed such that any stored storm water could be discharged from the structure. If overflow from the primary lagoon or earthen manure storage was to occur during a storm event, the emergency storage would store the storm water and overflow effluent. The overflow and any other water stored in the cell that was not acceptable for discharge would have to be land applied. Emergency storage cells are designed to be short-term water storage structures. The advantage of the emergency storage is that when the stored water (presumably only rain water) is acceptable for discharge, the stored water can be released to waters of the state. No land application costs would be incurred by the swine operation when the stored rainwater could be discharged.

5.4.3.2.1 Emergency Storage Cell Design Criteria

Selection of an extended duration design storm is the initial step in the design of an emergency storage cell. The emergency storage cell must be designed to provide a volume that will store the design storm plus storage for manure and wastewater during a longer design period so that land application can be accomplished in an environmentally satisfactory manner. Proposed emergency storage cell design criteria are:

- Provide additional storage volume to contain the 10-year, 10-day design storm and runoff from that storm that would be generated in the primary lagoon cell or earthen manure storage basin. Design volumes would be based on the geographic area rainfall data.

- Provide storage volume for an additional 30-days (one month) of manure and facility wastewater production.

- Rainfall collected during periods when manure and effluent is contained in the primary would be tested and, if not contaminated, would be discharged.

The emergency storage cell is sized based on the assumption that all manure, wash water, net precipitation, and lot and berm runoff is contained within the primary manure storage system unless a rainfall event occurs that exceeds storage design parameters. The occurrence of such a rainfall event requires the emergency storage cell to be of sufficient size to collect all overflows from the primary storage system, as well as precipitation falling directly into the emergency cell and runoff from the emergency cell berm.

Emergency cell volume is determined by calculating the maximum volume of flow that would need to be contained in any one-month period. This flow volume is comprised of the 10-year, 10-day frequency storm, and production system wash water volume and manure volume for a 30-day period. As long as the primary manure storage system is capable of containing all inflow, the emergency storage cell would be drained following storm events if the tested water is found to be free of ammonia nitrogen or other easily measured prediction compound.

For each geographic location, the 10-year, 10-day storm event was determined from Midwest Plan Service Publication No. 18. The states of Missouri, Oklahoma and North Carolina used in this study basically have a 10-year, 10-day storm event equaling ten inches of precipitation.

5.4.3.2.2 Emergency Storage Cell Examples

Based on the above criteria, emergency storage cell structures were designed for example operations from Missouri, Oklahoma, and North Carolina where anaerobic lagoons are the predominant manure storage systems. Additional pumpdown volumes from the emergency cells and construction costs were estimated. Results of emergency cell analysis are presented in Table 5-9.

Emergency storage cell volume calculations were based on local rainfall data and the stocking rate of the case study farm. Construction costs were estimated by assuming that 75% of total volume of the cell required soil excavation. The excavation yardage or cut yards were assumed to cost of $2.00 per cut yard.

5.4.3.2.3 Emergency Storage Cell Implications

Management of the emergency secondary containment cell requires that the cell be equipped with a manually operated “draw-down” device. This manually operated device would be normally closed so that any rainfall or runoff water would be collected in the cell. This water would be field tested for ammonia level or other indicative field test to insure that no manure flow from the primary storage had occurred. When the testing confirmed that the water in the emergency secondary containment was below some determined ammonia level (probably 2.5 to 5 ppm) or other acceptable test, it would be discharged. The secondary containment cell would then be available to collect any outfall flow from the primary lagoon cell or earthen manure storage basin. The proposed "zero discharge" rules specify no overflow of the primary manure storage structure. The proposed rules would have to be modified for this proposal to comply with the proposed "zero discharge" rule.

Table 5-9. Pumpdown volumes and costs associated with adding emergency storage to existing operations.

Facility Code	Existing Storage Period	Emergency Cell Liquid Volume (gallons)	Emergency Cell Total Volume (gallons)	Emergency Storage Construction Cost
MO-4	12 mo.	1,325,688	1,534,860	$11,400
MO-6	12 mo.	3,991,631	4,520,549	$33,575
NC-1	6 mo.	703,769	831,820	$6,178
NC-4	6 mo.	2,780,067	3,166,053	$23,515
OK-1	6 mo.	1,047,661	1,221,284	$9,071
OK-8	12 mo.	1,279,948	1,484,677	$11,027

5.5 ISSUES RELATED TO "ZERO DISCHARGE" REQUIREMENT

The comments in this section discuss issues that have indirectly risen if the "zero discharge" rule is implemented as presented in the Federal Register.

5.5.1 Outside Lots and Pasture Production

The EPA states "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 (Federal Register, page 3135)."

The EPA defines the production area under control of the CAFO owner or operator as a point source. Consequently, any operation with a confined area that is not under roof must collect, store, and properly dispose of all discharge storm water that has come in contact with animals or manure. Some swine operations utilize "Cargill" floors or open concrete feeding areas. For these types of open swine confinement systems, it is impossible to contain all discharge storm water and to meet the zero discharge requirements being proposed. The only option is to move the animals into confined housing under roof.

5.5.2 Dry Manure Systems

The EPA in the Federal Register promotes housing systems capable of using dry manure systems (pages 3061 & 3068). Dry manure system facilities include hoop housing, deep litter barns and “High-Rise” facilities. A carbon source is required for bedding or to be blended with the manure. Hoop barns use a significant amount of bedding because the facility is not designed to moderate inside temperatures. A deep litter swine barn is similar in function to a poultry litter barn. Less bedding is required as compared to a hoop barn because the inside temperature can be moderated for aid with pig comfort. A “High-Rise” facility uses a carbon source to blend with swine manure in a facility similar to a deep pit swine barn that uses a ventilation system similar to a high-rise layer facility.

For hoop house systems, an estimate of one pound of bedding material is required for each pound of gain by pigs housed in facility. For example, if 200 pigs were housed in a hoop barn and each pig gained 200 pounds while in facility, approximately 40,000 pounds of bedding would be required to raise the 200 pigs. For these 200 pigs, the 40,000 pounds of bedding must be gathered and hauled to facility and then the bedding must be hauled away from the facility with the incorporated swine manure. Bedding availability, in the quantities required for an operation, can be a challenge. In some locations, crop residue must be left on the fields to maintain soil conservation practices to minimize soil erosion. In these locations, bedding availability at a reasonable low may be a problem. If bedding costs become significant for an operation using hoop barns, this operation will be placed at an economic disadvantage because of high bedding costs.

5.5.3 Enclosed Treatment Systems

Enclosed manure treatment systems can be used in some situations to reduce the contact between manure and storm water. Several alternative technologies are being designed and operated to improve the handling characteristics of manure and to reduce manure storage volumes. Most alternative treatment systems implement some type of solid separation to divide the liquids and solids into two separate streams. Often there is additional treatment of the solids.

Solids can be digested to create methane for use as an energy source or composted to create a stable organic fertilizer that is more easily transported than manure in a liquid or slurry form. Processing of solids to produce an inert product suitable for packaging as a fertilizer is being examined as well. These systems are commonly contained within a covered structure so that storm water does not come into contact with the separated solids. This reduces the risk of contact between manure and storm water for the solid portion of the manure treatment system.

Although these methods of treatment are generally successful for processing and utilizing solids, the liquid portion of the waste stream must still be utilized. The most economical and practical use of the liquid stream is land application as a soil amendment. The nutrient content of the liquid fraction is lower than manure from traditional manure storage systems due to removal of the solids. Commonly, the liquid is stored in a lagoon where the water can be naturally treated by sunlight and anaerobic bacteria, or mechanically treated with aeration. However, the storage of the liquid portions of the manure stream does not comply with the "zero discharge" rule since contact with storm water is still possible. Advanced treatment of the liquid stream could merit re-use of the water for animal consumption. If treated to suitable nutrient levels for receiving streams, discharge permits similar to those for municipal treatment systems would need to be approved to make the treatment system a desirable option for producers.

5.6 EXISTING SYSTEMS CAPABLE OF MEETING "ZERO DISCHARGE" REQUIREMENT

This section describes the few existing systems that can currently meet the "zero discharge" rule. Any operation that is not using one of the systems below will need to invest in additional equipment or a technology to meet a "zero discharge" rule.

5.6.1 Outside Covered Slurry Storage

Concrete and metal storage structures that store manure as a slurry are capable of meeting the "zero discharge" requirement. Whereas lagoons are designed to treat the manure by sustaining microbes that break down and utilize the solids and nutrients in the manure, slurry storage structures are simply designed to store the manure until it can be utilized. Therefore, the volume and surface area of a fabricated slurry tank is much less than for a lagoon at the same operation. The smaller surface area makes an impermeable cover much more feasible than for an anaerobic lagoon or earthen slurry storage.

Operations that currently utilize a lagoon could meet the "zero discharge" requirement by converting their existing manure storage system to a covered slurry structure. This change in manure storage would drastically change the nutrient value of the manure being utilized for land application. A more in-depth discussion of the impacts of converting from a lagoon system to a slurry system for manure handing and storage is presented in Chapter 6 of this series of documents. In brief, the number of additional acres an operation would need for land application of manure if converting from a lagoon to a slurry system could increase by a couple of magnitudes.

The cost of converting from a lagoon system to a covered slurry storage system must also be considered. A slurry storage structure would not be capable of supplying recycled flush water to the barns as many lagoons currently do. This could potentially cause a need for using fresh water to flush barns. In addition to the cost of constructing the new slurry storage structure, the existing lagoon would need to be emptied and properly closed.

Operations currently applying lagoon effluent would likely also need to invest in new equipment capable of handling the slurry. Many operations with lagoons are presently using center pivot irrigation and traveling guns, which are not capable of handling slurry manure.

5.6.2 Under-building Slurry Storage

Confinement buildings that retain the manure in a deep pit beneath the animals will be capable of complying with a “zero discharge” requirement. Manure drops through a slotted floor on which the animals stand and is collected and stored in a pit until it is utilized for land application. A very high cost is associated with converting a current operation with a flush system to a deep pit system.

5.6.3 Other Systems

Any system where the animals are completely confined under roof and manure is collected and stored under roof will be capable of complying with the “zero discharge” rule. Hoop structures, high-rise buildings, and deep bedding systems all use a carbon source such as straw, sawdust, or cornstalks to combine with animals manure for easier handling and treatment of the manure. Most often, the manure and bedding material mixture is composted and land applied as a soil amendment.

Chapter 6
AGRONOMIC AND ECONOMIC IMPACTS OF CONVERTING MANURE SYSTEMS

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6.1 INDEX

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6.2 EXECUTIVE SUMMARY

The USEPA proposed in December 2000 that swine facilities be subject to a zero discharge rule. The zero discharge rule would mandate that all open manure storage structures not be allowed, under any circumstances, to discharge manure from the structure. Specific assumptions and results of the zero discharge study are presented below.

- Annual agitation of covered lagoons was assumed rather than tri-annual agitation as mentioned in the EPA preamble, because 3-year accumulations of phosphorus make land application difficult to attain. Agitated covered lagoons were assumed to have the same total nutrient content as slurry manure.

- Land requirements for agitated, covered lagoon effluent applied according to a nitrogen rule increase 6 to 12 times over that of open, unagitated lagoons.

- Land requirements for agitated, covered lagoon effluent applied according to a phosphorus rule increase 25 to 53 times over than of open, unagitated lagoon effluent applied according to a nitrogen rule.

- Land application of agitated, covered lagoon effluent usually cannot be accomplished with irrigation systems because the elevated phosphorous content of the effluent requires an application rate that is lower than can be applied with most irrigation systems (average cost of $.006/gallon). A tanker or dragline application system will often be needed to achieve the low application rate (average cost of $.011/gallon).

- The average cost:sales ratio, for the farms in this part of the study, increased from 2% for open, unagitated lagoons to 32% for covered, agitated lagoons. Sixty seven percent of these farms are in the EPA Financial Stress 3 category; 33% would be in the EPA Moderate to Financial Stress 2 categories (depending on their cash flow and debt to asset ratio).

- The average incremental cost:sales ratio for obtaining 18-month storage capacity by adding a second storage cell is 7% for the farms using lagoon effluent storage in this study. Fifty percent of these farms would be in the EPA's Moderate to Financial Stress 3 categories.

- The average incremental cost:sales ratio for adding an emergency storage cell designed to contain a 10-year, 10-day frequency storm plus 30 days of manure and facility wastewater production is 1%. All of the lagoon system farms studied would be in the EPA's Affordable 1 category.

- In this study, the average incremental cost:sales ratio for converting from lagoons to slurry storage tanks is 30%. Fifty percent of the farms are in the EPA Financial Stress 3 category; 33% would be in the EPA Affordable 2 to Financial Stress 2 categories (depending on their cash flow and debt to asset ratio).

6.3 INTRODUCTION

The USEPA proposed in December 2000 that swine facilities be subject to a zero discharge rule. The zero discharge rule would mandate that all open manure storage structures not be allowed, under any circumstances, to discharge manure from the structure.

Currently, lagoons are designed to store a specified amount of water. When these structures are permitted, they are afforded the opportunity of overflowing if a storm event larger than its design storm occurs. This opportunity is defined in the permit as an “upset and bypass” provision.

The USEPA does not mandate any particular technology to achieve the “zero discharge” rule but indicates that it believes that impermeable covers on lagoons would be the most cost effective manner to achieve the standard. This chapter evaluates the economic impact of various technologies to reduce the probability of an overflow. The technologies analyzed are: 1) using impermeable covers on agitated lagoons (see Section 5.4.2), 2) expanding storage capacity to 18 months, 3) building emergency storage, and 4) conversion to a slurry tank system. All analyses assumed application of effluent according to a rotational phosphorus rule (see Section 3.4).

6.4 PHYSICAL CHARACTERISTICS OF LAGOON EFFLUENT UNDER AN IMPERMEABLE COVER

Open lagoon cells volatilize nitrogen into the atmosphere and precipitate P_2O_5 into the sludge that collects at the bottom of the lagoon. The effluent that is pumped onto fields is nutrient dilute. The N: P_2O_5 ratio of lagoon effluent is also relatively balanced for use as a fertilizer on many crops (see Section 2.5.1).

Covering the lagoon with an impermeable cover prevents the volatilization of nitrogen into the air. The resulting nitrogen load in the lagoon then becomes very much like that of a slurry pit, which does not volatilize as much nitrogen as an open lagoon.

An impermeable lagoon cover prevents both evaporation of influent water from the lagoon and collection of rainwater into the lagoon. The volume of water in a lagoon with an impermeable cover will differ from an uncovered lagoon depending on the rainfall-evaporation factor for that geographic location. Covered lagoons in areas where rainfall exceeds evaporation will have less liquid volume than uncovered lagoons in the same area. Conversely, covered lagoons in areas where evaporation exceeds rainfall will have more liquid volume than uncovered lagoons.

Lagoon agitation is a recommended practice of the USEPA. In their economic analysis, they assume agitation every third year. Agitation every third year poses two problems. The first is that nutrient concentrations in the lagoon effluent vary greatly in the year of agitation and manure application equipment must be recalibrated. The second problem is that accumulating three years of phosphorus prior to agitation creates an effluent that has a higher phosphorus concentration. This concentrated effluent may not be able to be applied using equipment currently on the market.

An engineering manure storage design computer program was used to estimate the annual number of gallons and nutrient quantities in effluent that would be pumped from a covered lagoon. Table 6-1 presents the six farms modeled and provides a brief description of the swine production operation and the number of pounds of plant available nitrogen and phosphate expected from both the existing lagoon effluent and an agitated, covered lagoon effluent each year. The current management practice of these farms is not to agitate lagoons prior to pumping. The existing anaerobic lagoon effluent nutrient quantities listed in Table 6-1 assume no agitation of the lagoon effluent.

The quantity of nitrogen in the covered lagoon effluent increases due to the cover capturing nitrogen. The EPA recommends that agitation of the lagoon every three years accompany the installation of an impervious lagoon cover (Federal Register 3061). This study assumes annual agitation where the EPA assumed a 3-year interval. Annual agitation already produces a concentrated effluent that may be too phosphorous rich to be applied using irrigation equipment. Accumulating three years of phosphorus in the lagoon before agitating would make the concentration difficult to apply with typical manure application equipment.

Table 6-1. Estimated nutrient content of existing lagoons and covered lagoons for select farms.

Presentation Code	Production Type	Number of Animal Units	Existing Anaerobic Lagoon Plant Available N (lb/yr)	Existing Anaerobic Lagoon Plant Available P_2O_5 (lb/yr)	Covered Lagoon Plant Available N (lb/yr)	Covered Lagoon Plant Available P_2O_5 (lb/yr)
MO-4	Farrow to wean	818	6645	2355	39280	58879
MO-6	Feeder to finish	3200	31686	7752	194,517	175,830
NC-1	Nursery	304	2410	648	29212	25042
NC-4	Farrow to feeder	844	6227	2169	38719	51489
OK-1	Farrow to wean	200	1350	565	8,868	14,122
OK-8	Nursery	600	6521	1697	76611	90780

Notes: PAN_{lagoon} = (TKN*0.8) + (TKN*0.2*0.62)
PAN_{slurry} = (TKN*0.65) + (TKN*0.35*0.62)
Covered lagoon nutrients were estimated as identical to covered slurry storage.
Number of Animal Units calculated based on the EPA's proposed methodology.

Table 6-2 presents the nutrient concentration in lbs/1000 gallons for the existing open lagoons studied. Table 6-3 presents the nutrient concentration in lbs/1000 gallons for the modeled, agitated covered lagoon. Nutrient concentrations for the effluent from a covered lagoon were assumed to be the same as swine manure pit slurry. Values for covered lagoon were developed using the design model as if the operation was collecting and storing manure slurry in covered tanks. Both nitrogen and phosphorus concentrations were increased over a range of several magnitudes. The range of nitrogen and phosphorus in the open, unagitated lagoon is 0.5 to 16.6 lb/1000 gallons and 0.2 to 3.2 lbs/1000 gallons, respectively. The range of nitrogen and phosphorus in the covered, agitated lagoon is 4.0 to 224.0 lb./1000 gallons and 5.0 to 287.0 lbs./1000 gallons, respectively.

Table 6-2 and Table 6-3 also presents the estimated volume of effluent that would require application from each lagoon system. The volume in the covered lagoons, modeled as manure slurry, was less than that in all but one of the open lagoons. The one covered lagoon with greater effluent volume (OK-8) is located in western Oklahoma where evaporation far exceeds rainfall. The covered lagoon prevents both evaporation from leaving and rainfall from entering the lagoon.

Table 6-2. Average annual pumpdown and nutrient concentration of current lagoons.

Presentation	Current Lagoons		
Code	Annual Volume (gallons)	N Conc. (lbs/1000 gal)	P_2O_5 Conc. (lbs/1000 gal)
MO-4	1,787,886	4.0	1.3
MO-6	3,564,137	9.6	3.2
NC-1	851,444	1.5	0.6
NC-4	3,076,788	1.0	0.6
OK-1	2,988,239	0.5	0.2
OK-8	604,033	16.6	1.9

Table 6-3. Average annual pumpdown and nutrient concentration of covered lagoons.

Presentation	Covered Lagoons		
Code	Annual Volume (gallons)	N Conc. (lbs/1000 gal)	P_2O_5 Conc. (lbs/1000 gal)
MO-4	1,538,569	28.0	38.0
MO-6	2,790,224	80.0	63.0
NC-1	547,607	162.0	127.0
NC-4	1,159,365	39.0	44.0
OK-1	2,804,112	4.0	5.0
OK-8	1,635,433	224.0	287.0

Note: Estimated values above were modeled as if operation was using a manure slurry system.

6.5 LAND REQUIREMENTS

The average crop removal per acre of nitrogen and phosphorus for the 31 farms listed in Chapter 4, Appendix A is summarized in Table 6-4. These crop removal estimates assume that manure would be applied to a "composite" crop rather than an actual crop. For example, an acre of land in Missouri would consist of ½ corn and ½ soybean rather than just corn or just soybean.

Using the nutrient removal per acre for each respective state and the quantity of nutrients in each farm's lagoon (open and covered), the number of acres needed to land apply the manure was estimated. Covering the lagoon increased the average number of acres needed to land apply manure effluent based on a nitrogen rule from of 59 to 413 acres. The average additional land required is about 6 times for each farm; however, two farms (NC-1 and OK-8) needed 12 times as much land for land application of manure. Both of the swine operations needing 12 times as much land are nursery units.

Covering the lagoon increased the average number of acres needed to land apply manure based on a phosphorus rule from of 61 to 1829 acres. On average, each farm would need about 25 times more land but the two farms (NC-1 and OK-8) required 39 and 53 times as much land as was needed under a nitrogen rule, respectively.

Table 6-4. Crop nutrient requirements for application of lagoon effluent and slurry to land in a corn-soybean rotation.

			Existing Anaerobic Lagoon		Covered Lagoon	
Presentation Code	N Removal for respective state (lb/ac)	P removal rate for respective state (lb/ac)	Acres needed for N removal	Acres needed for P removal	Acres needed for N removal	Acres needed for P removal
MO-4	147	45	45	52	267	1308
MO-6	147	45	216	172	1,323	3907
NC-1	240	64	10	10	122	391
NC-4	240	64	26	34	161	805
OK-1	142	23	10	25	62	614
OK-8	142	23	46	74	540	3947

Note: Covered lagoon nutrients were estimated as identical to the nutrient content of covered slurry storage.

Applying manure to land controlled (owned or rented) by the CAFO is better than applying to non-controlled land. First, the CAFO realizes the fertilizer value of manure applied to controlled land. Second, the availability of the land for applying manure is more certain. Applying manure to land not controlled by the swine operation requires getting permission to apply manure and delivering the manure within the time constraints mandated by the receiving farmer.

Table 6-5 provides the current spreadable acres and the number of additional acres that would be needed for each of the modeled farms under both a nitrogen application limit and a rotational phosphorus application limit. The number of acres needed for land application increases due to the high nutrient concentrations in the covered lagoons Two farms have adequate acreage to land apply covered lagoon effluent according to a plant available nitrogen limit (MO-4 and OK-1). The other farms would need increased land area for manure application varying from 47% to 836% of the present land area used for manure application.

When covered lagoon effluent is applied according to a rotational phosphorus limit, none of the farms currently have enough controlled acres. They would need access to an average of ten times more land for manure application. The additional land needed had a range of 407% to 2910%.

Table 6-5. Controlled land vs. needed land for land application of covered lagoon effluent applied according to a rotational phosphorus limit.

Presentation Code	Spreadable Acres on Farm	N limit acres needed	Percentage increase	P limit acres needed	Percentage increase
MO-4	252	267	6%	1308	419%
MO-6	437	1,323	203%	3907	794%
NC-1	13	122	836%	391	2910%
NC-4	87	161	85%	805	825%
OK-1	121	62	0%	614	407%
OK-8	368	540	47%	3947	973%

6.6 MANAGERIAL AND ECONOMIC CONSIDERATIONS

Covering a lagoon affects the entire manure management system. In addition to land access, the producer must determine appropriate land application technology. Of the farms used in the zero discharge portion of this study, only MO-6 currently uses dragline technology. The other five farms currently use irrigation systems to land apply effluent.

MO-6 could continue to use dragline technology to land apply manure assuming that the necessary acres could be accessed by pipes and hoses. Applying effluent according to a rotational phosphorus rule, this operation would require eight times more land than is currently receiving lagoon effluent. All of the additional acres probably cannot be accessed with above ground pipe/hoses. Burying sufficient pipe would probably be cost prohibitive. If the additional land could not be accessed using pipes, a tanker transport system would need to be adapted to land apply the manure.

The concentration of N and P in the effluent requires application rates below what can practically be achieved using a typical effluent irrigation system. While irrigation equipment is sold that can pump at very low rates, the low pumping rate systems have a small swath width and would require more hours for setup and actual land application. The number of dedicated labor hours required for irrigation application of effluent with elevated nutrient concentrations is usually not practical. Farms using covered lagoons would probably convert to tanker technology in order to be able to apply at an appropriate rate and to access the additional acres needed to apply the effluent. The average custom application cost per gallon for operating a tanker according to the analysis in Chapter 4 was used to estimate the cost of effluent application from covered lagoons. The average custom application cost was $.011/gallon applied.

The cost of covering a lagoon considers the cost of buying the cover and the cost of land applying the manure. This will give an estimate of the incremental annual cost associated with the management practice. The cash flow implications of the initial investments for a lagoon cover and necessary additional equipment are discussed. The annualized cost of owning and operating the equipment overlooks the first year cash outlay that must be made in the form of a down payment and the subsequent years' payments being more accelerated than that shown in a 10-year annualized cost.

6.6.1 Initial Investment

The square foot of material needed to cover a lagoon was estimated as the area from berm midline to berm midline. The berm midline to berm midline area was used to provide an estimate of the largest potential cover size. If final economic analysis shows the largest potential cover size to be feasible, then a slightly smaller cover, depending upon installation, would be feasible. The EPA estimate of $4/square foot for impermeable covers (Cost Methodology Report for Swine and Poultry Sectors, p 61) was used to calculate the cover cost. Table 6-6 presents the initial cost and the annualized costs of impermeable lagoon covers for the six farms modeled. The annualized cost assumes a 10-year loan at 10% interest with a zero down payment and zero salvage value. It also includes 2% for taxes and insurance. No estimate of repair costs has been developed because of the geographic and structural variables affecting the technical feasibility of covers (Chapter 5).

Table 6-6. Cost for impermeable lagoon covers

Presentation Code	Cover Size (ft^2)	Initial Cost for Cover	Annualized Cost
MO-4	86,933	$347,732	$60,069
MO-6	319,790	$1,279,160	$220,969
NC-1	39,933	$159,732	$27,593
NC-4	186,624	$746,496	$128,954
OK-1	45,579	$182,316	$31,494
OK-8	76,388	$305,552	$52,783

Note: Cover size was assumed to be the area from berm centerline to berm centerline as given in Table 5-2.

Most farms using covered lagoons would need to purchase new application equipment because the application rate is lower than can reasonably be attained using present irrigation system technology and access to more acres is required for nutrient distribution. Table 6-7 indicates the initial investment necessary for purchasing a tanker system or a dragline system.

Table 6-7. Costs for application equipment components.

Equipment	Description (Size)	Dollar investment	Annual Ownership Cost
Tanker Technology			
Tractor	160 horsepower	$60,000	$10,365
Tanker	4250 gallon	$29,000	$5,010
Total		**$89,000**	**$15,374**
Dragline Technology			
Tractor	225 horsepower	$92,000	$15,893
Toolbar	15 foot	$11,000	$1,900
Drag hose	660 feet	$4,000	$691
Delivery Hose	660 feet	$2,200	$380
Total		**$109,200**	**$18,864**

Note: At least 2 draghoses will need to be purchased. The number of delivery hoses purchased will depend on the distance to the fields from the manure source.

Some CAFO operators may own tractors large enough to pull a tanker; while others will need to purchase a larger tractor. All operations will need to purchase either the tank or the dragline system components. Table 6-7 covers the cost of purchasing one tank or individual components of a dragline system. Most dragline systems require at least two drag hoses and two delivery hoses. The number of delivery hoses depends on the distance from manure storage to the application fields. The operations modeled needed from 391 to 3,947 acres (see Table 6-5) to apply effluent. The operations will probably require two to ten hoses for access to sufficient acres for spreading effluent. A booster pump is usually required for each mile increment greater than one mile when pumping effluent to draghose application systems. Booster pump investments and their associated operation costs are not included in this analysis. A second smaller tractor is often used to help manage the movement of hoses and this additional investment was not included in the analysis.

It is uncertain how farmers would finance these initial investments. Most equipment loans require a down payment and have a repayment schedule of three to seven years.

The lagoon systems used in this study show that farm NC-1 would have the smallest investment of $248,732 for an impermeable cover and tractor-pulled tanker. Farm MO-6 would have the largest investment of $1,368,160 for a cover and tractor pulled tanker.

A down payment of 30% would require farm NC-1 to have liquid cash assets of $104,620 in the year the change was implemented. This required liquid cash asset exceeds the $67,075 annual revenue from livestock production. This operation probably cannot finance the needed changes.

In the section estimating the annual cost of managing a covered lagoon, estimates did *not* include a down payment requirement or a loan repayment period of less than ten years. The USEPA Economic Analysis methodology of estimating annual ownership costs as the principle (or depreciation) and interest payments over a 10-year period at a 10% interest rate was used in the analysis.

The difference between evaluating true cash needs due to a down payment and an accelerated payment schedule as opposed to an annualized expense is that the annualized expense estimates profitability but not cash flow feasibility. An investment that is feasible from an annualized cost perspective may not be feasible from a cash flow perspective.

6.6.2 Nutrient Value

Table 6-8 presents the fertilizer value of the nitrogen and phosphorus contained in the lagoon effluents of both the existing open lagoon and the proposed covered lagoon. Potential nutrient values increased an average of 45 times by covering and agitating lagoons. The increased potential nutrient value comes from increased nitrogen quantity and part from recovering phosphorus from the sludge. The phosphorus value in the existing open lagoon has the same potential value as the phosphorous in the covered lagoon; however, the current management practice on the farms is to not agitate to recover the phosphorus in the sludge.

The realized value of the additional nutrients would benefit the producer if application is on land he owns or rents. Covering and agitating a lagoon increases the value of effluent on controlled acres by an average of 4.6 times. The value on controlled acres equaled the potential value for the existing lagoons because all manure was applied to controlled acres. Covering the lagoon forced most producers to apply most of the manure nutrients on non-controlled land and the increased value of the manure is not economically recovered.

Table 6-8. Nutrient value of open lagoons and covered lagoons for 6 US farms.

	Existing Anaerobic Lagoon		Covered Lagoon	
Presentation Code	Controlled Acres only	Potential value	Controlled Acres only	Potential Value
MO-4	$3,131	$3,131	$8,820	$45,795
MO-6	$8,723	$8,723	$15,295	$136,757
NC-1	$324	$324	$841	$25,324
NC-4	$1,204	$1,204	$5,631	$52,068
OK-1	$529	$529	$4,216	$21,392
OK-8	$1,600	$1,600	$12,821	$137,512

6.6.3 Annual Cost of Covered Lagoons

Table 6-9 presents the application and PNP costs of the current open lagoons for the farms detailed in Chapter 4. Chapter 4 used a comprehensive simulation model to estimate manure application and regulatory compliance costs.

The application costs for effluent from the covered lagoons is estimated using a custom rate of $.011/gallon of effluent pumped (see Table 6-3 for effluent volumes). This is the average tractor pulled tanker rate estimated in Chapter 4. The annual PNP costs are estimated based on the number of acres needed to apply the effluent. For the covered lagoon, the annualized cost of the lagoon cover is added to the application and PNP costs to arrive at the Total Annual Cost. The annual incremental cost is the difference between the current lagoon total annual cost and the covered lagoon estimated total annual cost.

Table 6-10 presents the estimated gross livestock revenue, total cost of manure management and the cost:sales ratio for the six modeled farms. The gross revenue was estimated by taking into account the number and type of animals raised and whether the producer was an independent producer or contract producer. Independent producers sold their animals at a 10-year market price. Contract producers received a premium for each animal raised based on contract specifications.

The average cost:sales ratio for the existing, open lagoon is 2%. The average cost:sales ratio increases to 32% for the same farms using a covered, agitated lagoon.

The EPA uses the incremental cost:sales as a criterion for determining the financial feasibility of the proposed regulations. The incremental cost:sales ratio averages 30% with a range of 7% to 78%. All but two of the farms used in this study would be in the EPA category of Financial Stress 3 by having a cost:sales ratio greater than 10%.

While an exact cash flow estimate was not made for each farm, the section above dealing with cash outlay in the initial year of compliance makes it clear that all farms would have difficulty with cash flow. The two Missouri farms not in the Financial Stress 3 category would probably be in Financial Stress 1 category.

This analysis shows that covering a lagoon presents a financial hardship to all operations currently using open lagoons. Most operations using lagoons would exit production because of an inability to comply with a “zero discharge” rule.

A “zero discharge” rule is also likely to have regional implications. Lagoons are more common in the southern US productions regions. Requiring lagoon covers will affect producers in these states more than producers in northern states.

A “zero discharge” rule will probably affect contract producers more than independent producers. Contract producers have smaller annual gross revenue because they are being paid for services and facility rent. Contract producers do not get paid the market value of the livestock they raise.

Table 6-9. Annual costs of application, permit nutrient plans and covering lagoons for 6 US swine farms.

	Existing Anaerobic Lagoon			Covered Lagoon				
Presentation Code	Application costs ($/year)	Annual PNP costs ($/year)	Total Annual Cost	Annualized Cover Cost ($/year)	Application Cost ($/yr)	Annual PNP Costs ($/year)	Total Annual Cost	Annual Incremental Cost ($/year)
MO-4	$10,123	$477	$10,600	$60,069	$16,924	$11,891	$88,884	$78,284
MO-6	$12,774	$525	$13,299	$220,969	$30,692	$35,162	$286,823	$273,524
NC-1	$2,439	$414	$2,853	$27,593	$6,024	$4,117	$37,734	$34,881
NC-4	$7,355	$434	$7,789	$128,954	$12,753	$8,237	$149,944	$142,155
OK-1	$5,426	$432	$5,858	$31,494	$30,845	$5,836	$68,175	$62,317
OK-8	$3,624	$417	$4,041	$52,783	$17,990	$36,540	$107,312	$103,271

PNP = permit nutrient plan and includes the cost of plan writing, soil sampling and record-keeping.

Table 6-10. Financial analysis of covering lagoons for 6 US swine farms.

		Existing Anaerobic Lagoon		Covered Lagoon		
Presentation Code	Gross Sales	Total Cost	Cost:Sales	Total Cost	Cost:Sales	Incremental Cost:Sales
MO-4	$1,110,689	$10,600	1.0%	$88,884	8.0%	7.1%
MO-6	$2,786,611	$13,299	0.5%	$286,823	10.3%	9.8%
NC-1	$67,075	$2,853	4.3%	$37,734	56.3%	52.0%
NC-4	$1,019,564	$7,789	0.8%	$149,944	14.7%	13.9%
OK-1	$337,201	$5,858	1.7%	$68,175	20.2%	18.5%
OK-8	$131,745	$4,041	3.1%	$107,312	81.5%	78.4%

6.7 ALTERNATIVE METHODS OF COMPLYING WITH THE ZERO DISCHARGE RULE

Lagoon covers were deemed to be the most economically feasible method by the EPA (Federal Register, p. 3060). Other ways of complying with the "zero discharge" rule include building second storage cells, building emergency storage cells or closing lagoons and building covered slurry storages. Each of these alternatives has an initial investment cost of constructing the modification and then distributing an increased volume or a more concentrated manure effluent. The construction costs, land application and PNP costs were estimated for the six operations used in the cover analysis. The financial cost:sales ratio analysis done for the cover analysis was completed for the three alternative options listed above.

6.7.1 Second Storage Cells

The technical information about second storage cells was presented in Section 5.4.3.1. The size of potential second storage cells necessary to expand storage capability to either 12 or 18 months is presented in Table 5-7. Since the EPA desires lagoons to overflow less often, the 18-month option presented in Section 5.4.3.1 was selected for the economic analysis presented below.

Table 6-11 gives the various costs for both the existing anaerobic lagoon system and the additional second storage cell. The annualized storage cost is estimated as the principle (or depreciation) and interest payments over a 10-year period at a 10% interest rate for the second storage cell construction costs given in Table 5-8. The annual application cost for the second storage cell was estimated as the existing application cost plus cost of pumping and irrigating the additional pumpdown volume presented in Table 5-8. The irrigation cost was estimated at $0.006 per gallon based on the average irrigation spreading cost from Chapter 4. The annual PNP costs were kept constant between the two scenarios because the total available manure nutrients were assumed to be constant. The cost of the effluent volume pumped was changed between the two scenarios.

The financial analysis of 18-month second storage cells is presented in Table 6-12. The EPA uses the incremental cost:sales ratio as a criterion for determining the financial feasibility of an option. The incremental cost:sales ratio averages 7% with a range of 1% to 27%. Results of the six operations studied are that three operations would be in the Affordable 1 category. One operation would be in the Moderate category and one in the Affordable 2 to Moderate category (depending on cash flow and debt to asset ratio). One operation would be in the Financial Stress 3 category.

Table 6-11. Annual costs of application, permit nutrient plans and building second storage cells for 6 US swine farms.

Presentation Code	Existing Anaerobic Lagoon			Second Storage Cell				
	Application costs ($/year)	Annual PNP costs ($/year)	Total Annual Cost	Annualized Cell Cost ($/year)	Application Cost ($/yr)	Annual PNP Costs ($/year)	Total Annual Cost	Annual Incremental Cost ($/year)
MO-4	$10,123	$477	$10,600	$6,319	$11,581	$477	$18,377	$7,777
MO-6	$12,774	$525	$13,299	$14,155	$15,611	$525	$30,291	$16,992
NC-1	$2,439	$414	$2,853	$8,975	$6,796	$414	$16,185	$13,332
NC-4	$7,355	$434	$7,789	$34,716	$25,796	$434	$60,946	$53,157
OK-1	$5,426	$432	$5,858	$14,591	$6,003	$432	$21,026	$15,168
OK-8	$3,624	$417	$4,041	$2,368	$3,624	$417	$6,409	$2,368

PNP = permit nutrient plan and includes the cost of plan writing, soil sampling and record-keeping.

Table 6-12. Financial analysis of constructing second storage cells for 6 US swine farms.

Presentation Code	Gross Sales	Existing Anaerobic Lagoon		Second Storage Cell		Incremental Cost:Sales
		Total Cost	Cost:Sales	Total Cost	Cost:Sales	
MO-4	$1,110,689	$10,600	1.0%	$18,377	1.7%	0.8%
MO-6	$2,786,611	$13,299	0.5%	$30,291	1.1%	0.6%
NC-1	$67,075	$2,853	4.3%	$16,185	30.8%	26.5%
NC-4	$1,019,564	$7,789	0.8%	$60,946	3.3%	2.5%
OK-1	$337,201	$5,858	1.7%	$21,026	7.9%	6.2%
OK-8	$131,745	$4,041	3.1%	$6,409	7.0%	3.9%

6.7.2 Emergency Storage Cells

The technical information about emergency storage cells was presented in Section 5.4.3.2. The size of the potential emergency storage cells for the six operations used in this portion of this study is presented in Table 5-9. Since the EPA desires lagoons to overflow less often, the emergency storage cell option presented in Section 5.4.3.2 can reduce the frequency of lagoon storage overflow. The economic analyses for emergency storage cells are presented below.

Table 6-13 gives the various costs for both the existing anaerobic lagoon system and the emergency storage cell. The annualized emergency storage cell cost is estimated as the principle (or depreciation) and interest payments over a 10-year period at a 10% interest rate for the emergency storage cell construction costs given in Table 5-9. The annual effluent application cost for the emergency storage cell was estimated as the existing application cost plus the cost of pumping and irrigating one tenth (10%) of the total liquid volume presented in Table 5-9. Ten percent of the volume was used to calculate the added annual effluent volume because the 10-year design frequency predicts that the emergency cell will fill one year of every ten years. Irrigation cost was estimated at $0.006 per gallon based on the average irrigation spreading cost from Chapter 4. The annual PNP costs were kept constant between the two scenarios because the total available manure nutrients were assumed to be constant. The effluent volume pumped was changed between the two scenarios.

The financial analysis of emergency storage cells is presented in Table 6-14. The EPA uses the incremental cost:sales ratio as a criterion for determining the financial feasibility of an option. The incremental cost:sales ratio averages 1% with a range of 1% to 2%. All lagoon operations in this portion of the study would be in the Affordable 1 category. Emergency storage cells, if approved as a method to improve environmental protection, should be financially feasible for most swine operations currently using anaerobic lagoons.

Table 6-13. Annual costs of application, permit nutrient plans and building emergency storage cells for 6 US swine farms.

	Existing Anaerobic Lagoon			Emergency Storage Cell				
Presentation Code	Application costs ($/year)	Annual PNP costs ($/year)	Total Annual Cost	Annualized Cell Cost ($/year)	Application Cost ($/yr)	Annual PNP Costs ($/year)	Total Annual Cost	Annual Incremental Cost ($/year)
MO-4	$10,123	$477	$10,600	$1,969	$10,918	$477	$13,365	$2,765
MO-6	$12,774	$525	$13,299	$5,800	$15,169	$525	$21,494	$8,195
NC-1	$2,439	$414	$2,853	$1,067	$2,861	$414	$4,342	$1,489
NC-4	$7,355	$434	$7,789	$4,062	$9,023	$434	$13,519	$5,730
OK-1	$5,426	$432	$5,858	$1,567	$6,055	$432	$8,054	$2,196
OK-8	$3,624	$417	$4,041	$1,642	$4,392	$417	$6,451	$2,410

PNP = permit nutrient plan and includes the cost of plan writing, soil sampling and record-keeping.

Table 6-14. Financial analysis of constructing emergency storage cells for 6 US swine farms.

		Existing Anaerobic Lagoon		Emergency Storage Cell		
Presentation Code	Gross Sales	Total Cost	Cost:Sales	Total Cost	Cost:Sales	Incremental Cost:Sales
MO-4	$1,110,689	$10,600	1.0%	$13,365	1.2%	0.2%
MO-6	$2,786,611	$13,299	0.5%	$21,494	0.7%	0.3%
NC-1	$67,075	$2,853	4.3%	$4,342	6.2%	2.0%
NC-4	$1,019,564	$7,789	0.8%	$13,519	1.3%	0.5%
OK-1	$337,201	$5,858	1.7%	$8,054	2.3%	0.6%
OK-8	$131,745	$4,041	3.1%	$6,451	4.9%	1.8%

6.7.3 Converting to Slurry Storage Tanks

The last option evaluated to comply with the proposed "zero discharge" rule was to convert the operation to a slurry manure system from the current anaerobic lagoon system. The size and estimated costs of a covered, circular slurry manure storage tank for the operations used in this analysis are presented in Table 6-15. The tanks were assumed to provide 12 months of storage capacity. The annualized cost is estimated as the principle (or depreciation) and interest payments over a 10-year period at a 10% interest rate for the initial costs of implementing the slurry tank system.

Table 6-15. Cost for covered circular slurry storage tanks.

Presentation Code	Storage Diameter (ft^2)	Initial Cost for Storage	Annualized Cost
MO-4	120	$214,433	$37,042
MO-6	160	$381,213	$65,853
NC-1	108	$173,690	$30,004
NC-4	72	$77,196	$13,335
OK-1	164	$400,512	$69,187
OK-8	128	$243,977	$42,146

Notes: Storages were assumed to be 20' deep and provided 12 months of storage for operation. Total initial cost of storages included actual total storage and cover costs. Storage cost was estimated as $0.10 per gallon of storage, and cover cost was estimated as $4.00 per ft^2 of tank surface.

Table 6-16 gives various costs for both the existing anaerobic lagoon system and the covered slurry storage tank. The annual application cost for the covered slurry storage system was estimated using the volumes presented in Table 6-3 and an average of $0.011 per gallon to apply manure slurry (Chapter 4). The PNP costs for the covered slurry storage were estimated based on the land area required for phosphorus removal of manure applied as slurry (Table 6-4). The required acres, as shown in Table 6-4, are based on a composite crop rotation use on the farms modeled in Chapter 4. The composite crop rotation concept is further discussed in Chapter 3.

The financial analysis of converting to a slurry manure system using a covered slurry storage tank is presented in Table 6-17. The EPA uses the incremental cost:sales ratio as a criterion for determining the financial feasibility of an option. The incremental cost:sales ratio averages 30% with a range of 3% to 70%. Based on the costs included in Table 6-17, one operation would be in the Affordable 1 category; two operations would be in the Affordable 2 to Financial Stress 2 category (depending on their cash flow and debt to asset ratios); and three operations would be in the Financial Stress 3 category. There are however, other costs and issues that will affect the feasibility of converting to a slurry manure system.

All costs to convert the operations to a slurry based manure system are not included in the analyses presented in Table 6-16 and Table 6-17. Other costs, not currently considered, include swine production facility conversion costs, manure transfer costs, and current lagoon closure costs. Swine production facility conversion costs would include costs to convert the current manure collection and handling system to slurry based system. Depending upon the current manure collection and handling system in the production buildings, converting to a slurry system could range from $0 to $10,000 per building. Each operation studied has multiple buildings; so building conversion costs could be a minimum of $40,000 per operation.

Added manure transfer costs include any costs for pumping manure into the slurry storage tank. If the site topography does not allow manure to gravity flow from the buildings into the top of the 20-foot tall tank, a pumping system will be required to transfer the manure from the buildings into the storage tank. Manure pumping systems can range from $25,000 to $35,000 per installation.

Lagoon closure costs must also be added to the analysis. Lagoon closure costs data is very limited. The EPA reported a cost of $42,000 lagoon closure cost based on very limited data (Federal Register, p. 3014). If the sludge removed from a lagoon must be land applied on an annual crop removal basis, the phosphorus concentration will require a large land area for spreading. Lagoon closure costs could become very expensive. Chapter 3 provides more information about the difficulties of applying large amounts of phosphorus at low application rates. Adding the costs not included in the current economic analysis might add $100,000 to the cost of converting from the current anaerobic lagoon system to a slurry storage system. This additional cost would probably relegate those swine manure lagoon system operations not already in the Financial Stress 3 category to the Financial Stress 3 category.

Another issue related to converting the current manure system to a slurry-based system includes land available for spreading manure nutrients. The increase in required acres from the current lagoon system to a slurry system can be seen in Table 6-4. The conversion will require a substantial increase in the number of required acres. The increased acres needed to apply slurry may not be readily available to a particular operation. If the land is not available, the operation is placed in a situation of not being able to comply with the proposed regulation change. Chapter 4 presents additional information about access to additional land areas for manure application.

Table 6-16. Annual costs of application, permit nutrient plans and converting to slurry storage tanks for 6 US swine farms.

	Existing Anaerobic Lagoon			Covered Slurry Storage Tank				
Presentation Code	Application costs ($/year)	Annual PNP costs ($/year)	Total Annual Cost	Annualized Tank Cost ($/year)	Application Cost ($/yr)	Annual PNP Costs ($/year)	Total Annual Cost	Annual Incremental Cost ($/year)
MO-4	$10,123	$477	$10,600	$37,042	$16,924	$11,891	$65,857	$55,257
MO-6	$12,774	$525	$13,299	$65,853	$30,692	$35,162	$131,707	$118,408
NC-1	$2,439	$414	$2,853	$30,004	$6,024	$4,117	$40,145	$37,292
NC-4	$7,355	$434	$7,789	$13,335	$12,753	$8,237	$34,325	$26,536
OK-1	$5,426	$432	$5,858	$69,187	$30,845	$5,836	$105,868	$100,010
OK-8	$3,624	$417	$4,041	$42,146	$17,990	$36,540	$96,676	$92,634

PNP = permit nutrient plan and includes the cost of plan writing, soil sampling and record-keeping.

Table 6-17. Financial analysis of converting to slurry storages for 6 US swine farms.

		Existing Anaerobic Lagoon		Covered Slurry Storage		
Presentation Code	Gross Sales	Total Cost	Cost:Sales	Total Cost	Cost:Sales	Incremental Cost:Sales
MO-4	$1,110,689	$10,600	1.0%	$65,857	5.9%	5.0%
MO-6	$2,786,611	$13,299	0.5%	$131,707	4.7%	4.2%
NC-1	$67,075	$2,853	4.3%	$40,145	59.9%	55.6%
NC-4	$1,019,564	$7,789	0.8%	$34,325	3.4%	2.6%
OK-1	$337,201	$5,858	1.7%	$105,868	31.4%	29.7%
OK-8	$131,745	$4,041	3.1%	$96,676	73.4%	70.3%

Chapter 7
CO-PERMITTING PROVISIONS IN THE PROPOSED REVISIONS TO THE NPDES PERMIT REGULATION AND EFFLUENT GUIDELINES AND STANDARDS FOR CAFOS

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7.1 INDEX

7.2 EXECUTIVE SUMMARY

Co-permitting is a regulatory tool currently applied to discharging facilities under the Clean Water Act. With co-permitting, the EPA and associated permitting authorities would require both owners and operators of concentrated animal feeding operations (CAFOs) to hold NPDES permits.

Three environmental objectives of co-permitting are:
- to improve manure management by contractors/growers via regulatory pressure on the integrators;
- to create a nutrient management system for manure that cannot be utilized on site by the CAFO owners; and
- to create an incentive for the integrator to minimize source loading of nutrients and compounds (e.g. in feed) that directly or indirectly impact the composition of the manure residual.

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The apparent environmental policy objective of co-permitting and the EPA proposed alternatives is to increase environmental oversight of excess manure transferred offsite from CAFOs and applied to land not covered by a CAFO's Permit Nutrient Plan.

Co-permitting would impact several business organizations operating in Missouri. Entities that own animals housed in a CAFO or have significant control over how the animals are raised may be required to have a NPDES permit (and associated environmental liability) along with the owner of the CAFO. Co-permitting would definitely affect integrated poultry production and large-scale integrated hog production. It would likely affect cattle feeding, locally owned sow coops and heifer replacement arrangements in dairy production where these enterprises fall under the definition of a CAFO.

Potential positive aspects of co-permitting include:

- better feed management to reduce excreted nutrients;
- integrator fostering better environmental compliance of growers; and
- additional compliance resources from corporate entities.

Potential negative aspects of co-permitting include:

- decrease the operator's leverage in contract negotiations with the corporate entity;
- increase corporate pressure on operators to indemnify corporate entities against potential liability for non-compliance on the part of the operator;
- encourage corporate entities to interfere in the management of the CAFO;
- provide pretext for corporate entities to terminate contracts;
- restrict the freedom of operators to change integrators; and
- add costs that would be passed from corporate entities to small operators.

Co-permitting will result in an increase in administrative and manure management costs as well as regulatory monitoring and enforcement costs related to excess manure that had previously been transferred from CAFOs. Co-permitting will likely have a negative impact on market transactions for excess manure. The environmental objectives of co-permitting may be obtained with market mechanisms or other regulatory rules.
The EPA is soliciting comments on who should be covered by the proposed co-permitting regulations and how the rules should be implemented, but the EPA is not soliciting comment as to the authority of the agency to require co-permitting. The EPA is also considering alternatives to the co-permitting requirement.

7.3 INTRODUCTION

The objective of this paper is to provide background information on an environmental policy mechanism typically referred to as co-permitting. While not a new regulatory concept, co-permitting in relation to concentrated animal feeding operations is a recent development. The primary focus is to state the objectives of entities proposing co-permitting, consider who would be affected in Missouri by a co-permitting rule, present the questions, issues and concerns surrounding the implementation of co-permitting regulations and offer alternatives to co-permitting.

7.4 BACKGROUND

Under the Clean Water Act (CWA), the Environmental Protection Agency (EPA) or a National Pollution Discharge Elimination System (NPDES) permitting authority can require either the owner or operator, or both the owner and operator, of a discharging facility to hold an NPDES permit.

To understand co-permitting, consider the situation where a municipality owns a wastewater treatment facility but contracts with an independent firm to operate the facility. Co-permitting would require that both the owner (municipality) and operator (private firm) of the wastewater treatment facility have NPDES permits. The operator is required to have a permit because it controls what happens at the "end of the pipe" with treatment practices and technology. The municipality is required to have a permit because it can influence what goes into the "beginning of the pipe" with zoning and discharge ordinances. The EPA points out that in certain cases under the CWA, it is appropriate for only the operator of a facility to be permitted and likens the CAFO owner to an investor that builds a factory and leases it to a manufacturing entity. The owner of the factory may not need a NPDES permit to discharge, as the investor does not control the industrial process.

The apparent rationale for permitting both the owner and the operator is at least threefold: 1) requiring the operator to have a permit and associated liability should ensure proper operation of the plant; 2) requiring the municipality to be permitted and liable for the performance of the facility provides additional environmental oversight and; 3) liability faced by both entities theoretically provides an incentive for the municipality to work with the operating contractor to minimize the chance of noncompliance.

Significant environmental regulation of livestock has been proposed and enacted at almost every level of government, from local to federal levels. The impetus to this regulatory activity is related to the increase in the density of livestock production in many areas.

Changes in the structure of ownership of livestock feeding operations have also caused some to call for increased regulations. Poultry production has been a contract production industry for many years. There has recently been a substantial increase in contract hog production as well. Increased contract production has resulted in: 1) partitioning of decision making (e.g. the grower feeds the animals but does not decide what feed ingredients are used) and control rights (e.g. the integrator decides how the birds are to be raised while the grower decides how the manure from the birds is to be land applied), and 2) divergence in the ownership of livestock and ownership of the facilities in which they are raised. These differences in ownership and control with respect to permitted facilities gives the impression that co-permitting of CAFOs may be similar to other historically regulated entities under the Clean Water Act.

Recently the state of Kentucky proposed the co-permitting of owners and operators of CAFOs using language similar to that proposed by the EPA regulation (Federal Register-1/12/01, vol. 66, no.9). This co-permitting regulation was vacated (set aside) in late May 2001 by a Franklin County, KY circuit court, primarily due to questions regarding the method utilized by the governor to establish the regulation, not because of the regulation itself. The recently vacated co-permitting regulation can be found in the Kentucky Statement of Emergency 401 KAR 5:074E, contained in Appendix A.

7.5 ENTITIES SUBJECT TO CO-PERMITTING

Co-permitting for CAFOs is a regulatory mechanism proposed by the EPA that could require both the owner of a CAFO (grower) **and** entities that exercise substantial operational control over the CAFO (integrator) to obtain a permit under National Pollutant Discharge Elimination System (NPDES) permit regulations. From page 3136 of the Federal Register-1/12/01, vol. 66, no.9:

"(3) *Co-permitting.* Any person who is an ''operator'' of a CAFO on the basis that the person exercises substantial operational control of a CAFO (see § 122.23(a)(5)(ii)) must apply for a permit. Such operators may apply for an NPDES permit either alone or together as co-permittees with other owners or operators of the CAFO."

The EPA defines "substantial operational control" on page 3024 of the Federal Register-

:

> "The proposed regulation lists factors relevant to ''substantial operational control,'' which would include (but not be limited to) whether the entity: (1) Directs the activity of persons working at the CAFO either through a contract or direct supervision of, or on-site participation in, activities at the facility; (2) owns the animals; or (3) specifies how the animals are grown, fed, or medicated. EPA is aware that many integrator contracts may not provide for direct integrator responsibility for manure management and disposal. EPA believes, however, that the proposed factors will identify integrators who exercise such pervasive control over a facility that they are, for CWA purposes, co-operators of the CAFO."

Under the proposed regulations, two key factors will trigger co-permitting on a given animal feeding operation: 1) designation as a concentrated animal feeding operation, and 2) existence of multiple "Operators" under the substantial operational control definition above. It is likely the EPA will change the CAFO definition to 500 or perhaps 300 animal units, down from 1000, thus increasing the number of integrated animal feeding operations classified as CAFOs. It would also seem clear that most integrated poultry and integrated pork production in Missouri would meet the definition of "substantial operational control." Consequently, it appears that most of the state's integrated swine and poultry operations would be in a co-permitting situation under the proposed rules. Other production arrangements that may or may not require co-permitting include: 1) cattle feeding, where livestock are owned by one person who has very little other control over the raising of the animals; 2) sow cooperatives where several farmers combine to hire someone to manage sows they own to provide them with weaner or feeder pigs; and 3) dairy herd replacement operations, where a dairy hires another to feed its replacement females.

While most references to co-permitting are made in respect to large integrators, it is not clear whether or not it will have an impact on small scale business organizations.

7.6 THE ENVIRONMENTAL OBJECTIVES OF CO-PERMITTING

There are two explicit objectives of the proposed co-permitting rules. The first objective is to improve manure management by contractors/growers via regulatory pressure on the integrators.

> "Today's proposal would specify that the disposition of excess manure would remain the joint responsibility of all permit holders. See proposed § 122.23(i)(9). Integrators would thereby be encouraged to ensure compliance with NPDES permits in a number of ways, including: (a) establishing a corporate environmental program that ensures that contracts have sound environmental requirements for the CAFOs; (b) ensuring that contractors have the necessary infrastructure in place to properly manage manure; and (c) developing and implementing a program that ensures proper management and/or disposal of excess manure. The proposed requirement will give integrators a strong incentive to ensure that their contract producers comply with permit requirements and subject them to potential liability if they do not. Integrators could also establish facilities to which CAFOs in the area could transfer their excess manure (Federal Register-1/12/01, vol. 66, no.9, page 3025)."

The second stated objective is to create a nutrient management system for manure that cannot be utilized on site by the CAFO owners:

> "All permittees would be held jointly responsible for ensuring that manure production in excess of what can be properly managed on-site is handled in an environmentally appropriate manner (Federal Register-1/12/01, vol. 66, no.9, page 3025)."

There may be an implicit goal of creating an incentive for the integrator to minimize source loading of nutrients and compounds that directly or indirectly impact the composition of the manure residual. The typical structure of production contracts is that feed and live animals are the property of the integrator while manure and dead animals are the property and responsibility of the contractor/grower. Thus, economic considerations on the part of the integrator in feed formulation or input compound choices are likely to be solely based on the economic value or return per hog/bird. For example, the integrator chooses the level of supplemental phosphorus added to the feed, which in turn affects the phosphorus level in manure. Under the proposed rules, increased levels of phosphorus in the manure will likely result in increased manure management costs. With co-permitting, the integrator may also incur new and/or increased manure management costs. Without co-permitting, the integrator would not experience the increased manure management costs associated with excess phosphorus in the manure and would likely choose a supplemental phosphorus level greater than would be the case if co-permitted.

7.7 APPARENT POLICY OBJECTIVES OF CO-PERMITTING

While not explicitly stated by the EPA, the apparent policy objective of co-permitting as well as the co-permitting alternatives presented in the Federal Register (and below) is to increase the level of environmental regulation of manure that is applied outside of Permit Nutrient Plans (PNP) on land not owned or controlled by CAFO owner/operators (See Appendix B for a brief explanation of the PNP). Currently, CAFO owners must follow a PNP for all manure that is applied to land owned or controlled by the CAFO. However, the CAFO owner may transfer (sell or give away) manure in excess of what can be applied on-site. Currently, the CAFO owner is not responsible or liable for the excess manure transferred to a third party. The third party recipient of the manure does not have to apply the manure under a PNP. As detailed in the above Federal Register excerpt, the EPA clearly intends that “the disposition of excess manure would remain the joint responsibility of all permit holders” and would create new liability and expense for integrators and growers/contractors who were previously transferring excess manure.

Co-permitting appears to be a means of creating a consistent level of environmental oversight on all land applied manure, i.e. all land receiving manure would be subject to a PNP. The liability created by the co-permit is apparently intended to provide the incentive to integrators to enforce NPDES requirements, but also assure that all manure generated on the CAFO is applied under the same standard as manure applied by the CAFO owner. The increased scrutiny of manure exported from CAFOs has the benefit of insuring better environmental oversight then under current rules. However, a policy objective that has the unintended consequence of making manure a very undesirable substitute for unregulated commercial mineral fertilizer will only increase the degree of infrastructure and institutional development requirements needed to achieve the policy objective. Specific issues related to this last point are contained in the last section of the paper.

7.8 COMMENTS RECEIVED BY THE EPA

In the normal regulatory process, the EPA seeks comments from interested parties and is required to solicit input from entities affected by proposed regulation. A portion of the input that the EPA has already received is presented here. In the following section, issues and concerns beyond these EPA comments are presented.

(For the readers of this paper who may go to the Federal Register in follow-up, it useful to understand that the following comments were made to/obtained by the EPA upon announcement of the new CAFO regulations as required by the Regulatory Flexibility

Act (RFA) and the Small Business Regulatory Enforcement Fairness Act (SBREFA). The RFA and SBREFA require the EPA to carefully consider the economic impacts rules will have on small entities. The SBREFA amended the RFA to require the EPA to convene a small business advocacy review panel prior to proposing any rule that will have a significant economic impact on a substantial number of small entities. Thus, the following comments were solicited upon announcement (prior to the current proposal) of the CAFO regulations per RFA/SBREFA.)

Some of these comments and concerns have been reported on pages 3025 and 3026 of the Federal Register-1/12/01, vol. 66, no.9 and the following are paraphrased or verbatim highlights from those pages:

- A majority of the SERs (Small Entity Representatives) were opposed to co-permitting, expressing concern that co-permitting could:
    - decrease the operator's leverage in contract negotiations with the corporate entity,
    - increase corporate pressure on operators to indemnify corporate entities against potential liability for non-compliance on the part of the operator,
    - encourage corporate entities to interfere in the operation management,
    - provide pretext for corporate entities to terminate contracts,
    - restrict the freedom of operators to change integrators

- A few SERs, who were not themselves involved in a contractual relationship with a larger corporate entity, favored co-permitting as a way of either leveling the playing field between contract and independent operators, or extracting additional compliance resources from corporate entities.

- SERs were not convinced that co-permitting would result in additional corporate resources being directed toward environmental compliance.

- SERs were not convinced that co-permitting would result in any benefit to the environment, given that the operator generally controls those aspects of a feedlot's operations related to discharge.

- Despite general concern over co-permitting due to the economic implications for the contractor, several SERs voiced their support for placing shared responsibility for the manure on the integrators, especially in the swine sector.

- The SBAR (Small Business Advocacy Review) Panel also expressed concern that any co-permitting requirements may entail additional costs, and that co-permitting cannot prevent these costs from being passed on to small operators, to the extent that corporate entities enjoy a bargaining advantage during contract negotiations. The Panel thus recommended that the EPA carefully consider whether the potential benefits from co-permitting warrant the costs, particularly in light of the potential shifting of these costs from corporate entities to contract growers.

- Commenters have noted that integrators have a bargaining advantage in negotiating contracts, which may ultimately allow them to force producers to incur all compliance costs as well as allow them to pass any additional costs down to growers that may be incurred by the processing firm.

The EPA also entered the following in the Federal Register on page 3026:

> "The Panel did not reach consensus on the issue of co-permitting. On the one hand, the Panel shared the SER's concern that co-permitting not serve as a vehicle through which the bargaining power and profits of small contract growers are further constrained with little environmental benefit. On the other, the Panel believed that there is a potential for environmental benefits from co-permitting. For example, the Panel noted (as discussed above), that co-permitted integrators may be able to coordinate manure management for growers in a given geographic area by providing centralized treatment, storage, and distribution facilities, though the Panel also pointed out that this could happen anyway through market mechanisms without co-permitting if it resulted in overall cost savings. In fact, the Agency is aware of situations where integrators do currently provide such services through their production contracts. The Panel also noted that co-permitting could motivate corporate entities to oversee environmental compliance of their contract growers, in order to protect themselves from potential liability, thus providing an additional layer of environmental oversight."

7.9 ALTERNATIVES TO CO-PERMITTING

The EPA has proposed two alternatives to co-permitting. The following is from the Federal Register-1/12/01, vol. 66, no.9, page 3027:

> "EPA also considered alternative approaches under which EPA would waive the co-permitting requirement for States and processors that implement effective programs for managing excess manure and nutrients. One such approach would require the disposition of manure that is transported off-site to remain the joint responsibility of the processor and other permit holders, unless an enforceable state program controls the off-site land application of manure. For example, if the State program addressed the off-site land application of manure with PNP [Permit Nutrient Plans] development and implementation requirements that are equivalent to the requirements in 40 CFR 412.13(b)(b) and 122.23(j)(2) [i.e. the regulations currently imposed on CAFOs], it would not be necessary to permit the processor in order to ensure the implementation of those requirements. Another approach would be based on whether the processor has developed an approved Environmental Management System (EMS) that is implemented by all of its contract producers and regularly audited by an independent third party. EPA anticipates that the alternative program would be designed to achieve superior environmental and public health outcomes by addressing factors beyond those required in this proposed regulation, such as odor, pests, etc."

There is little discussion in the Register with regard to enforceable state programs addressing the off-site application of excess manure. However, there are a number of issues associated with a Permit Nutrient Plans, (PNP) that are currently required of CAFOs (requirements in 40 CFR 412.13(b)(b) and 122.23(j)(2)), that would increase costs to producers and make third party or off-site applicators reluctant to buy or receive manure. With regard to the second alternative, the EPA only describes some desirable features an EMS should or would contain and not what would constitute an "acceptable" EMS. While there are a number of positive features of the EMS approach, it is not readily apparent from the EMS discussion of pages 3027 and 3028 of the Federal Register-1/12/01, vol. 66, no.9, that the entity avoiding a co-permitting situation via an EMS approach reduces its compliance costs or environmental liability relative to co-permitting. Furthermore the EPA acknowledges that "... an EMS approach could be more difficult to administer and enforce [than co-permitting]."

7.10 OTHER CONCERNS AND ISSUES

The current disparity in environmental oversight between manure applied under the CAFO owner's PNP and excess manure transferred to a third party is a serious environmental issue. It is apparent that both the co-permitting proposal and the EPA proposed alternatives are means to bring a greater proportion of land applied manure under a PNP. The co-permitting and EMS alternative would appear to cover excess manure application in contract CAFO situations. The alternative involving enforceable state programs regulating the application of excess manure based on a PNP would appear to bring excess manure from both contract and independent CAFOs under a PNP.

The overriding issue with regard to excess manure is that under the current regulations, no one bears the direct and significant costs that would be associated with the liability, administration/red tape and manure management, as well as the regulatory burden, if the manure were subject to the NPDES CAFO rules. The proposed regulations would monetize these costs via co-permitting, EMS or PNP-based state regulations. Numerous questions and issues arise as the existence and distribution of these new costs are considered.

Clearly the alternative of an enforceable state PNP-based program places the regulatory monitoring and enforcement costs on the state NPDES permit authorities. Under this scenario, the costs of managing the excess manure under a PNP would fall on the CAFO owner and the third party accepting the manure if it chose to do so. The CAFO owner in this situation would incur increased liability to the extent that application of excess manure would now fall under the CAFO's NPDES permit. The integrator under this arrangement would not be required to contribute any resources to the new compliance burden and would not have any liability for the manure management or composition of the manure.

Under a co-permitting or EMS situation, as mentioned above, the regulatory cost burden would be borne by the integrator. In addition to monitoring and enforcement costs, the integrator would incur: 1) environmental liability and manure management cost of the excess manure and, 2) liability for the manure managed onsite and previously the responsibility of the CAFO owner. The increased costs and risks to the integrator, in reality, are borne by consumers, the growers and investors. The allocation between the three is difficult to estimate. However, the process by which increased costs and risks are allocated or absorbed in the market is not a friendly one, but one where growers and integrators who are least able to comply face failure.

Under either scenario a difficult issue arises as to the third party that had previously bought or accepted the manure (and may well have applied it in a responsible manner). In any of the co-permitting or alternative scenarios it would appear that the regulations create a disincentive to farmers to accept manure from CAFOs. Under current and proposed regulation, a non-CAFO landowner can purchase and apply commercial fertilizer without a PNP. Thus in the marketplace, nutrient variability and application challenges combined with regulation make manure an increasingly undesirable substitute for commercial fertilizer. Under co-permitting there is the potential that farmers receiving manure from a CAFO will need to supply the CAFO or the integrator managing the manure with data needed to complete a PNP. The new data requirements include extensive soil test results, crop yield histories, tillage practices, 5-year crop rotation, and annual yield data at harvest. The farmer receiving the manure also will be unable to apply additional fertilizer on the field in addition to manure unless it is acceptable based on the EPA recommendations.

Once a PNP is introduced into the excess manure transaction, transaction costs increase, the non-CAFO landowner loses flexibility as to fertility management and may be incurring new liability. At best, these issues would increase the cost to the CAFO owner in terms of inducing the manure transfer transaction but may preclude the transaction completely. Environmental degradation from manure is also likely to be associated with the absence of a market for the manure. Were an efficient market to exist for manure nutrients, managers would participate in it to maximize their profit. An alternative to co-permitting (which adds costs without certain gain in environmental quality) would be to foster markets for manure.

Given co-permitting or an EMS arrangement, it would be unreasonable to assume that the status quo would be maintained with respect to manure managed by the CAFO owner. At the very least it would seem likely that the added liability to the integrator would result in increased expense to the CAFO owner in terms of proving compliance to the integrator. Another significant possibility would be that the integrator would assume all responsibilities for manure management. Under this arrangement, grower compensation would almost certainly decline and the grower would lose control of the nutrient resource. Under this arrangement, the neighbor that previously was willing to accept manure would be faced with dealing with a third party that would dictate compliance with a PNP that may be inconsistent with the environmentally responsible agronomic goals of the neighbor. The possibility of the integrator assuming responsibility for manure management may sound equitable or appealing to some stakeholders, but given a reduction in contract returns, the tradeoff could be an economic burden.

The greatest impact of increased regulation of excess manure would fall on those growers with the least land relative to the manure produced in the CAFO. Under current regulations, for example, poultry growers that often own only small acreages have been able to transfer excess manure to third parties, often at positive prices or in exchange for new litter. Under co-permitting or state PNP-based regulation, this economic arrangement changes dramatically. The likely move from a nitrogen to a phosphorus standard for manure application under PNPs will only exacerbate the situation.

How firms that engage in CAFO level contract production would react to these new costs and liabilities is not clear. It is plausible that packers engaged in contract production would seriously consider abandoning the practice in the face of dramatically increased liability. In the swine industry, the majority of hogs are procured under marketing contracts or cash transactions, which according to the EPA would not typically constitute “significant operational control” and thus would not require co-permitting. Poultry processors on the other hand procure birds almost exclusively under contract production arrangements, so the implications are more severe for that industry. Some pork and poultry integrators may consider owning or leasing production facilities and eliminate the contract growers. In the near term, it is questionable if this latter consideration is a realistic option for most integrators, given the enormous capital requirements of owning or controlling the production facilities with little additional profit from doing so. Furthermore, meatpacking and poultry processing have not been high return industries and thus increased risk and lower returns associated with the proposed regulation would not seem to facilitate debt or equity financing.

> Often, contract production is associated with large corporations; however the proposed regulations will likely impact a number of smaller operations as well. There are a number of relatively small operations in the state that regularly or occasionally contract with nearby farmers to finish swine. While these smaller contractors should not be held to a lower environmental standard, these operations will typically not have the resources to absorb an adverse environmental outcome caused by another contracting farmer. Dairy herd replacement operations, if classified as a CAFO, could be threatened as well. Often the dairy operation that contracts for the replacements is hundreds of miles away and may be reluctant to be responsible for the actions of another farmer over such distances. Members of the emerging sow cooperatives around the state may face difficult liability positions as well. In these situations, if the farmer that has a small interest in the co-op must be co-permitted, the liability relative to his/her home farm operation may be dramatically out of proportion. These local co-permitting situations perhaps best illustrate the instance where the cost of what may be a very small marginal and uncertain environmental improvement will likely be greater than these entities are able to bear.