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A COMPREHENSIVE NUTRIENT MANAGEMENT PLAN ON
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A COMPREHENSIVE NUTRIENT MANAGEMENT PLAN ON MICHIGAN STATE UNIVERSITY FARMS

By

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ABSTRACT

A COMPREHENSIVE NUTRIENT MANAGEMENT PLAN ON MICHIGAN STATE UNIVERSITY FARMS

By

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The increased intensification of the livestock industry and the segregation from crop production farms has left a nutrient imbalance. Nonpoint source phosphorus is the primary source of pollution degrading water quality (Kerr et al, 2001). Implementation of a Comprehensive Nutrient Management Plan (CNMP) assists in balancing phosphorus (P) inputs with phosphorus outputs. The development and implementation of a CNMP is one way Michigan plans to improve water quality and decrease P problems in waterways.

Michigan State University is part of the group that developed and supports the use of Generally Accepted Agricultural Management Practices, GAAMPS. GAAMPS encourages manure management system plans. The development of a CNMP on MSU farms revealed an imbalance of P production by animals to P removal by plants. Analyses of field soil test levels for the previous ten years revealed an overall increase in Soil Test Phosphorus (STP) levels, reflecting an unbalanced nutrient system. Because of the vast information and the differing management techniques on the individual facilities development of the CNMP was a challenge.

Two software programs being utilized in Michigan to assist in CNMP development were assessed for user friendliness and data output. The Purdue Manure Management Planner (MMP) and the MSU nutrient management program (MSUnm) both have beneficial aspects dependent upon the needs of the producer.

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CHAPTER 1: INTRODUCTION AND OBJECTIVES

The once picturesque scene of cattle grazing in open pastures has been greatly transformed over the last 30 years. The onset of technology has brought many changes in all aspects of the industry, especially in agriculture. The farming system has gone from diverse, open range production to more industrialized confinement facilities designed to increase production while decreasing production cost. This has been accomplished by improving efficiency with larger animal confinement operations that allow for the production of more animals on less land. Because of the additional amount of manure being generated in smaller areas, producers must develop new manure handling and distribution systems.

The trend toward larger livestock operations is driven primarily by economies of scale (Michigan Agricultural Commission, 2002). Industrialization of the livestock industry has allowed for increased efficiency, producing more head per unit of time, feed or space. Increased productivity allows for more animals to be run through the system, resulting in greater profit because of a larger output. As a result, the number of livestock units per livestock operation has increased over the last thirty years. Approximately 450,000 livestock operations confine animals in the United States. As of 1992, 6,600 of these livestock operations contained more than 1,000 animal units (AU) (Unified National Strategy for Animal Feeding Operations, 1999). The trend of increasing operation size is likely to continue.

Michigan State University (MSU) farms, located south of campus in East Lansing, are a large sprawling complex system of cropland and livestock facilities. MSU farms consist of nine individual facilities with six different species of animals, horse, poultry, sheep, mink, swine and cattle, totaling 6,684 head or 1,798 AU in 2001. Approximately 1400 acres of land are utilized by MSU farms for crop production and manure applications. A wide variety of crops are grown primarily to feed the MSU farms livestock. The management of nutrients from livestock manure with crop requirements requires a high degree of management and can be accomplished by implementing a CNMP.

A CNMP includes a full accounting of the phosphorus (P) contained in livestock manure or imported as fertilizer. An operation that meets the goal of P balance will have equal amounts of P inputs, such as manure and fertilizer and P removal by harvested crop. Ultimately, maintaining soil test P levels in compliance with GAAMPs further requires that STP levels remain below 300 pounds/acre if manure is to be applied. Maintaining this level demonstrates the test of balance.

The objectives of this project are to:

- Determine the total manure P generated by animals at the MSU farms campus, and to estimate the P removed by the crops to which the manure is applied;
- Analyze the past 10 years of soil test data to see if soil P levels are within the limits established in the GAAMPS and whether there is any change in levels;
- Develop a CNMP for MSU farms; and,
- Compare the two most popular software packages used for CNMP development in Michigan.

CHAPTER 2: LITERATURE REVIEW

The farming system has changed over the years, from diverse, open range production to more industrialized, confinement facilities. Confinement operations allow for the production of more livestock per acre of land, resulting in cheaper food prices at the market. With this change in farm operations also comes a change in manure handling and management. The once picturesque scene of cattle grazing on open pastures has been transformed dramatically over the last thirty years.

Because of the change in livestock farm operations to more confined conditions, the management of manure nutrients has become a large environmental concern. Confined animal feeding operations typically import a majority of their livestock feed; while that helps to maximize production, it results in a net input of nutrients. Efficiencies of feed conversion to animal product are not 100% and thus manure is produced (Mullinax, et al., 1998). Manure contains a large percentage of the nutrients fed to the animal. Depending on the species of animal, 70-80% of the nitrogen (N), 60-85% of the phosphorus (P), and 80-90% of the potassium (K), fed to animals will be excreted as manure (MDA, 2002). Since many confinement operations do not produce all of their own feed and are located in grain deficit areas, feed nutrients are imported while manure nutrients are not always exported to the location of crop production where the nutrients could best be utilized (Wood, et al., 1996). Agricultural production systems are specialized. Specialization separates crop production from livestock production (Janzen, et al., 1999). The geographic separation and the cost to transport manure to the fields exacerbates the manure management problem. Instead, manure is applied to the parcels of land available, often exceeding crop nutrient requirements (USDA, EPA, 1999).

Continuous application of manure beyond crop requirements leads to P buildup in the soil. A survey of farms on the east coast found that nine out of ten farms surveyed have high soil test phosphorus (STP) levels (Comis, 1999). High STP levels are a result of nutrient applications greater than nutrient removal in crops.

Sustainability of a farm requires both ecological and economic considerations to be in balance. A phosphorus balance developed for 33 Nebraska confinement livestock farms found 17 with significant P imbalances (Koelsch and Lesoing, 1999). They observed that nutrient inputs in the form of feed and fertilizer were 2 to 4 times greater than nutrient outputs. Phosphorus has no gaseous state, so when applied to soil in excess of the removal rate, it accumulates. The phosphorus cycle shows the movement of phosphorus in the environment (Figure 1). As the amount of accumulated P increases, so does the potential for surface water pollution from erosion and runoff. It has also been established that in high concentrations P will move with water flow through the soil, infiltrating groundwater systems (Busman, et al. 2001). Nitrogen, on the other hand, easily volatilizes into the atmosphere in several different gaseous compounds, or readily leaches through the soil profile, but tends not to accumulate in soil (Figure 2). Furthermore, most non-leguminous agricultural crops use approximately twice as much nitrogen as phosphorus during the growing cycle. As the crop residue decomposes, almost all phosphorus returns to the soil, while only a fraction of the nitrogen is returned. The disproportionate level of P to N applied and maintained in the soil are likely to cause more significant nutrient imbalances in the future.

Farm nutrient imbalances continue to be a hindering issue in the livestock industry. A potential resolution is to transport nutrients greater distances to areas of need.

Specialized livestock production systems must be in contact with their crop production counterparts in order to complete the cycle or balance the production system. In some cases, this requires manure nutrients to be transported long distances, even beyond the break-even distance where manure nutrient value meets the cost of transportation (Janzen, et al., 1999). Transportation will become an even greater issue as regulations are expanded and strengthened.

The continuous over application of manure nutrients has brought many soils to the point of P saturation. Over fertilization of P causes the availability or solubility in soils to increase and in turn increase P mobility with water (Jacobs, 1995). Phosphorus saturated soils do not have the ability to bind or fix additional nutrients, thus P is free to move with water in runoff or to percolate through the soil profile. When soil is eroded, the P absorbed to the soil particle is also transported. STP levels greater than 150 parts per million (ppm) are categorized as high and are likely to lose some nutrients to the surrounding landscape, via runoff, erosion or leaching. Over application of P will increase potential economic loss and environmental degradation.

To maintain sustainability, manure nutrients should be applied at crop removal rates. This is difficult due to the disproportion of manure nutrients to crop needs. Manure nutrients are typically expelled from the animal at a ratio of P: N of 1:1, crop requirements of P: N are typically in a ratio of 1:2, however when the ratio of manure nutrients when applied are P: N of 2:1 (Powell, et al., 2001). The imbalance of manure production concentrations to crop needs creates a problem when trying to meet all crop requirements with only manure. Also, depending on the manure handling technique of the farm, the proportion of manure nutrients, P: N can be even greater. This increased difference is primarily due to the volatilization of nitrogen (N) gases to the atmosphere, which decreases the nitrogen content of the manure, complicating the nutrient balance issue even further. The over application of manure has led to the buildup of manure nutrients in soils, and increased the risk of environmental problems.

Phosphorus contamination comes from point sources, sewage treatment plants and factories and non point sources such as agriculture and urban runoff. Over the last two decades, point sources of contamination have markedly decreased due to the ban of phosphorus in detergents and the onset of the National Pollutant Discharge Elimination System, requiring permits for discharging into water resources. The Federal Clean Water Pollution Control Act of 1972 implemented the use of permits to control the discharge of pollutants into surface waters (Department of Environmental Quality, 2002). However, nutrients in surface waters continue to be a major problem.

Several water quality problems have been linked to nutrient enrichment, primarily from agriculture (EPA841-F-96-004A, 2001). Prior to intensification of livestock, many states based manure application rates on nitrogen. Balancing for nitrogen typically resulted in the over application of phosphorus, even though farms were more diversified, and manure was spread over larger areas. Phosphorus levels increased from years of over application, although increases may not have been as dramatic as seen today in some confinement facilities. The current excess of P inputs over exports indicates a need for adjustment in P management to further reduce the imbalance (Bundy, 1998).

Agriculture is the primary contributor of nonpoint source pollution in the United States today (EPA841-F-96-004A, 2001). Non point source pollution implies that there is not a point source location that can be identified which is directly responsible for the contamination, however the source of pollution is dispersed, sometimes over thousands of miles (USGS, 2001). The National Water Quality Inventory indicates that agriculture is the leading contributor to water quality impairments, degrading 60 percent of the impaired river miles and half of the impaired lake acreage surveyed by states, territories and tribes (EPA841-F-96-004A, 2001). The primary reason for the degradation of water resources from agriculture is due to the over application and stockpiling of manure nutrients. Estimated annual P losses in runoff and erosion represent approximately 1.6% of the P applied each year or an average loss of 0.3lb P per cropland acre (Bundy 1998). Applying P beyond production requirements is detrimental from both environmental and economic viewpoints (Waskom, 1994). Some farms have elected the quickest approach to manure hauling and consistently haul manure to the field closest to the source, which results in enrichment of soil P.

Excessive manure loading can cause excessive nitrate levels in groundwater and phosphorus accumulation in the upper soil profile, increasing the incidence of nonpoint source pollution (Jacobs, 1995). Many water quality problems are the result of phosphorus buildup in soils and the mismanagement of manure. Today, many states have evolved to a more phosphorus restrictive approach for manure and nutrient applications. However there continue to be water quality concerns due to P-enrichment.

Phosphorus enrichment of waterways causes aesthetic, recreational, and water utilization issues. Phosphorus is generally the limiting nutrient, the nutrient lacking for organic production, for plant growth in most water resources. Thus when phosphorus is added, plants grow rapidly. The accelerated plant growth reduces light and can hinder the quality of the reservoir's natural food chain (Waskom, 1994). As the vegetation begins to decay, aerobic or facultative organisms utilize a large amount of dissolved oxygen in the water, diminishing available oxygen for other organisms, such as fish. In many instances, these fish will move to other areas or suffocate and die from asphyxiation (USDA, 1992). The excess plant growth and diminished dissolved oxygen leads to the early aging or eutrophication of surface water resources, reducing the quality and quantity of natural surface waters. Another problem being linked to phosphorus is the occurrence of pfisteria in the Chesapeake Bay area. There has been no other link found for the pfisteria outbreaks except the rising levels of P in soils (Comis, 1999). This means high manure applications, loading of phosphorus in soils, and the subsequent runoff and erosion of those soils may cause health concerns for humans and animals from increased bacteria in the water. There is a link between high STP levels in soils and subsequent P levels in runoff (SERA-17, 2000). The instance of high STP levels, especially in water sensitive areas, will result in the movement of P and degradation of nearby water sources. There are issues and consequences with enriching the nation's surface waters with phosphorus.

In 1997, Senator Harkin introduced a bill initiating regulations on management of phosphorus. The data show applying manure to meet the crop nitrogen requirement creates excess phosphorus loading resulting in numerous water quality issues, especially in sensitive areas (Copeland, 1997). Until the introduction of the Harkin bill, many states based manure application on crop N needs. Some states continue to base manure applications on N, however, many have changed to a phosphorus-based standard. Since 1988 Michigan has based manure application rates on phosphorus except for soils with low (<75 ppm) soil test phosphorus levels (MDA, 2002).

Michigan, known as the Great Lake State, has set voluntary regulations for producers. The Great Lakes comprise the largest system of fresh surface water on the planet and provide over 10,000 miles of shoreline (EPA, 2002). In its attempt to reduce phosphorus enrichment of water sources Michigan has adopted a zero discharge policy of nutrients into water resources (Manure Management, 2001). Application of nutrients beyond crop requirements has no benefit to the crop but can be detrimental to natural resources. In 1987 The State of Michigan, amended the Right –to –Farm Act (R to F) to include generally accepted agricultural management practices (GAAMPS). There are several sets of GAAMPS, but the most applicable to livestock operations are for manure management and for citing of new and expanding livestock operations (MDA, Site Selection GAAMPS, 2002). In 1988, GAAMPS established phosphorus as the base upon which manure would be applied. In special circumstances where soil phosphorus levels are low (below 150 lbs Bray P1 per acre [75 ppm]), manure application to soil is limited by plant nitrogen needs. Where soil phosphorus is high (above 300 lbs Bray P1 per acre [150 ppm]), manure may not be applied. In most cases, the soil P is between 150 and 300 lb per acre, and the amount of manure applied is limited to the amount of P the plant will remove from the land (MDA, Manure GAAMPS, 2002). These are specified soil test phosphorus ranges for manure application rates dependent upon the soil test phosphorus level of a field. Most recently, in 2002, the State of Michigan came to an agreement with the United States Environmental Protection Agency (USEPA) that all livestock operations with 1000 or more animal units must take one of two avenues for environmental assurance. The producer must either seek environmental assurance through the Michigan Agricultural Environmental Assurance Program (MAEAP), or seek a general National Pollutant Discharge Elimination Program (NPDES) permit (Scott Piggott, 2000). In either case, a Comprehensive Nutrient Management Plan (CNMP) must be developed for the livestock operation. The smaller livestock producer can utilize the standards set by GAAMPS as a guideline for manure management. However, a more complete analysis for potential P-movement would be to utilize a soil phosphorus index, which takes other potential factors of phosphorus loss into consideration. A soil phosphorus index takes more factors into account when predicting the potential for phosphorus movement than just a soil test level and several versions have been adopted in other states.

A phosphorus index includes factors that assess the potential for P delivery from fields. Some factors used in this assessment include, soil erosion, slope gradient and length, soil runoff class, distance to water drainage, tillage, vegetation, as well as the soil phosphorus level (Mallarino, et al., 2000). When all of these factors are analyzed, each field is given a rating on its potential for phosphorus loss. This rating can be utilized to determine which fields have the highest risk of phosphorus loss. High-risk fields should be used as a last resort for manure application or only in ideal weather and soil conditions. The implementation of a soil phosphorus risk index requires an individual assessment of each field. However it gives a more accurate analysis of which fields have the highest potential for P-movement.

Natural Resource Conservation Service (NRCS) and Dr. Robert von Bernuth developed the Manure Application Risk Index (MARI) in 1998 as a part of the CNMP process (http://www.maeap.org/mari_oct02.xls). MARI is a modified version of the P index being utilized in Michigan as part of the CNMP process for manure application.

MARI is used to identify fields with high P movement potential. The Michigan Agricultural Environmental Assurance Program (MAEAP) has adopted MARI to address water quality concerns from P enrichment. The goal of MARI is to maintain a voluntary approach to meeting the national water pollution non-point standards. It is a tool for assessing the relative risk of applying manure and is useful in determining the order in which manure is applied to the fields (Grigar, Jerry, and Jay Blaire, 2001)

The movement of nutrients into surface water is a preventable concern of animal production. According to a Census Report and survey done in Michigan, manure could provide 19% of the nitrogen, 37% of the phosphorus, and 25% of the potassium, for Michigan's primary crops (von Bernuth & Salthouse, 1999). Phosphate production from manure is in deficit by 24Kg/Ha before fertilizer. When fertilizer is considered, the state is in excess by 15Kg/Ha. Sixty-nine of Michigan's 83 counties are in excess by 25 Kg/Ha or more, and most are lakeshore counties. The excess areas tend to be geographically separated from the areas in need of nutrients (von Bernuth & Salthouse, 1999). Michigan as a whole is not much different from the national perspective. Although Michigan is not in excess of manure nutrients, problems exist because of uneven distribution of the nutrients. Nationally this is the root of the problem as well; the geographic segregation from where nutrients are produced to where they are deficient for crop production.

Phosphorus in Soils

The Bray P1 soil test is the primary analysis of soil phosphorus levels adopted in the Midwest. Bray P1 measures only a portion of the phosphorus in the soil. Although the Bray P1 does not give the exact level of soil phosphorus in acid soils, it gives a much more representative sample than that of the other two primary soil tests used, Olsen P and Melich III. The Olsen P soil test is used primarily in calcareous soils, and the Melich III soil test is considered universal across any pH soil for phosphorus and other nutrients. The Bray P1 test is most widely used in the acidic soils of the Corn Belt because it is better adapted to soil pH less than 7.4 (Sawyer et al., 2003).

As mentioned, Bray P1 only measures a portion of the phosphorus in soils. Most of the phosphorus not measured by this test is bound by other elements in the soil. Phosphorus, typically taken up by the plant as phosphate ions, $H_2PO_4^-$ and HPO_4^{2-}, readily binds with positively charged cations in the soil profile. Minerals such as Al^{3+} and Fe^{2+} readily absorb the phosphate ion in acid soils, making them unavailable for plant uptake. In Calcareous soils, Ca^{3+} is the primary binding site for phosphate. Soil pH plays a large role in the availability of phosphorus to the plant. A pH range of 5.5-6.5 is the pH of maximum plant phosphorus uptake (Garcia, 1999). When the soil pH is above or below this range, phosphorus uptake is reduced. Another factor affecting phosphorus availability is soil type. Fine-textured or clay soils typically have the capacity to absorb or fix more phosphorus than coarse or sandier soils (Garcia, 1999). The capacity to absorb large quantities of P is due to the increased surface area of the soil to attach phosphate ions. In coarser soils, less surface area results in fewer binding sites, and a reduced ability to fix large amounts of soil phosphorus. The soil type and pH are the two primary factors when determining the availability of phosphorus to the plant and the phosphorus concentration reported on the Bray P1, soil phosphorus test.

Various soil types will respond differently to manure applications and soil test levels because different soil types absorb different amounts of P. Thus when a farmer applies the same manure to two different fields, soil test levels could show very different levels. Some soils bind phosphorus to the extent that very little P is available for crop uptake (Tisdale, et al, 1993). These soils require larger amounts of nutrients to meet the crop needs, primarily because soil minerals and soil particles bind most of the phosphorus applied. On the other hand, because coarser textured soils have fewer binding sites, more phosphorus is likely to be available to the plant. All soils have the potential to become saturated, resulting in the soils' absorption sites being filled. The point of saturation varies with each soil and its respective mineral content and texture. Nutrients applied beyond the point of saturation do not become fixed, but move freely with water (Jacobs, 1995). In most instances, phosphorus moves with runoff or water moving laterally over the surface. However, there is the potential for phosphorus to leach through the soil profile and into shallow aquifers. This phenomenon has a higher likelihood of occurring in sandier soils, where there are few binding sites, or when organic matter is high. Organic matter occupies potential phosphorus binding sites, allowing P to leach further into the soil profile (USDA, 1992). The potential for phosphorus leaching occurs when there is an absence of available absorption sites. The range of soil types and minerals present will alter the predictability of phosphorus in soil. Predicting the soil test phosphorus level after phosphorus additions is difficult and variable.

Interactions of soil P are complex. The rate at which soil P levels change when phosphorus is added as manure or extracted by the plant depends on several factors. The factors to consider when dealing with soil phosphorus change are, soil pH, soil texture, initial P soil test value, type of soil, crop removal, soil P buffering capacity, etc. Each of these factors plays an important role in the amount of P to be added or removed to change soil test P values. The general rule for the midwestern states is 18-20lbs/acre of P_2O_5 added or removed to change the Bray P1 soil test by 1lb/ac. (Vitosh et al, 1995). In a paper from the Communications in Soil Science and Plant Analysis (Ontario), the average increase in P soil test was about 1ppm on the Olsen test for every 35kg/ha (~35lbs/acre) of added P_2O_5 (Bates, 1997) found that an application of 4kg/ha (~4lbs/acre) was required to raise the extractable P of a medium textured Mollisol and Alfisol 1kg/ha (2.29lb/acre P_2O_5). For sandy to clay loam textured Utisols, an application of 5-6kg P /ha (11.45-13.74lbs/acre P_2O_5) was required to raise the extractable P 1kg/ha (1 lb/acre or 2.29 lb P_2O_5/ac). But on clayey textured soils, 12kg P/ha (12lbs/acre or 34.8 lbs P_2O_5/ac) was required to change the soil test values 1 kg/ha (Zenter et al).

The P absorption characteristic of the soil and the initial P soil test value play a large role in how much phosphorus is extractable (Sera-17, Minimum P losses). Soils with strong sorption capacity will release less dissolved P at a given soil test value than those that have a weak sorption capacity. Strong sorption capacity soils will tend to bind P within the soil, not allowing it to be extracted, and thus not showing up on the soil test or being removed by the plant. Utilizing the general rules of P change will give guidance when looking at soil tests and deciding whether to add P or not, as well as when trying to reduce STP levels. These are general guidelines; each farm must be assessed on an individual basis to find specific phosphorus change levels.

The initial level of P within a soil also plays an important role when trying to predict soil test P changes and applying nutrients. The greater the initial soil test P level, the more the soil test level will change after application of a P source. Results have been obtained with absorption isotherms, which indicate that the increases in soil solution P are a curvilinear function of P addition rather than a linear function. When P applications are doubled and tripled, the relative increases of soil test levels were approximately 3 to 6 times greater. Information from both Gary M. Pierzynski, Professor, Soil and Environmental Chemistry Department of Agronomy at Kansas State University, and Bill Thom, Department of Agronomy, at the University of Kentucky have found similar results (communication via e-mail 10-27-2000). According to Pierzynski of Kansas State University, if initial STP is low, then it takes more P to raise the STP 1 lb/acre, than if the initial STP is high.

Kansas State University has also done work on phosphorus extraction and the results are a bit more variable. Generally, however, if STP levels are high they decrease rapidly with crop removal. As you remove more P from the system, eventually STP levels off, despite the fact that you continue to remove P. As STP becomes low, the soil buffering capacity comes into effect. This means that at a certain level even though P is still being removed, STP levels remain stationary. Phosphorus is being mineralized from fixed soil compounds or organic phosphorus is being released when STP is low. The soil P buffering capacity has also been seen in a 24-year study in Western Canada where the initial level of Olsen P was 19kg/ha and after 24 years of cropping without any phosphorus fertilizer application, the P content of the 0-15cm depths on a medium texture Orthic Brown Chernozemic soil, did not change. The phosphorus removed (exported from the system) in the grain of the wheat-averaged 3.5kg/ha/yr. It was believed that the P was being released from organic and inorganic P sources within the soil (Zetner et al).

Thom's work has shown similar results. His study also looked at both soil test increase and soil test decrease related to P additions and removal, for a Belknap soil in western Kentucky (e-mail conversation 10-27-00). Table 16 and Figure 3 show the soil test phosphorus changes with the addition and extraction of phosphorus from the Belknap soil. Both the change in phosphorus levels with the addition and extraction are curvilinear functions, making phosphorus prediction complicated.

The ideal of using one number to predict how much soil test values will change when a quantity of fertilizer is applied, gives us an estimate of where a fields' levels will be the following year. Agriculture should be aware, however, that when soil test levels are already high adding small amounts of P to that field will cause large increases in STP levels.

Environmental Issues

Many environmental clubs and associations believe laws for confined animal feeding operations (CAFOs) are too lenient. In 1995, a lagoon in North Carolina burst, obliterating aquatic life in the New River, due to the 23 million gallons of raw manure that was discharged (Sierra Club, 1999). This spill was catastrophic to the life that once inhabited the river. A major manure spill occurred in February of 2002 by Maple Ridge Dairy in Wisconsin. The Dairy applied 250,000 gallons of manure on 32 acres of frozen ground, causing manure to run off the field and disperse in unnamed tributaries of the Eau Pleine River (Sierra Club, 2002). The application of manure onto frozen ground greatly increases the risk of runoff. The Wisconsin Department of Natural Resources (DNR) has listed the Big Eau Pleine River as having too much bacteria and too little oxygen since the winter 2002 spill. Both lack of oxygen and too many bacteria can lead to fish kills. Cargill Pork, Inc., in Missouri discharged hog waste directly into surface water, violating the Clean Water Act and killing more than 50,000 fish (Bornestein, 2002). Spills involving large volumes of manure from livestock facilities result in the degradation of water resources and cause the death of thousands of fish and aquatic species

Some actions have been taken to try to minimize the issues created by large confinement operations. New regulations require producers to meet either Environmental Assurance through MAEAP guidelines or to obtain pollution permits; both require the development of a CNMP.

As farms grow and number of livestock in confinement increases, water quality will be of greater concern unless action is taken to promote balanced farm systems and minimize soil and P-losses. The development of a CNMP can benefit producers by meeting nutrient requirements with manure rather than expending on commercial fertilizers. Meeting crop needs with available manure nutrients can save capital for the producer while reducing the potential for environmental degradation due to excess loading of nutrients to fields. Crop and livestock producers will benefit from the development and implementation of Comprehensive Nutrient Management Plans.

CHAPTER 3: CNMP BACKGROUND

The concept of manure management and manure management plans is not new. It amounts to little more than an accounting for nutrients available through manure application that has been utilized for centuries. Formalization in Michigan first came through the Manure Management GAAMPS. Comprehensive Nutrient Management Plans were described in the March 9, 1999, Unified Strategy for Animal Feeding Operations issued jointly by EPA and USDA (USDA, EPA, 1999). Section 3.2 of that document states the following:

> *In general terms, A CNMP identifies actions or priorities that will be followed to meet clearly defined nutrient management goals at an agricultural operation. Defining nutrient management goals and identifying measures and schedules for attaining the goals is critical to reducing threats to water quality and public health from AFO's (animal feeding operations). The CNMP should fit within the total resource management objectives of the entire farm.*
>
> *CNMPs should address, as necessary, feed management, manure handling and storage, land application of manure and management, record keeping, and other utilization options. While nutrients are often the major pollutants of concern, the plan should address risks from other pollutants, such as pathogens, to minimize water quality and public health impacts from AFOs.*
>
> *In addition to protecting water quality and public health, CNMPs should be site-specific and be developed and implemented to address the goals and needs of the individual owner/operator, as well as the conditions on the farm...*

In August 2000, the Michigan Agricultural Environmental Assurance Program (MAEAP) Steering Committee approved CNMP's as a component of MAEAP (http://www.maeap.org/). They defined a CNMP as "the production practices, equipment, and structure(s) that the owner/operator of and agricultural operation now uses and/or crop production in a manner that is both environmentally and economically sound (MAEAP)." The CNMP is a planning tool, record of decisions, and documentation of land used for manure application. The basis for the CNMP as defined by MAEAP was the manure management system plan as developed by the Natural Resources Conservation Service (NRCS) with modifications as appropriate to the MAEAP program. A complete CNMP contains the following components:

- Overview
- Farm Headquarters Map
- Animal Outputs
- Conservation Practices on Fields Used for Land Application
- Land Application Management
- Record of CNMP Implementation
- Inputs to Animals--Feed Management (where applicable)
- Alternative Utilization Activities (where applicable)
- Inspection, Operation and Maintenance, Training
- Schedule of Implementation
- Emergency Action Plan
- References
- Appendices

For the purposes of this study, perhaps the most significant section is the land application management. The three key elements of this section are nutrient budgets for nitrogen, phosphorus, and potassium; the determination of application rates; and the application schedule. Much of this study will focus on the nutrient budget for phosphorus because phosphorus is generally the limiting nutrient for manure application on MSU farms. The driving force for nutrient budgeting is the production of manure as addressed in the animal outputs section. For that reason, the first analysis will be in animal outputs. Following are the MAEAP components and information that should be contained within each section.

Overview

An overview is a brief statement outlining the farm operation including goals, enterprises, and long-term plans for resource management.

Farm Headquarters Map

A site map showing locations of farm buildings, animal housing, manure storage structures, other sources of manure and wastewater, feed storage, farm house(s) and any other relevant physical features.

Animal Outputs

Record and assess all aspects of manure handling, including production, collection, storage, treatment, and transfer for application.

Conservation Practices on Fields Used for Manure Application

Evaluation of potential for nitrogen or phosphorus transport off-site includes evaluation of such factors as: soil, water quality, surface cover, and manure. Identifying sensitive areas, conservation and management practices needed for erosion control and water management to control off-site transport of nutrients, feasibility of winter manure application, maps showing sensitive areas, setbacks and locations of practices/activities.

Land Application Management

A nutrient budget for nitrogen, phosphorus and potassium from all sources should be assessed.

Calibration of application equipment and planned application schedule and application rates by field based on crop, yield goal, crop nutrient needs, soil test results, previous crop and if any nitrogen credits are applicable, manure and wastewater nutrient content, whether applying based on phosphorus or nitrogen, and special considerations need to be given for fields potentially used for winter spreading. At time of application, field-specific conditions (wet, dry, frozen, snow covered) should be considered and application rates adjusted accordingly.

Record of CNMP Implementation

Records should be kept by field and include: soil test reports, dates of manure/wastewater applications, sources and rate of all nutrients applied, dates of incorporation, method of application, acres and area of field applied, weather and field conditions during application, recommended nutrient application rates, previous crop grown and yields, plant tissue sampling and testing reports (where applicable), and pre-side dress nitrate test (PSNT) reports (where applicable). Other records such as manure/wastewater quantities produced and nutrient analysis results, inspection and maintenance reports, records of rental agreements or other agreements for application of manure/wastewater on land not owned by the producer and record of manure/wastewater sold or given away to other landowners (where applicable) should be kept. The Strategy establishes a national expectation that all animal feeding operations develop and implement comprehensive nutrient management plans by the year 2008 (Salazar, 1998)

Inputs to Animals- Feed Management

The management of animal diets that result in:

- Optimum production and/or animal body maintenance

- Best economical use of feed materials
- Minimize the amount of (recoverable) nutrients contained in manure.

Alternative Utilization Activities (where applicable)

Transport and environmentally sound off-site utilization, including such processes as power generation and conversion to value-added products (e.g. compost).

Inspections, Operations & Maintenance Training

This section should include: 1) schedule for inspection of structural and vegetative practices and equipment, and operation and maintenance practices/activities; 2) schedule for a review of management practices/activities to ensure implementation of plan; 3) a plan for training employees how to follow CNMP, including when training will be provided, such as: training new employees hired, new processes, procedures or equipment, and employee responsibilities.

Schedule of Implementation

The Schedule of Implementation includes new components that are planned and the implementation schedule for each new component as well as an annual review and update of plan as necessary.

Emergency Action Plan

An emergency action plan should include actions to take in the event of a spill, discharge, or failure of a collection, storage, treatment or transfer component as well as telephone numbers to report and seek assistance in the event of an emergency, and the anticipated flow paths in the event of a spill, discharge, or failure, shown on a site map.

References

Sources of information cited/used in the development of the plan

Appendices

Copies of pertinent references cited in the plan, environmental documentation, as appropriate and other appropriate supporting documents not included in other parts of the plan (i.e., worksheets, forms, etc).

CHAPTER 4: NUTRIENT PRODUCTION ON MSU FARMS

There are three generally accepted methods for estimating the nutrient production from animals. The first method, and likely the most accurate if adequate data are available, is mass balance. In this method, an accurate account is kept of the nutrients contained in the feed that the animals consume. In some cases this is done per animal per ration formulation, in other cases it is done per herd, and in a few cases it is done on a whole farm basis. This generally is easiest with P because no gaseous losses occur. Hence the amount of P consumed by the animal less the amount retained in the animal or excreted in milk and eggs equals the amount lost in the waste product. This requires careful maintenance of records, but is the best method for long term planning.

Method 2 used to estimate animal outputs is to measure the quantity of manure produced and analyze manure samples to get a representative concentration of the nutrients contained within the manure. Knowing the amount of manure produced and the respective concentrations of nutrients, total nutrient production can be estimated. The shortcomings of this method are two-fold: 1) it is difficult to obtain truly representative samples, and 2) estimates of total volumes of manure are impacted by weather, bedding and accuracy of determination methods. This method is essential for determining load-by-load application rates.

Method 3 of estimating animal outputs is by using representative average values known as book values. In this method reference charts such as shown in the GAAMPS for manure management, adopted from the 2000 Midwest Plan Service (MWPS-18, 2000) are used to estimate the total volume of manure and the amount of the individual nutrients produced. This method is probably the least accurate method, but does not require as much testing or record keeping as the other two. This method does not account for various feed management strategies such as diets or supplements, but is currently acceptable if the other two methods are not available.

MSU farms involve 36 sources of manure from nine different livestock facilities (Table 10). Because it is a research facility, there are innumerable diets fed for varying lengths of time, so attempting to compute a mass balance would be very difficult for the entire MSU farms. Hence, the determination of animal outputs will be based on the second and third methods.

Method 2 utilizes manure analysis and tons or gallons hauled. The volume of manure hauled from each facility was calculated (Table 11). A representative manure sample was taken from each of the manure sources and analyzed (Table 10). The concentrations for each nutrient from analysis were then multiplied by the volume of manure hauled from each source to calculate the total nutrient production for N, P_2O_5 and K_2O production from each of the manure sources. Utilizing manure analysis from the individual manure sources allows for specific farm management practices and feed differences to be seen, rather than simply basing production levels from book values. However, a precise record of manure volumes hauled must be kept in order to result in accurate production levels. Because of unrecorded manure applications, a close estimate was developed for the dairy barn.

Method 3, book values, although the least specific for individual farm management practices, does give an estimated nutrient production level. Utilizing book values requires livestock numbers, species and production level, and a book value data source. There are two versions of the most commonly used source MWPS-18. The 1985 edition is significantly different from the 2000 edition. For this study, both editions were used and compared along with manure analysis values (Table 15). Because of the multiple livestock species and production levels, each facility was determined separately and then added as a whole. This method also required some estimation because mink and ferrets are not included as a livestock species. Production levels for these species were figured as 4-pound chicken layers. Quail body weights of 0.5 pounds and pheasants at 3 pounds were figured as 2-pound broiler chickens. Only one production weight is given for sheep and horses, in MWPS-18, so overestimation is likely because young animals were counted. Total P_2O_5 production estimates were 153,700 lbs by Method 2 (Table 13), about 143,000 lbs for method 3 using 1985 MWPS values (Table 8) and 128,000 lbs for method 3 using 2000 MWPS values (Table 9).

CHAPTER 5: COMPARISON OF TWO SOFTWARE PROGRAMS

There are two primary software programs being utilized in Michigan to assist producers in the development and implementation of a CNMP. The two are the Manure Management Planner (MMP) developed by Purdue University and associates and the MSU Nutrient Management Program (MSUnm), developed by Michigan State University Faculty and Staff. Each program was designed with a specific use in mind and is being continuously updated. There is a large amount of data associated with a CNMP, and changes in the programs seriously complicate the process.

The Purdue program was set up as a planning tool; it is not designed to be a record keeper. This program was to plan for manure generation, crops, animal number changes, and other planning aspects of an operation. MMP allows for manure management planning for 1-5 years. This allows for the opportunity to look at future goals and the probability of reaching them.

MSUnm was designed specifically for record keeping, and not as a planner. This program designed to manage nutrients, was designed specifically for Michigan producers. MSUnm was designed to keep track of the information while allowing for some analysis and planning for the following year. This program keeps track of all aspects of the farm activities, including: manure spreading, pesticide management, crop yields, manure and soil test labs, fertilizer management and livestock information. All of this information can be stored and added to the MSUnm program.

Both programs have aspects, which are beneficial to a producer. There is a lot of overlap between the two programs, and because each involves a large amount of data, producers should decide which program will best suit their needs and utilize just that one.

Data Differences/Errors

MSUnm utilizes MWPS-18, 1985 manure nutrient values with in the program, while reports are reported using MWPS-18, 2000. Also in the Nutrient Balance Report there is a decimal error for the P_2O_5 production of a 1,000 lb lactating dairy cow, making the phosphorus production 1,000 times less than it should be. Fertilizer recommendations and crop nutrient needs for both programs appear to be very similar.

Purdue uses MWPS-18 2000 manure nutrient values.

Personal likes and dislikes

The Purdue program is self explanatory and easy to utilize. Upon opening, program tabs appear across the screen, highlighting only those available, until a farm is set up. The MSUnm program is not especially difficult, but it is a DOS based program and takes a little longer to become acquainted with in the initial format. When beginning a new plan, MSUnm assumes the plan is developed for use by a Michigan farmer and has all relevant information specifically and exclusively for Michigan farmers. The Purdue program, on the other hand, was developed for use by the Midwest and thus contains information for the Midwest region. This requires the user to indicate the state and county for which the plan applies, in order to get soil information. The plan can be made from 1 to 5 years. The Purdue program is more versatile within the Midwest area and allows more flexibility for planners.

A problem arises with MMP if a plan involves more than one county. Soil types may be missing from a plan in such an instance.

In the MSUnm program, crops to be grown must be selected. Unlike the MMP program, MSUnm has the ability to select field crops as well as fruit, vegetable and turf crops. This is an asset to fruit and vegetable farmers.

The MSUnm has an area to input all fertilizer and liming materials used and the nutrient analysis of each. Included in the liming and fertilizer section is the ability to record nutrient costs. This allows a producer the ability to estimate fertilizer expense or to figure the cost- benefit analysis from efficient use of manure nutrients. MSUnm has also implemented the ability to record the soil-testing laboratory used and download the soil test levels directly from the web. This can be a tremendous time saver for farmers compared to manually inputting the data. Once a testing lab is selected, units are automatically given.

The pesticide/herbicide section is another record keeping aspect of MSUnm, allowing producers to track where, when and what chemicals were applied and who applied them. This allows for accountability in the instance of a problem.

Another beneficial aspect of MSUnm is the section for tillage information. This area allows for the input of different tillage practices used on different fields. However, when a type of tillage is specified, a message comes up saying that the acres are incorrect, acreage should be between zero (0) and zero (0), please enter correct acreage. This is likely a glitch in the program that has not been worked out at this time, although it is a concern for producers currently using this version.

One feature that is found in both programs is the ability to make notes and comments. This allows some freedom for descriptions, special notes and explanations if needed. This feature is handy, especially on a large or widely variable farm system.

MSUnm requires a sub field ID, where MMP does not. While MSUnm will use the last available soil test level entered, MMP does not accept soil test levels older than start of the plan. This is an issue if a producer is just beginning the planning process and soil tests only a portion of his fields every year. GAAMPS allows for soil tests every three years as long as fields are not in excess of 300 lbs of P/acre. Not accepting a soil test older than the start of the plan can be discouraging when trying to plan for a field that does not have a new soil test. Another aspect of MMP that is worrisome is the lack of restriction on yield goals for crops. Yield goals can range from 0-500+ for any crop. Fertilizer recommendations will increase with the yield goal, except in the case of fallow ground where no fertilizer recommendations are given, no matter what the yield. This feature can allow a producer to overestimate yield goals and achieve apparent nutrient balance. MSUnm, on the other hand, is more realistic in their range of yield goals for different crops.

The programs were designed to be used differently, however either of the programs has the potential to meet the needs of different producers for manure and nutrient management.

Some other useful items in the MMP program are the automatic default nutrient recommendations for N, P and K, when crop information is input. This is beneficial if the farmer is strictly crop farming, and needs fertilizer projections, or when trying to match nutrient needs from livestock manure with crop needs. Also useful is the manure application section. This section can be confusing at first however it is a great planning tool, showing approximately when pits will become full. This allows for some pre-planning. For example, if the pits are predicted to be full at the current fill rate in

February and there is good weather in December, it is worth hauling some of the manure early to prevent overfill or having to haul manure in adverse weather. The color-coding of manure storage facilities allows for a quick and easy assessment of manure levels. Green means that the pit is low and has available capacity. The color Purple reveals a pit that had more manure removed from the pit than what should have been produced based on animal manure generation levels from animal numbers.

The manure application section of MMP calculates the acres that should have been covered when manure load is applied. This allows the producer to see if a field was completely covered with each manure source, if applied correctly or if there are areas that did not receive some manure.

MMP does not have enough space for all of the animals to be listed for MSU farms. However, most production facilities are not likely to have the variability in species that MSU farms maintain. It would be better if the set-up for animals present to be every two weeks instead of every month. Producers who buy or sell, or have newborns regularly would have animal numbers continuously changing. This could be a crucial issue for producers in close balance on manure.

A desirable additional feature for MMP would be a record-keeping function for dates of manure applications. This would reduce confusion if the same manure and number of loads were applied to the same field, but on different dates. Otherwise there is the potential for a field to appear to have been completely covered on twice on the same day. It would be useful to print different sections of the plan for records or to take to the field as a reference.

CHAPTER 6: RESULTS AND DISCUSSION

Michigan State University Farms is facing several challenges in the development and implementation of a CNMP. First, the removal of farmland from production is creating problems when attempting to balance nutrients for MSU farms. The decrease in spreadable acres over time is shown in figure 4A. In 1996, MSU farms utilized 1,455 acres for crop production and manure applications. Some fields have been developed and that acreage has been taken permanently out of University farm use. This includes the building of the Livestock Pavilion, the Spartan football field's grass turf growing area, the Animal Health Diagnostic Laboratory, and the new or south swine farm. In 2001, the usable acres totaled 1,377. The reduction in land available has been further complicated with an increase of animals that are now housed in the new facilities.

The new swine farm and the livestock pavilion increased the production of manure nutrients due to this addition. This complicates an already difficult situation by reducing the land base and increasing the generation of manure nutrients. An average crop removal rate of 51.1 lb/ac times 1,377 acres gives a total of 69,535 lbs P_2O_5 taken up on MSU farms cropland. This divided by the yearly production of P_2O_5 from one animal will total the number of head that can be sustained on MSU farms. Based on this information and the production values from MWPS-18, 2000 edition, 453.5 mature lactating dairy cattle, 907 Mature 1,100 lb beef cattle, 1,465 lactating sows weighing 375 lbs, 9,525 mature sheep at 100 lbs or 1,731 mature 1,000 lb horses can be sustained on MSU farms. Sustainable animal numbers are based on total available acres and do not take into account acres which should not receive manure application due to high soil test levels.

While the land base is decreasing, overall animal numbers are increasing, heightening the problem even more. Animal units (AU) have increased over the last five years as shown in Table 2. In 1996 MSU farms housed 1,480 animal units. The animal numbers vary due to research projects, newborns and production. In 1999 the number of animal units heightened to 1,796, then decreased in 2000 to 1,678 (Figure 8). Many of the livestock are kept for production and not always used for research purposes. As of 2001, animal units are at their peak of 1,798. The current equation of animal unit change over time is: y=77.486x+1336.5, indicating an increase of 77 animal units per year.

The decrease in acreage without the subsequent reduction in livestock exacerbates the problems faced by the MSU farm system and a subsequent accumulation of P. For every piece of land lost from production, there should be an equivalent reduction in livestock to balance for the phosphorus that would typically have been recycled on the land area. For example, Powell et al., found that approximately 0.71 ha or 1.75 acres is required to properly recycle the phosphorus excreted by a lactating cow fed a P adequate diet. Adding supplemental P beyond the feed requirement increases the cropland area required to recycle the manure P. Thus, if the initial system is balanced, one lactating cow or an equivalent source of phosphorus, should be taken out of production for every 1.75 acres lost. Thus when the Animal Health Diagnostic Laboratory was built on field E38, a 9-acre field, just over 5 lactating cows should have been taken out of production. However, this has not been the trend seen on the MSU farms. While acreage has been decreasing, the overall trend of animal units is increasing without increasing nutrient exports.

The lack of compensation for reduction in land-base has led to the concentration of manure nutrients on less acreage and a subsequent build up of soil phosphorus levels. To adequately recycle nutrients, removal rates must be equivalent to production. The average rate of P_2O_5 removal based on the 2001 crop plan is 51.1 lbs/acre (Table 7). Production levels for the three different assessments of nutrient production, each resulted in a different P_2O_5 value. Mid West Plan Service-18, 1985 edition predicted 142,577 lbs for 2001(Table 8). Based on a removal rate of P_2O_5, 2,790 acres are required to adequately recycle P. Mid West Plan Service –18, 2000 edition estimates a production of 127,961 lbs of P_2O_5 (Table 9), requiring 2,504 acres to properly recycle P. Manure analysis assessment revealed the highest estimate of P_2O_5 production at 153,721 (Table 13) and requiring 3,008 acres based on average crop removal data to adequately recycle the P nutrient. MSU farm's currently maintains 1,377 acres for manure application and nutrient recycling, obviously resulting in the over application of nutrients.

The application of more manure on less land has increased the nutrient application per acre. Because of the increased nutrient application, the soil test phosphorus levels of the MSU farm fields have increased. Soil test phosphorus levels over the last 10 years show a yearly increase of approximately 4.5 lbs of Bray P/acre/year (Table 17, Figure 9). Soil test phosphorus levels were taken from the last 10 years and weighted according to the number of acres that had been tested for each year. The weighted average was then utilized to look at the overall trend of soil phosphorus levels. At this rate, if the farms were to become compliant with GAAMPs and manure applications ceased to fields which tested 300 lbs of P or more, it would be a short time before all fields were beyond the P threshold level for manure application.

The soil test phosphorus results show there is reason for concern. However not all fields are tested every year, and some fields have not been tested at all in the last 10 years, thus more analysis needs to be done. Utilizing the Mid West Plan Service-18, and crop removal values, a balance was done to see if, according to book values, MSU farms are generating more phosphorus than can be utilized by the crops. The balance shown in Table 15, looks at the 1985 version, the 2000 updated edition of MWPS-18 and manure analysis levels. All three balances revealed nutrient P production in excess of what was utilized by the crop rotation for 2001. However, it has been noted that the book values of nutrient content can be different from true excretion levels due to different diets and management practices and thus manure analysis results were compared against the book values to account for potential feed management differences. The comparison of book values with manure analysis levels saw nutrient predictions of book values actually lower than the manure analysis results. In other words, P production is greater than originally predicted by book values. This also means P is likely being supplemented beyond livestock requirements, which will increase the amount of land required to adequately recycle manure P from each animal. A closer look shows that there is a significant difference in the manure analysis levels over the book values. The manure analysis shows P production is 62% higher than what was predicted by book values.

This research project has shown that MSU farms produce between 127,000 and 154,000 pounds of P_2O_5 annually. In 2001 there were approximately 1798 animal units (see table 2) on the farms and there were about 1377 acres in crop production. Furthermore, soil test data over ten years shows that the weighted average soil test phosphorus is about 150 pounds of Bray P1 per acre and it is increasing by 4.5 pounds per year. Average P_2O_5 removal by the crop produced is 51.1 pounds P_2O_5 per acre. In 2001, animal on MSU farms produced more than 58,000 pounds of P_2O_5 in excess of crop removal.

MSU farms are an unbalanced system, and the problem is getting worse. MSU farms have a definite manure P excess issue. This has been seen with the increase in soil test levels over the last ten years, the balance of crop removal versus book values and manure analysis levels. The imbalance will continue unless some action is taken to reduce P production or some exportation of nutrients out of the system occurs.

CHAPTER 7: LIMITATIONS AND IMPLICATIONS OF A CNMP ON MSU FARMS

Throughout the development of this plan, many communication barriers were encountered. Improvement in communicating plans of facility expansion, changes in livestock numbers or animal management, would greatly improve efficiency of planning. Leaking water for example, decreased available storage time in the structure and should be brought to the attention of the facility management. Significant changes in animal numbers should be made known to the land management as well, as changes affect the volume of manure produced. Livestock numbers will vary depending on research, reproduction rates, and farm management of each facility. Numbers in some facilities fluctuate significantly throughout the year, as in the case of BCRC. All of the livestock facilities undergo some fluxuations throughout the year; but the extent of the change is unknown. Typically, one person oversees a farm. MSU farms' has 9 individual people making decisions about the goal of their livestock facility without conferring with the other farm managers as to their plans. Changes occurring at one facility are not likely known by the others, but Land Management must deal with whatever changes occur in manure production and crop management.

Planning for manure application and crops to be grown is also difficult. Each facility requests a volume of feed that will be needed for the following crop year, but acreage is limited and yield goals are not always met. In a typical farm setting, if feed is limited, animals are sold to compensate. The problem arises as to which farm has to sell animals and how many must go. This can be challenging when each facility has already set goals and plans for the year.

Implementation of a CNMP can be challenging. The sources of manure on MSU farms are many and varied. Some facilities have long-term storage and some require daily haul. The labor form includes students and professionals, and the plan is not always well communicated. It has not been unusual for some land to be double applied and some to be skipped. Nonetheless, the key to implementation of the plan is good communication at all levels.

Ultimately, decisions affecting the farms are made at levels much higher than farm management yet have significant impact on nutrient balance. There are more animals on the farms than the land can support. The managers have no control on the number of animals or the land on which to apply manure. In order to balance nutrients, the animal numbers need to be reduced or nutrients must be exported or a combination of the two must be implemented.

CHAPTER 8: CONCLUSIONS

MSU farm system will benefit from the implementation of a CNMP. The plan shows that the problems are, primarily with the Dairy, Swine, and Poultry facilities. There are phosphorus issues on MSU farms. The rising STP levels over the last ten years are one indication that P is out of balance. The overall increasing STP trend is approximately 4.5 lbs P_2O_5/acre/year. The rising STP levels are due to the overproduction of manure P nutrients beyond crop P removal rates.

Objective 1: An estimate of total P production and P removal for MSU farms has been presented. The estimate of P production was done using 3 different methods and they range from 128,000 lbs (MWPS-2000) to 154,000 (manure analysis). Removal for 2001 was estimated to be 69,535 lbs P_2O_5. This is an imbalance of 58,426 lbs (MWPS-2000) to 84,186 lbs (manure analysis) P_2O_5.

Objective 2: Soil Test Phosphorus levels were determined for MSU farms by analyzing existing data. The weighted average level is between 130 and 150 lbs/A and it is increasing 4.5lb/A/year.

Objective 3: A CNMP for MSU farms is presented in Appendix A.

Objective 4: Two Software programs were compared. The intended purpose of the programs differs, and consequently there are advantages and disadvantages based upon the use to which they are put.

All three P-balance methods reveal excess P production. MWPS-18, 1985 edition shows an excess of 73, 042 lbs P_2O_5; MWPS-18, 2000 production levels are in excess by 58,426 lbs P_2O_5/year and manure analysis results reveal P production in excess by 84,186 lbs P_2O_5.

The trend of increasing animal units and decreasing land area foretells an even greater future P imbalance for MSU farms. Limited crop varieties are grown on the MSU farms in an attempt to meet livestock nutritional needs, which further constrains the system. MSU farms are unable to produce all livestock feed required to meet livestock needs and thus there is a need to import feed.

At this time MSU farms are an unbalanced system, and the problem continues to deteriorate as land is removed from production and livestock numbers continue to rise. This trend will only increase the phosphorus levels of the farm fields and the potential for non point source pollution.

CHAPTER 9. RECOMMENDATIONS FOR MSU FARMS

There are several methods that MSU farms could utilize to reduce the imbalance. Most likely, a solution consists of a combination of several solutions. The first is to reduce the production of nutrients. This can be done by reducing the number of livestock present on MSU farms, and reducing the nutrient content of the feed that is being fed.

Reduction in animal numbers would reduce production of nutrients as a whole. The potential removal of livestock below sustainability numbers for a period of time would permit fields above the allowable manure application threshold an opportunity to recover and move to a lower threshold range. Once all fields have recovered and are within allowable manure application range, animal numbers could be brought up to sustainability levels, but not beyond, in order to maintain a balanced system.

Livestock diets should be made to meet the NRC (National Research Council) basic dietary requirements for growth and production. Reduction in feed nutrient content will also reduce the nutrient excretion content of the manure.

Application of manure over a larger area will reduce the nutrient concentration level being applied in any one area. Acquisition of land may not be feasible, but another possibility is to haul manure to other MSU farms land, off campus. This raises the cost of manure handling, and would have to be assessed. There is the potential of applying nutrients to other farmer's land nearby, but there are few farms within a close proximity of MSU campus. Also this option would require the adherence of that farm's schedule and guidelines.

A more sustainable solution is to compost some of the manure, especially that which is hauled daily, and sell or give the compost away. Exporting the nutrients through a value added product is a potential long-term assistance to the P balance issue. However it is not likely solve the entire P problem. The potential market for compost could be huge, if connections can be made and kept. Exporting of nutrients in the form of compost could result in increased public relations with individuals and businesses, while reducing the nutrient problem on MSU farms.

An additional way to balance the P-budget is by maximizing P removal from crop uptake through the intensive management of crop type and rotations. Although this method is also not likely to solve the P issue, it can help to increase removal of soil P.

APPENDIX: CNMP

Farm Details

Michigan State University is a major agricultural research institution with various types and numbers of animals on its farms. Much of the land and many of the animals are located at the MSU campus in East Lansing, MI. It has experienced a substantial growth of non-agricultural population adjacent to its agricultural land. Okemos High School, a $35 million structure completed in 1995, is just 0.5 miles from MSU farms. A proposed $200 million golf course and up-scale housing development is proposed directly across Hagadorn Street from the farms and about 0.25 miles from the beef cattle research center. The encroachment of non-agricultural population in close proximity with University farms has a high potential of increasing scrutiny and conflicts.

MSU farms are located south of the MSU campus, in East Lansing, Michigan. MSU Farms are bounded by Collins road to the West, Hagadorn road to the East, Mount Hope road to the North and Sandhill road to the South. (Figure 4 map of farm, Figure 5 aerial photograph of farms, and Figure 6 topography map of farms).

MSU land base is utilized for the application of manures, crop production for the purpose of livestock feed, and some grain for export. Crops grown on MSU farm fields are primarily dictated by the amount of feed needed by each of the livestock facilities. However, some feed is also brought in from off-campus to meet the nutritional requirements of all the livestock facilities.

University farm contains eight different research, teaching and production livestock facilities. These facilities include, poultry/mink, sheep, swine, dairy, beef cattle, cow/calf, equine and veterinary farm. Animals included within these facilities are:

mink, ferrets, turkeys, chickens, quail, pheasants, sheep, donkeys, swine, dairy cattle, beef cattle, and horses.

The MSU livestock pavilion, located on the corner of Forest road and Farm Lane, must also be included in this plan. The pavilion, typically rented out for weekend livestock shows, is a large contributor of nutrients in the form of manure, feed, and bedding materials. These nutrients are applied to University farmland and thus contribute nutrients to the system.

Animal numbers vary throughout the year at each of the facilities depending on birthing times, buying and selling of animals, or as in the case of the pavilion, date of shows and number of participants. These factors contribute to fluxuations of manure production volumes.

Each year animal inventories are taken from the farm facilities around June 30th; these numbers will be utilized for manure generation purposes throughout the year, except for the Beef Cattle Research Center (BCRC) and the pavilion. The BCRC tends to be at a low point for the year at the time inventory is taken, so an average number of animals for the year will be used. This will give a more accurate head count to determine yearly manure production for the BCRC. The pavilion manure generation will be calculated using the number of days animals are present and the average number of animals present at the shows. Based on animal inventory data (Table 1), MSU farms consisted of just over 2100 total animal units (Table 2), in 2001.

Pavilion numbers were calculated using the number of show days with an average count of animals at each show. There were 54 days when shows were occurring, and an average of 250 head at each show, which averages out to approximately 37 head per day for one year. This accounts for the animals present, however the majority of material being hauled out of the pavilion is bedding material. Nutrients contributed from bedding were not accounted for in this table.

Overview

MSU farms are primarily used for the purpose of teaching and research, but operate similar to a production facility. The seven different livestock facilities operate as separate units, but are all connected by the University farmland base. While each farm operates as a single unit, the University land managers connect with them for the purpose of hauling manure and crop production for livestock feed purposes.

The University land manager utilizes projected feed requirements from each of the farms, to produce the collective feed needed for the livestock facilities. The goal of university farms is the development and maintenance of a balanced livestock/crop system; attempting to maximize livestock feed production, with manure generated nutrients while minimizing potential environmental and human health problems.

Farm Headquarters Map

Attached is a map showing the individual livestock farms and fields as labeled by MSU farm's Land management (Figure 4). As well as an aerial photograph of the University farm fields and facilities (Figure 5).

<u>Animal Outputs</u>

An animal inventory list is attached showing species, weight, production level and number of livestock (Table 1). Amount of manure generated was calculated using the animal inventory and Mid West Plan Service 2000 for Manure Characteristics for total manure production per day and per year. Also included is the total amount of manure hauled from each facility, as calculated by University farms land management (Table 11). The loads of manure taken from each facility were counted and periodically weighed to verify the approximated mass value. Total gallons hauled were based on capacity of the spreader and liquid level.

Water control measures

The new swine and horse facilities both have rain gutters to direct rain to each side of the barn. The dairy farm has a sewer drain at the low spot in the front of the facility, this water is sent to the East Lansing Sewage Treatment Plant, but may contain manure nutrients from the barns. All liquid pits are covered or enclosed, to prevent excess precipitation from filling the pits early and diluting the nutrient content of the manure.

Animal Mortalities

Swine farm composts animals that die. The Dairy, Horse and Sheep farm each render dead animals.

Veterinary Wastes

Veterinary wastes are disposed of in sharpies containers or trash depending on contents. However, some veterinary wastes have been found in pits at the dairy farm.

Collection

Method of collection varies between facilities. There are several liquid storage pits; most of the facilities have some manure pack or solid manure with bedding and some manure directly deposited on pastures by grazing livestock.

Dairy Barn

The dairy barn has several different ways of handling manures. Tie stalls have a gutter system that is cleaned three times per day on a regular basis, except for three months when some of the animals are out on pasture. When animals are on pasture the gutter system is cleaned twice daily. The Dairy North, Dairy South and Dairy Heifer pens are grated floors with pits underneath, bags with sand are available in stanchions for the cattle to lie on, and no other bedding material is used. The parlor is sprayed down with water and flushed into a pit. The maternity pens, where calves are born are bedded with straw. The manure pack from the maternity pens is added to the daily haul material as the barn is cleaned. The calf pens are also bedded with straw and handled the same as the maternity pen material.

BCRC

The BCRC has two manure handling systems. The majority of the cattle are kept on grated floors with a large manure storage pit below. The other cattle are kept in the wings or pens bedded with shavings.

Cow/calf

The cow/calf facility rotates animals on pastures for most of the year. Cows are brought inside around December for calving. Animals calve in pens bedded with shavings, and are put out to pasture. Most of the cattle are back out to pasture by the end of April. Manure is handled as a manure pack at this facility.

Sheep

The sheep facility is very similar to the Cow/calf facility. Manure is handled as a manure pack, with straw bedding. Animals are kept on pasture for most of the year, and brought in for lambing in early spring. More straw is added to the pens as needed and cleaned when lambing is finished.

Horse

The horse farm only collects manure as a manure pack with bedding. Most of the manure is not collected, but spread by the grazing animals. Horses are rotated through pastures throughout the year. Horses foaling and some horses used for show or equitation classes are kept in stalls. Stalls are cleaned daily and manure is hauled to a pile in the woods where it will undergo some composting and volume reduction. Occasionally dairy parlor water is added to the horse pile to increase composting rate. The pile is hauled 1-2 times per year.

Poultry

The poultry unit has two different manure handling methods. Most poultry are housed in cages and litter falls through to the floor. Some animals are in open floor bedded pens and manure is scraped when the animals leave. There is one liquid pit where turkeys are typically housed; this is pumped one time per year.

One other manure handling system is used with mink. Pens are stacked under a covered structure, and pans are kept under each pen to collect the mink and ferret manure. These are cleaned as needed.

Swine

The old or north swine farm has six different pits under different production areas. The pigs are on slotted floors and the manure is collected in the pits below.

The new or south swine farm has a liquid-solid isolation system. Liquids are drained with the use of gravity and pumps into the slurry storage tank. The nursery is a pull plug system and the total slurry is sent to the slurry storage tank. Solid manure is scraped to one of two covered buildings, from where it is transported to a covered cement slab, mixed with pavilion bedding material, and composted. Some compost materials are utilized to assist in the composting of dead animals.

Pavilion

Most of the pavilion manure is bedding material and is collected as solid manure. The soiled bedding and manure are taken to an allotted field and spread. Bedding material with little or no soiling is transported to the BCRC where it will be reused as bedding for the cattle.

Storage

Dairy farm

Dairy North pit, located on the north side of the main barn is an anaerobic pit with outside fans with dimensions: 136' X 27' X 10', total volume: 36,720 cu ft. The total manure volume this pit can hold is 274,000 gallons with 4-5 months storage capacity. Dairy South Pit, located on the south side of the main barn is an anaerobic pit with outside fans with dimensions: 136' X 27' X 10', total volume of 36,720 cu ft. (Figure 11) The total volume this pit can hold is 274,000 gallons with 4-5 months storage capacity. Dairy Heifer pit, located under the dairy heifer barn to the south of the main barn is an anaerobic pit with fans with dimensions: 112' X 30' X 10', total volume of 33,600 cu ft. The total capacity of the dairy heifer pit is 250,000 gallons and is hauled approximately every 6 months. (Figure 12)

Dairy Parlor pit, located under the dairy parlor has dimensions: 40' X 18' X 8', and total volume of 5,760 cu ft. Capacity of the parlor pit is 43,000 gallons and must be hauled about every 2 weeks (Figure 13).

The Dairy Milk house is adjacent to the parlor pit but is not connected. It has dimensions: 20' X 18' X 8'and total volume of 2,880 cu ft. Total volume of the milk house pit is 21,000 gallons; the milk house is only occasionally flushed, and thus only has to be hauled about once a year (Figure 13). The maternity pens and calf pens are cleaned as needed; this manure is added to the daily hauled manure from the tie stall area. The tie stall area has a gutter system that is cleaned 2-3 times per day, depending whether animals are on pasture or not. This area has no storage time. Some of the manure from the tie stall area has been composted in the past, however the composting area is not covered and the manure is exposed to the elements.

The size of the storage pits seems to be adequate for the number of animals present at this time with 4-6 month storage time. Some manure could be applied late in the summer or early fall if needed to give ample storage capacity if necessary. The parlor pit does not contain adequate storage capacity for winter. Spreading liquid on frozen ground during winters is not recommended and an alternative method or increased pit size is advised. There is no storage f or the tie stall manure necessitating hauling 2-3 times per day. This is risky and definitely not recommended. The idea to compost this manure is ideal, however the compost area should be covered, and have some sort of solid footing or structure underneath to deter leaching and minimize rutting when ground is soft. The amount of manure being hauled on a daily basis may still be a problem because of the time it takes to compost, and the structure will need to be large enough to handle the volume of manure being generated on a daily basis. Composting will reduce the volume being hauled on a daily basis.

BCRC

The BCRC pit is an anaerobic pit located beneath the BCRC barn. The pit dimensions are 200' X 40' X 10', totaling 80,000 cu ft (598,400 gallons). The BCRC pit is hauled about every 6 months, which gives ample planning time for spreading, and enough storage for the winter. (Figure 14)

The BCRC wings are cleaned about every six weeks. This gives some time to work around the weather, but not enough to make it through the whole winter. Another strategy or plan should be set up to better manage the solid manure at the BCRC. One possibility may be to add it to the dairy compost pile, or start a composting area at the BCRC.

Horse

The horse barn stalls are cleaned once a day and the manure is hauled to a manure pile hidden from site by surrounding trees. The manure will self-compost, reducing the total volume of the pile. The pile is hauled as needed. However, there is no barrier beneath the pile to prevent movement of nutrients downward, and there is no cover directly above the pile thus exposing it to the elements and allowing for potential runoff. Manure has been piled in this same location for many years, so the potential of downward movement is high. The plan of action is a good one, except a structure or barrier of some kind should be kept beneath the manure to prevent or reduce the potential of leaching. All horse manure is handled as a solid (Figure 20).

Sheep

The sheep barn is cleaned after lambing and all of the animals are put out to pasture, usually in May. This is a good time to apply the manure where needed at planting time. All manure is handled as a solid for the sheep farm (Figure 23).

Poultry

The poultry unit hauls about half a load per month. There is no storage area during the winter months, and thus manure is applied year round or stockpiled when fields are wet or in production. The poultry unit also maintains a turkey liquid tank, which holds 3,000 gallons and is typically hauled 1-2 times per year (Figure 22).

The turkey tank seems to be adequate for the number of turkeys present. Although a very small amount of volume produced each month, some method of storage should be developed to maximize use of the nutrients.

Cow-Calf

The cow-calf facility maintains animals on pasture for the majority of the year. Animals are brought inside in December, where they are kept until calving and then returned back to pasture after calves are born, typically in April. Pens are cleaned after the animals are put back out to pasture. All manure is handled as a solid or manure pack.

Swine

The old swine farm still houses some pigs, but all are on pits. There are six pits at the old swine farm.

Pit 1- Farrowing barn small pit, capacity 2,000 gallons

Pit 2- Farrowing barn large pit, capacity 10,000 gallons, and dimensions: 12' X 12' X 12'

Pit 3- New Farrowing, has two 1,000-gallon pits.

Pit 4- New Finishing, capacity of 30,000 gallons, dimensions: 10' X 8' X 54'.

Pit 5- Lane Septic, capacity 13,000 gallons, and dimensions: 12' X 12' X 12'.

Pit 6- Breeding Septic, capacity 8,000 gallons.

Each of these pits is hauled about every 6 months.

(Figure 15)

(Dimensions of Slurry Storage Tank or capacity)(Figure 16)

The new swine farm has a large slurry storage tank that must be hauled about every 5 months, and a separate solid covered area where solids which are composted on a concrete covered structure, or taken straight to the field depending on time and space availability. There are some problems. The compost tends to take longer than planned, causing excess solid manure to be stockpiled outside the covered area or 'hot' compost to be applied to fields.

Pavilion

The pavilion is rented out for weekend shows; amount of manure generated varies depending on the number of shows and animals present at each show for the year. The pavilion has small concrete bunkers where manure is dumped when the pavilion is cleaned. This allows for some storage of manures, but it is open to the elements. Leaching is prevented by the impermeable concrete surface. However the potential for nutrient rich runoff from draining gutters and the concrete surface risk penetrating the nearby drainage ditch (Figure 21). Manure generation from this facility varies significantly over the year and from year to year.

One management strategy that has been implemented is the recycling of some of the pavilion bedding. This greatly reduces the volume of material that has to be hauled onto the field at any particular time. The bedding material that is not soiled or only slightly soiled is being reused by the BCRC.

Treatment

Generally, treatment to the manure prior to application is minimal. The primary form of treatment is physical agitation to all of the liquid storage pits prior to pumping. The other treatment done to some of the solid manures or manure packs is composting. Although some ozonation has been done on a small amount of swine manure. The majority of the solid fraction of the swine manure at the new facility is composted. Minimal composting is being done at the dairy farm, however lack of overhead cover from the weather is a detriment to the speed and consistency of the material. There is also concern of runoff from the composting area.

Transport

Equipment used for manure transport (Table 10).

Method of application

Both solid and liquid manure are typically surface applied or broadcast. Generally this is followed by incorporation within 3 days for liquid manures and within 7 days for solid manure. Injection of dairy manure has been attempted and was somewhat successful, there were some problems with plugging hoses, additional agitation was being utilized to help reduce particle size.

Frequency of Hauling

The University land management workers apply most of the manure hauled onto the University farm fields. However, facilities that require frequent hauling will haul the manure themselves. Land management allocates fields for the individual farm workers to apply frequently hauled manure in order to prevent the overapplicaton of manure to the same fields.

Dairy Regular: gutter manure from the dairy tie stalls is hauled 2-3 times per day. Workers from the MSU dairy farm haul this manure regularly. The Dairy North, and Dairy South: pits are hauled out every 4-5 months. The Dairy Heifer: pit is hauled about every 6 months. Dairy Parlor: is hauled about every 2 weeks. The Milk house: is only hauled about 1 time per year.

Beef Cattle Research Center: pit is hauled every 6 months, while the bedded wings are cleaned out about every 6 weeks.

Horse stalls: are cleaned on a daily basis and a horse farm worker takes it to the pile and dumps the load. The pile is hauled as needed, and at least once a year is completely cleaned by the land management workers.

Sheep pens: are cleaned once a year.

Half a load of Poultry manure is applied once a month by the poultry farm manager. The turkey tank is pumped and applied by the land management workers 1-2 times a year.

Conservation Practices on Fields used for Manure Application

MSU farms use several methods of conservation to conserve soil and minimize any nutrient movement. Buffer and or filter strips near and around areas of standing or moving water and along ditch banks. No-till is used in several fields to minimize soil loss and maintain soil structure and moisture. Incorporation of manure within 1-3 days also reduces potential for nutrient movement.

Soil

Table 4 shows soil types, slopes, and soil test phosphorus value. Most of the soils present on MSU farms are medium textured with a range of 0-6% slopes. Soil test values vary around the farm with the highest fields (300+) all located on the east side of College Road. There are a few water bodies present on the MSU farmland area, and dispersed areas of wet ground.

Water Quality

Topography (Figure 6)

University Farm fields have dispersed areas of wet spots where water may stand after a rainstorm for short periods of time. Areas of concern when trying to minimize potential of nutrient runoff and erosion include the Banta Drained area and areas that appear to drain toward the Herron Creek which eventually drains to the Red Cedar River. These are the primary areas where nutrients have the potential to be moved off-site. The Banta Drain drains the section of fields on the corner of Jolly and Collins Rd. This area includes fields W70-W80 and fields W56-W58. The area is drained toward the corner of Jolly and Collins Rd where a large grated area flows into a drainage ditch. There is a 10' area around the drain where grass is kept in place to reduce nutrient loss into the drainage ditch. However the rest of the drained area is farmed. In average or dry growing seasons this practice may be acceptable, but in the case of a wet and rainy season, it is likely that some nutrients are lost to the drainage ditch.

The area south of the Sheep farm, encompassing fields E62, E82-1 and E82-2 drains toward the Herron Creek area. Herron Creek empties into the Red Cedar River.

The area south of the sheep farm that drains toward the Herron Creek is in pasture, and it is always covered by vegetation, minimizing nutrient losses.

Another area of concern is south of Jolly Rd, fields E124, and E126, where a drain runs along the west side of these two fields. A buffer area should be implemented to minimize any potential loss of nutrients from these fields.

There are several water bodies present on University farmland area. The main water areas are south of Jolly Rd, on the East and West Side of College Road. These areas are not farmed, but are most often used for research purposes. These areas are shown as W98, E90-1 and E90-2 in Figure 4. Another small water body present is located behind the BCRC between fields E27-1 and E27-2. Both of the fields are extremely high in phosphorus and pose a large threat to the quality of this water body.

Surface Cover

A large portion of the University farm fields are planted into pastures utilized by the beef cattle, sheep, horses and dairy cattle. These pastures are seldom tilled for the purpose of row crops. It is also the practice of the farm managers to leave crop residues or stubble in the field as long as manure is not applied; when manure is applied, the schedule is to till the manure into the soil within 3-7 days to prevent nutrient loss. This leaves several fields tilled and susceptible to winter erosion because of the manure that is applied after harvest but prior to frozen ground and snow.

Winter spreading is occurring on University farms. There are several fields that should not be utilized for winter spreading due to potential water issues or already high soil test phosphorus levels (Figure 10). Fields E90-1 and E90-2 do not receive manure applications at any time. E27-1 and E27-2 already have high phosphorus levels and a water body is present, so the potential of runoff and erosion of phosphorus exists. The Banta Drain area includes fields W70-W80, as well as fields W56-W58. The area south of the sheep farm drains toward Herron Creek, fields E62, E82-1 and E82-2. Fields E124 and E126, should also be exempt from winter spreading due to the drainage system to the west of these fields.

Fields that are fairly level and do not contain drainage or wet areas and are not already high in phosphorus are better suited for potential winter spreading events. (Table 5) These fields suit the specifications of fields utilized for winter spreading, however they may not suit the needs of the farm to spread manure on. Many of these fields are allocated for pastures, and some are planted to alfalfa that restricts these fields from the list of possible fields to spread manure on.

Manure P application

Phosphorus generation levels for 2001 were assessed with three different tools, MWPS-18, 1985 book values, MWPS-18, 2000 book values and manure analysis test values.

Total manure P_2O_5 generation as calculated with MWPS-18, 1985 is approximately 142,500 lbs of P_2O_5. Total manure P_2O_5 generation as calculated with MWPS-18, 2000 approximately 128,000 lbs of P_2O_5. Manure P_2O_5 generation as calculated with manure analysis results total approximately 153,700 lbs of P_2O_5.

As shown by the different analysis assessment for phosphorus production, MWPS-18, 1985 is very close to the manure analysis results generated at MSU farms.

Manure N application

Utilizing the same methods as were used for calculating phosphorus levels, manure N levels can also be assessed.

MWPS-18, 1985 calculated an estimated Nitrogen production of 225,000 pounds.

MWPS-18, 2000 resulted in approximately 273,000 pounds of Nitrogen being produced.

Manure Application Methods

Manure application methods consist of broadcasting the solid or liquid manure, followed by incorporation within 1-3 days. Injection of some liquid dairy manure has been partially successful.

Land Application Management

Nutrient Budget: a nutrient budget is a method of predicting the amount of nutrients that will be required for a crop plan. For 2001 crop plan, 274,587 lbs of Nitrogen, and 70,585.4 lbs of P2O5 were required by the crops.

Calibration of equipment

In most cases no calibration is done. The rate of manure application is set by the Power Take Off (PTO) speed and tractor speed. Personnel need to be mindful of both parameters. The end of each load should be marked so spreading the next load begins in the right place. One method uses an orange cone. Every time the employee hauling the manure finishes spreading a load they are supposed to move the cone so the next employee knows where to begin spreading their load so as not to overlap or miss areas.

Application schedule

There is not an actual application schedule. Manure sources are hauled as they become filled or just before planting or shortly after harvest. Most pits have an approximate time frame but there is not an exact date. Schedule varies depending on animal numbers, health, feed wastage, bedding materials, and technical problems, such as water faucets leaking.

Application rates by field:

Application rate is variable depending tractor speed and the Revolutions per Minute (RPMs) of the tractor. Unfortunately, this can cause the nutrient concentration level to vary between fields and even within a field if the operator chooses to change speeds or RPM levels. Not knowing the application rate is probably the greatest shortcoming in accomplishing effective management of manure nutrients. (Jacobs, 1995)

Driving at a higher gear is likely to reduce application rate unless RPMs are high. Traveling at a lower gear with higher RPMs will increase the application rate per acre and thus the concentration of nutrients that are being applied.

Emergency Action Plan

MSU farms' does not have a written Emergency Action plan in place. What is presented here is a rudimentary plan.

The first step is an assessment of a situation. Determine the severity of the situation. How much manure has been lost? Holding tank capacities range from 3,000 gallons at the poultry unit (Figure 22) to 587,000 gallons at the BCRC (Figure 14).

Secondly, control the situation. Stop manure pumps. Close any valves that remain open. Transfer manure liquid to another tank, storage facility. Plug any holes or shut off the water in case of a waterline break. On most of MSU farm pits the pump is not on site, thus, these facilities need to be in contact with MSU land management to get the proper equipment to manage the spill or leak. They have access to pumps and transport vehicles to remove overflowing materials as well as large dirt moving equipment if necessary.

Next, contain the spill. Build a containment dam, ditch or stream to stop or minimize any further movement of the contaminant, especially in sensitive areas. Tile drainage areas should be sought out and preventive measures taken to minimize flow into tile drains. The containment basin should be down slope from the affected area. Limit the area impacted. The use of absorbent materials, such as sawdust and old feed, will also help to reduce impact and flow of spillage. The availability and use of a dirt pile to barricade ditches or sensitive draining areas will improve reaction time and greatly reduce the size of the affected area.

MSU farmland management has taken into account sensitive sites as well as potential for damage from large storage facilities. Due to the large volume of the new or south swine farm and the potential flow site into a sensitive wetland area, a dirt mound has been put into place in the case of an emergency situation. In the case of a spill, the flow would be directed into the ditch, from which it can enter directly into tile lines that flow into the Okemos wetland area. Also, the south swine facility is an above ground storage, so it has the capacity to unload a large volume of manure in a very short period of time.

The old or north swine facility has two small lagoons at the test station area. These primarily contain water but can receive runoff from the upland facilities. The lagoons are presently left and allowed to overflow onto the surface. Any breaches that occur at the north swine facility would flow in an easterly direction from site of breech and into the nearby ditch.

The Dairy barn pits would tend to flow to the east if any breach or spill were to occur. The primary concern is the manhole, which dumps directly into the East Lansing Waste water treatment facility. The occurrence of spill would cause an influx of flow to the treatment facility and potential overflow at that site. To the west of the barns are two other manholes, which also flow to the north. In the instance of a spill or silage leachate that entered either of these areas, a shut off valve is available just south of the dairy pasture area and can be shut off. The flow from the north manholes does come above ground for a short distance in the pastures to the north. This is another potential point of interception before the material goes off site.

BCRC has a very large underground storage pit. If the pit were to breech the waste would travel to the south and into a drainage ditch. The scale house pit would have the same flow route, but the volume is much smaller. There is not a nearby sensitive area, which is a direct route of concern, however tile drains run nearby and infiltration into tile drains is always an issue. Because the pit is below ground level, a catastrophic failure is unlikely.

The poultry unit contains one small 3,000-gallon tank. In an event it was to leak it would flow to the south under the expressway. This pit is small, however the nutrient concentration is high and thus precautions need to be taken.

After assessment, controlling, and containing the spill has occurred, the spill or leak should be properly reported to the necessary agencies. If the release reached any surface waters, streams, well casings or other sensitive areas it needs to be reported immediately to the state environmental management agencies. Any manure spills on public roads should be reported immediately to the local authorities, such as the county sheriff. Other spills, which did not affect sensitive or water reservoirs, should have a summary report prepared and filed for future reference and to document the actions taken. In the case of MSU farms, the order of contact in the case of a spill would be:

1. Individual Farm Manager of the facility

   Swine: 355-7485; Sheep: 355-7477; Dairy: 355-7473; BCRC: 353-2245; Poultry: 355-0360; Horse: 355-7484; Pavilion: 432-5566; Purebred: 355-7452.

2. Land Management Manager: 719-2153

3. Department of Police and Public Safety: 911

4. ORCBS: 355-6651

5. Michigan Department of Agriculture's Agriculture Pollution Emergency Hotline: 1-800-405-0101

6. Michigan Department of Natural Resources: 1-800-292-4706

See Figure 17 for an Emergency Contact form.

Finally, Clean up can begin. Assess the full impact and restore the affected area or areas. Collect spilled manure and apply it or return it to storage. Restore damaged areas. Prepare a summary report.

Summary

MSU farms have some problem areas. First are the high soil test phosphorus levels of several fields. The higher P level fields are closest to the farms, which contribute the greatest concentration of nutrients. The three prime areas are the swine farm, the Dairy farm and the poultry farm. This is risky when water sources are nearby or the potential of runoff to tile drain exits. An even larger issue is the continued application of manure to fields already in the high phosphorus level category of GAAMPs. The University farm system is not in phosphorus balance. The number of livestock present is greater than sustainable levels on the farmland base. This imbalance contributes to rising STP levels in the fields.

Daily haul at the dairy barn is a potential problem. The lack of storage for this facility is critical in Michigan due to the varying weather conditions. Applying manure to frozen or snow-covered is not an acceptable continued practice. A storage facility needs to be put into place in order to give a greater window for application.

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TABLE 1. ANIMAL INVENTORY (2001)

Livestock Farm	Livestock type/ Production Phase	No. of head Present/day	Avg Weight Per head (lbs)
Poultry	Chickens	190	2
	Leghorn Adults	1165	4
	Quail	500	3
	Pheasants	9	3
	Turkeys	790	20
	8 week Turkeys	9	4
	Total	**2663**	
Mink	Mink	788	4
	Ferrets	3	4
	Total	**791**	
Cow/Calf-	Angus Calves	60	500
Purebred Beef	Angus Herd Bulls	2	1100
	Angus Yearling Heifers	13	750
	Angus Cows	57	1100
	Angus Leased Bull	1	1100
	Hereford Calves	94	500
	Hereford Yearling Bulls	2	1100
	Hereford Herd Bulls	4	1100
	Hereford Yearling Heifers	15	750
	Hereford Cows	57	1100
	Hereford Cows Leased	36	1100
	Hereford Bull Leased	1	1100
	Fall Calves	19	500
	Commercial Cows	80	1100
	Gomer Bulls	3	1100
	Total	**444**	
Sheep	Mature Rams	4	100
	Yearling Rams	2	50
	Ram Lambs	21	100
	Wether Lambs	13	25
	Mature Ewes	125	100
	Yearling Ewes	62	50
	Ewe Lambs	40	25
	2001 Lambs	130	25
	Teaser Ram	3	100
	Total	**400**	
Swine	Sows	171	275
	Bred Gilts	198	250
	Boars	21	350
	Gomer	1	350
	Baby Pigs	101	12
	15-30 pounds	138	23

TABLE 1 (contd)

Livestock Farm	Livestock Type/ Production Phase	No. of head Present/day	Avg Weight per head (lbs)
Swine	30-75 pounds	333	53
	75-125 pounds	211	100
	125-200 pounds	289	163
	200 + pounds	185	225
	Total	**1648**	
Beef Cattle Research Center	Yearlings	221	750
	Calves	186	500
	Steers	14	750
	Additional Yearlings	179	1100
	Total	**600**	
Dairy	Cows	178	1400
	Heifers	178	750
	Fistula Cows	2	1400
	Bull Calves	18	500
	Research Cull Cows	6	1000
	Total	**382**	
Horse	Adult Arabs	51	1000
	Yearling Arabs	12	500
	Newborns	16	350
	Belgium Adults	5	2000
	Belgium Newborns	2	1000
	Miscellaneous	9	1000
	Total	**95**	
Pavilion	250 hd @ 54 show days/yr	**37**	1000

Table 1: Animal inventory numbers were taken June 30th, 2001. Numbers are a head count of animals present and are used as an estimation of total number for the year, except the Pavilion and Beef Cattle Research Center numbers, which are variable, thus the yearly average was used. Weight is the average weight in pounds for each production phase group. Number of livestock was totaled for each facility.

*Animal numbers here are the yearly average for the Beef Cattle Research Center facility and Pavilion

hd= head; yr= year

TABLE 2. ANIMAL UNITS BASED ON ANIMAL INVENTORIES (1996-2001)

Livestock		1996		1997		1998		1999		2000		2001		AU
Dairy	**Weight**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**Factor**
Cows	1400	190	266	179	250.6	194	271.6	187	261.8	172	240.8	178	249.2	1.4
Heifers	750	154	115.5	168	126	184	138	187	140.25	180	135	178	133.5	0.75
Bulls	1400	0	0	18	25.2	0	0	26	36.4	3	4.2	0	0	1.4
Steers	750	5	3.75	0	0	18	13.5	9	6.75	18	13.5	0	0	0.75
0-18 months	500	2	1	0	0	5	2.5	0	0	0	0	18	9	0.5
Fistula Cows	1400	0	0	0	0	0	0	9	12.6	18	25.2	2	2.8	1.4
Cull Cows	1000	8	8	10	10	2	2	2	2	2	2	6	6	1
Total		**359**	**394.25**	**375**	**411.8**	**403**	**427.6**	**420**	**459.8**	**393**	**420.7**	**382**	**400.5**	
Poultry	**Weight**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	
Chickens	2	525	5.25	206	2.06	207	2.07	203	2.03	252	2.52	190	1.9	0.01
Chicks	0.5	0	0	130	0.65	50	0.25	100	0.5	87	0.435	0	0	0.005
Leghorn Adults	4	2114	21.14	2600	26	3951	39.51	1027	10.27	943	9.43	1165	11.65	0.01
Quail	3	640	6.4	197	1.97	339	3.39	485	4.85	560	5.6	500	5	0.01
Pheasants	3	0	0	0	0	0	0	0	0	0	0	9	0.09	0.01
Turkeys	20	0	0	0	0	27	0.54	12	0.24	542	10.84	790	15.8	0.02
8 week Turkey	4	0	0	0	0	0	0	0	0	0	0	9	0.09	0.01
Total		**3279**	**32.79**	**3133**	**30.68**	**4574**	**45.76**	**1827**	**17.89**	**2384**	**28.825**	**2663**	**34.53**	
Horse	**Weight**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	
Adult Arabs	1000	28	56	29	58	33	66	38	76	39	78	36	72	2
Yearling Arabs	500	13	13	7	7	16	16	17	17	11	11	12	12	1
Newborns	350	5	5	13	13	19	19	14	14	15	15	16	16	1
2yr olds	750	13	26	18	36	6	12	11	22	18	36	9	18	2
3yr olds	900	8	16	28	56	6	12	1	2	4	8	6	12	2
Belgium Adults	2000	0	0	0	0	0	0	3	6	3	6	5	10	2
Belgium Newborn	1000	0	0	0	0	0	0	0	0	0	0	2	4	2
Miscellaneous	1000	15	30	0	0	12	24	9	18	8	16	9	18	2
Total		**82**	**146**	**95**	**170**	**92**	**149**	**93**	**155**	**98**	**170**	**95**	**162**	

Table 2 (contd)

		1996		1997		1998		1999		2000		2001		AU
Swine	**Weight**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	Factor
Sows	375	142	56.8	135	54	134	53.6	190	76	183	73.2	171	68.4	0.4
Gilts	275	84	33.6	78	31.2	63	25.2	99	39.6	82	32.8	198	79.2	0.4
Boars	350	5	2	10	4	10	4	12	4.8	18	7.2	21	8.4	0.4
Mixed Nursery	40	226	45.2	183	36.6	136	27.2	354	70.8	324	64.8	101	20.2	0.2
Grow-Finish	150	0	0	0	0	0	0	714	285.6	0	0	0	0	0.4
Gomer Boar	350	7	2.8	0	0	9	3.6	2	0.8	5	2	1	0.4	0.4
15-75 # Feeder	45	392	78.4	334	66.8	263	52.6	0	0	463	92.6	471	94.2	0.2
75-125 # Feeder	100	214	85.6	214	85.6	201	80.4	28	11.2	148	59.2	211	84.4	0.4
125-200# Feeder	160	176	70.4	32	12.8	283	113.2	57	22.8	335	134	289	115.6	0.4
200 # + Feeder	250	136	54.4	202	80.8	128	51.2	58	23.2	126	50.4	185	74	0.4
Total		**1382**	**429.2**	**1188**	**371.8**	**1227**	**411**	**1514**	**534.8**	**1684**	**516.2**	**1648**	**544.8**	
Cow/Calf	**Weight**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	
Calves	500	64	32	101	50.5	137	68.5	109	54.5	119	59.5	173	86.5	0.5
Yearling Bulls	750	4	4	4	4	5	5	4	4	3	3	2	2	1
Herd Bulls	1100	4	4	5	5	6	6	4	4	7	7	6	6	1
Yearling Heifer	750	37	37	29	29	40	40	36	36	35	35	28	28	1
Brood Cows	1100	61	61	83	83	83	83	98	98	138	138	114	114	1
Leased Bull	1100	1	1	1	1	0	0	2	2	2	2	2	2	1
Cows Leased	1100	0	0	0	0	0	0	29	29	26	26	36	36	1
Commercial Cows	1100	61	61	80	80	75	75	73	73	94	94	80	80	1
Gomer Bulls	1100	3	3	4	4	3	3	3	3	3	3	3	3	1
Horses	1000	2	2	2	2	0	0	0	0	0	0	0	0	1
Total		**237**	**205**	**309**	**258.5**	**349**	**280.5**	**358**	**303.5**	**427**	**367.5**	**444**	**357.5**	
BCRC	**Weight**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	
Yearlings	750	126	126	0	0	62	62	154	154	22	22	0	0	1
Calves	500		0	0	0	12	6	0	0	0	0	0	0	0.5
Steers	750	74	74	120	120	43	43	128	128	121	121	239	239	1
Cows	1100	38	38	15	15	7	7	9	9	0	0	22	22	1
Total		**238**	**238**	**135**	**135**	**124**	**118**	**291**	**291**	**143**	**143**	**261**	**261**	

Table 2 (contd)

Sheep	Weight	1996 No.	1996 AU	1997 No.	1997 AU	1998 No.	1998 AU	1999 No.	1999 AU	2000 No.	2000 AU	2001 No.	2001 AU	AU Factor
Rams	100	7	0.7	5	0.5	7	0.7	7	0.7	5	0.5	7	0.7	0.1
Yearling Rams	75	4	0.4	6	0.6	2	0.2	4	0.4	1	0.1	2	0.2	0.1
Ram Lambs	50	6	0.3	5	0.25	14	0.7	10	0.5	14	0.7	21	1.05	0.05
Wether Lambs	50	5	0.25	44	2.2	9	0.45	14	0.7	0	0	13	0.65	0.05
Mature Ewes	100	107	10.7	72	7.2	119	11.9	124	12.4	132	13.2	125	12.5	0.1
Yearling Ewes	75	64	6.4	45	4.5	156	15.6	34	3.4	21	2.1	62	6.2	0.1
Ewe Lambs	50	38	1.9	9	0.45	35	1.75	41	2.05	62	3.1	40	2	0.05
Commercial Lamb	50	116	5.8	137	6.85	342	17.1	116	5.8	123	6.15	130	6.5	0.05
Total		**347**	**26.45**	**323**	**22.55**	**684**	**48.4**	**350**	**25.95**	**358**	**25.85**	**400**	**29.8**	
Mink	**Weight**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	**No.**	**AU**	
Adult Mink	4	248	2.48	205	2.05	191	1.91	263	2.63	164	1.64	302	3.02	0.01
Kits	2	679	6.79	462	4.62	502	5.02	599	5.99	465	4.65	489	4.89	0.01
Total		**927**	**9.27**	**667**	**6.67**	**693**	**6.93**	**862**	**8.62**	**629**	**6.29**	**791**	**7.91**	
GRAND TOTAL			**1480**		**1407**		**1487**		**1796**		**1678**		**1798**	

Table 2. Total Animal Units present on MSU farms from 1996-2001 based on animal inventory. Animal Units were calculated based on the Unified National Strategy for Animal Feeding operations factor for animal units of different species and production phases. In some instances the factor was weighted in proportion with livestock weight. Ie. 1,000 lb horse has a factor of 2, thus a 500 lb horse was weighted to have a factor of 1. Weighting the factor gives a more accurate number of animal units. Animal Units were not calculated for the Pavilion. The new structure is fairly new and animals do not reside at this facility year round. The numbers for Beef Cattle Research Center was as inventoried at this time of year. Looking at the change in animal units over time, not manure nutrient production, and since inventories are taken at the same time each year, the actual inventory number taken was sufficient. Animal Units were summed for each year to look at the change over time. (See figure 8) Totals are shown for each farm facility as well as a total for the year.
#= Pounds; BCRC= Beef Cattle Research Center; No.= Number

TABLE 3. ANIMAL UNIT FACTORS

Livestock Type	AU Equivalency Factor
Slaughter and Feed Cattle	1
Horses	2
Mature Dairy Cow	1.4
Swine (>55lb)	0.4
Sheep	0.1
Turkeys	0.02
Chickens (broiler or layer)	0.01

TABLE 3. The animal unit factors used to calculate the number of animal units in Table 2. Factors were calculated using the Unified National Strategy for Animal Feeding Operations 1000 animal unit equivalent factor. The number of animals equal to 1,000 animal units was divided by 1000 to get the factor for 1 individual animal unit.

TABLE 4. PHYSICAL AND QUANTITATIVE FEATURES OF FARM FIELDS

Field	Subfield	Acres	Soil Type	% Slope	Soil Test P	STP year
E14	6	4	Capac	0-3	181	2001
E27-1	7	5	Riddles	2-6	618	2002
E27-2	8	5	Riddles	2-6	636	2002
E30	9	22	Riddles	2-6	217	2002
E32	4	5	Spinks	2-6	543	2002
E34	10	14	Riddles	2-6	181	2001
E36	11	20	Riddles	2-6	471	2002
E40	13	4	Marlette	2-6	69	2002
E42	14	18	Marlette	2-6	275	2002
E44-1	15	13	Riddles	2-6	275	2002
E44-2	16	13	Riddles	2-6	224	2002
E46	18	4	Riddles	2-6	224	2002
E47	19	4	Riddles	2-6	325	2001
E48	20	3	Riddles	2-6		**
E49	21	4	Capac	0-3		**
E50	22	22	Capac	0-3	148	2002
E51	23	24	Capac	0-3	60	2002
E52-1	24	18	Capac	0-3	149	2000
E52-2	25	18	Riddles	2-6	143	2002
E53	26	10	Marlette	2-6	386	2001
E54	27	6	Marlette	2-6	138	2002
E55	29	0	Marlette	2-6	105	2002
E56	30	16	Capac	0-3	128	2002
E57	31	12	Capac	0-3	43	2002
E58	32	12	Riddles	2-6	174	2002
E59	33	12	Capac	0-3	262	2000
E61	34	16	Capac	0-3	78	2000
E62	35	16	Riddles	2-6	149	2000
E64	36	7	Riddles	2-6	148	1996
E65	37	7	Houghton	0-2	116	1996
E66	38	9	Houghton	0-2	217	2001
E67	39	9	Riddles	2-6	69	2001
E68	40	11	Capac	0-3	42	1998
E70-1	41	11	Capac	0-3	46	2002
E70-2	42	12	Capac	0-3	69	2002
E72-P	45	6	Colwood	0-3	86	2002
E73	44	13	Marlette	2-6	55	2002
E74-1	46	22	Capac	0-3	86	2002
E74-2	47	23	Colwood	0-3	124	2002
E75-1	48	18	Riddles	2-6	300	2002
E75-2	49	18	Colwood	0-3	108	2002
E75-3	50	19	Capac	0-3	190	2002

TABLE 4 (Contd)

Field	Subfield	Acres	Soil Type	% Slope	Soil Test P	STP Year
E76	53	8	Marlette	2-6	62	2002
E77	54	10	Marlette	2-6	38	2000
E78	55	5	Marlette	2-6	31	1995
E79	56	12	Marlette	2-6	112	2002
E82-1	57	17	Marlette	2-6	116	2000
E82-2	58	17	Houghton	0-2	154	2000
E84	59	26	Houghton	0-2	139	2000
E85	60	16	Riddles	2-6	254	2000
E86	61	20	Houghton	0-2	131	2000
E87	62	16	Colwood	0-3	181	2000
E90-1	63	45	Udorthents	0-3		**
E90-2	64	40	Udorthents	0-3		**
E90-3	65	15	Udorthents	0-3	217	2002
E90-4	66	5	Capac	0-3	248	2002
E92	67	8	Palms	0-2	428	2002
E116	68	20	Capac	0-3	76	2002
E124	69	10	Marlette	2-6	57	2002
E126	70	34	Capac	0-3	60	2002
W24	71	18	Gilford	0-3	69	2002
W30	72	23	Aubbeenaubbe	0-3	39	2002
W31	73	7	Marlette	2-6	40	2002
W33-1	74	17	Aubbeenaubbe	0-3	254	2000
W34	75	17	Aubbeenaubbe	0-3	247	2000
W35	76	20	Marlette	2-6	33	2002
W36	78	20	Marlette	2-6	50	2002
W40	80	9	Marlette	2-6	65	1995
W41	81	6	Marlette	2-6	26	1995
W42	82	9	Capac	0-3	36	1995
W44-1	83	8	Riddles	2-6	25	1995
W44-2	84	12	Riddles	2-6	66	2002
W46	85	15	Sisson	0-3	36	1996
W47	86	13	Sisson	0-3	53	1996
W48	87	25	Sisson	2-6	57	2002
W50	89	5	Capac	0-3	120	2001
W51	90	34	Capac	0-3	43	2002
W52	91	18	Riddles	2-6	43	2002
W53	92	18	Capac	0-3	64	2002
W54	93	4	Marlette	2-6	80	2002
W56-1	94	9	Capac	0-3	154	2002
W56-2	95	9	Capac	0-3	160	2002
W58	96	6	Capac	0-3	50	1994
W60	103	8	Riddles	2-6	128	2002
W70	104	14	Capac	0-3	108	2002
W71	105	12	Capac	0-3	224	2002
W72-1	106	14	Capac	0-3	224	2002
W72-2	107	14	Capac	0-3	190	2002

TABLE 4 (Contd)

Field	Subfield	Acres	Soil Type	% Slope	Soil Test P	STP Year
W73-T	108	3	Riddles	2-6	95	2002
W75-1	109	14	Capac	0-3	86	2002
W75-2	110	14	Capac	0-3	95	2002
W75-3	111	14	Capac	0-3	73	2002
W76	113	11	Colwood	0-3	131	2000
W77	114	15	Marlette	2-6	20	2002
W78	115	12	Capac	0-3	112	2001
W80-H	118	5	Marlette	2-6	167	2002
W80-J	121	8	Capac	0-3	66	2002
W90-1	122	16	Aubbeenaubbe	0-3	167	2002
W90-2	123	17	Owosso	2-6	148	2002
W90-3	124	17	Capac	0-3	88	2002
W94-1	125	9	Marlette	2-6	64	2002
W94-2	126	9	Marlette	2-6	78	2002
		1377				

Table 4. Physical and Quantitative Features of farm fields gives a list of MSU farm fields as labeled by MSU farm management with subfield, current acreage of each field, most prominent soil type in each field as well as average slope for the prominent soil type and the most recent soil test phosphorus level for that field. STP year column indicates the most recent soil test taken within the last ten years.

*STP= Soil Test Phosphorus

** No soil test available for these fields within the last ten years.

TABLE 5. MSU FARM FIELDS BEST FIT FOR WINTER APPLICATION OF MANURES.

EAST FIELDS			WEST FIELDS	
FIELD	ACRES		FIELD	ACRES
E50	22		W24	34
E51	24		W30	18
E52-1	18		W31	7
E52-2	18		W35	20
E54	6		W36	20
E55	4		W44-2	12
E56	12		W48	25
E57	12		W50	5
E61	16		W51	34
E62	16		W52	18
E67	9		W53	18
E70-1	11		W54	4
E70-2	12		W60	8
E72-P	6		W70	14
E73	13		W73-T	3
E74-1	22		W75-1	14
E74-2	23		W75-2	14
E75-2	18		W75-3	14
E76	8		W76	11
E77	10		W77	15
E79	12		W78	12
E82-1	17		W80-J	8
E84	26		W90-3	17
E86	20		W94-1	9
E116	20		W94-2	9
E124	10			

Table 5. Lists fields best suited for winter manure application based on MARI. These fields have phosphorus loss ratings of low potential for phosphorus movement, making these field locations the best fit for winter manure application.

TABLE 6. MANURE APPLICATION RISK INDEX SUMMARY

TOTAL ACRES BY "MARI" RISK	0	771	17	4	792		
CATEGORY:	V. LOW	LOW	MEDIUM	HIGH	TOTAL	771	Total Low and Very Low

TABLE 6. Manure Application Risk Index (MARI) Summary is a Phosphorus loss risk assessment of potential of Phosphorus movement. MARI was used to evaluate the P loss potential from winter manure applications. Physical and Quantitative Features (Table 4) of the farm fields were used for the assessment. All fields assessed have a potential for phosphorus movement based on MARI.

TABLE 7. FARM FIELDS WITH CROPS AND YIELD GOALS

		2001 Crop Plan			P-rem	Total P
Field	Ac	Crop	YG	Units	Lb/ac	Lbs/field
E14	4	Wheat	75	Bu/ac	52.5	210
E27-1	5	Corn silage	16	Ton/ac	45	225
E27-2	5	Corn silage	16	Ton/ac	45	225
E30	22	Corn silage	16	Ton/ac	45	990
E32	5	Corn silage	16	Ton/ac	45	225
E34	14	Corn silage	16	Ton/ac	45	630
E36	20	Alfalfa	6	Ton/ac	60	1200
E40	4	Corn silage	16	Ton/ac	45	180
E42	18	Corn silage	18	Ton/ac	48	864
E44-1	13	Corn silage	18	Ton/ac	48	624
E44-2	13	Corn silage	18	Ton/ac	48	624
E46	4	Corn	120	Bu/ac	68	272
E47	4	Corn	120	Bu/ac	68	272
E48	3	Pasture, ext. grazed	3	Ton/ac	55	165
E49	4	Pasture, ext. grazed	3	Ton/ac	55	220
E50	22	Grass maintenance	2	Ton/ac	20	440
E51	24	Corn	120	Bu/ac	68	1632
E52-1	18	Pasture, ext. grazed	3	Ton/ac	55	990
E52-2	18	Pasture, ext. grazed	3	Ton/ac	55	990
E53	10	Pasture, ext. grazed	3	Ton/ac	55	550
E54	6	Corn silage	14	Ton/ac	41	246
E56	16	Corn	120	Bu/ac	68	1088
E57	12	Alfalfa	4	Ton/ac	40	480
E58	12	Pasture, ext. grazed	3	Ton/ac	55	660
E59	12	Pasture, ext. grazed	3	Ton/ac	55	660
E61	16	Pasture, int. grazed	3	Ton/ac	55	880
E62	16	Pasture, ext. grazed	3	Ton/ac	55	880
E64	7	Pasture, ext. grazed	3	Ton/ac	55	385
E65	7	Pasture, ext. grazed	3	Ton/ac	55	385
E66	9	Pasture, ext. grazed	3	Ton/ac	55	495
E67	9	Trefoil hay	4	Ton/ac	55	495
E68	11	Pasture, ext. grazed	3	Ton/ac	55	605
E70-1	11	Alfalfa	6	Ton/ac	60	660
E70-2	12	Alfalfa	6	Ton/ac	60	720
E72P	6	Corn	130	Bu/ac	75	450
E73	13	Alfalfa	6	Ton/ac	60	780
E74-1	22	Wheat	80	Bu/ac	54	1188
E74-2	23	Wheat	80	Bu/ac	54	1242
E75-1	18	Wheat	80	Bu/ac	54	972
E75-2	18	Wheat	80	Bu/ac	54	972
E75-3	19	Wheat	80	Bu/ac	54	1026
E76	8	Corn silage	18	Ton/ac	48	384
E77	10	Pasture, ext. grazed	3	Ton/ac	55	550
E78	5	Pasture, ext. grazed	3	Ton/ac	55	275

Table 7 (contd)

Field	Ac	Crop	YG	Units	Lb/ac P-rem	Lbs/field Total P
E79	12	Alfalfa	6	Ton/ac	60	720
E82-1	17	Pasture, ext. grazed	3	Ton/ac	55	935
E82-2	17	Pasture, ext. grazed	3	Ton/ac	55	935
E84	26	Pasture, ext. grazed	3	Ton/ac	55	1430
E85	16	Pasture, ext. grazed	3	Ton/ac	55	880
E86	20	Pasture, ext. grazed	3	Ton/ac	55	1100
E87	16	Pasture, ext. grazed	3	Ton/ac	55	880
E90-1	45	Grass maintenance	2	Ton/ac	20	900
E90-2	40	Grass maintenance	2	Ton/ac	20	800
E90-3	15	Corn silage	14	Ton/ac	41	615
E90-4	5	Corn silage	14	Ton/ac	41	205
E92	8	Corn silage	14	Ton/ac	41	328
E116	20	Corn silage	14	Ton/ac	41	820
E124	10	Corn	110	Bu/ac	65	650
E126	34	Corn	110	Bu/ac	65	2210
W24	18	Orchard grass	4	Ton/ac	64	1152
W30	23	Alfalfa	6	Ton/ac	60	1380
W31	7	Alfalfa	6	Ton/ac	60	420
W33-1	17	Pasture, int. grazed	3	Ton/ac	55	935
W33-2	17	Pasture, int. grazed	3	Ton/ac	55	935
W35	20	ACP Grass-legume imp	2	Ton/ac	20	400
W36	20	ACP Grass-legume imp	2	Ton/ac	20	400
W40	9	Pasture, int. grazed	3	Ton/ac	55	495
W41	6	Pasture, int. grazed	3	Ton/ac	55	330
W42	9	Pasture, int. grazed	3	Ton/ac	55	495
W44-1	8	Pasture, int. grazed	3	Ton/ac	55	440
W44-2	12	Pasture, int. grazed	3	Ton/ac	55	660
W46	15	Pasture, int. grazed	3	Ton/ac	55	825
W47	13	Pasture, int. grazed	3	Ton/ac	55	715
W48	25	Alfalfa	6	Ton/ac	60	1500
W50	5	Soybean	50	Bu/ac	48	240
W51	34	Trefoil hay	3	Ton/ac	55	1870
W52	18	Alfalfa	6	Ton/ac	60	1080
W53	18	Alfalfa	6	Ton/ac	60	1080
W54	4	Corn silage	16	Ton/ac	45	180
W56-1	9	Alfalfa seeding	6	Ton/ac	60	540
W56-2	9	Alfalfa	6	Ton/ac	60	540
W58	6	Corn	120	Bu/ac	68	408
W60	8	Corn	120	Bu/ac	68	544

Table 7 (contd)

Field	Ac	Crop	YG	Units	Lbs/ac P-rem	Lbs/field Total P
W70	14	Corn silage	18	Ton/ac	48	672
W71	12	Corn silage	18	Ton/ac	48	576
W72-1	14	Corn silage	18	Ton/ac	48	672
W72-2	14	Corn silage	18	Ton/ac	48	672
W73	3	Corn silage	16	Ton/ac	45	135
W75-1	14	Corn silage	18	Ton/ac	48	672
W75-2	14	Corn silage	18	Ton/ac	48	672
W75-3	14	Corn silage	18	Ton/ac	48	672
W76	11	Corn silage	18	Ton/ac	48	528
W77	15	Alfalfa seeding	6	Ton/ac	60	900
W78	12	Corn	130	Bu/ac	75	900
W80-H	5	Corn silage	18	Ton/ac	48	240
W80-J	8	Corn silage	18	Ton/ac	48	384
W90-1	16	Corn silage	18	Ton/ac	48	768
W90-2	17	Corn silage	18	Ton/ac	48	816
W90-3	17	Corn silage	18	Ton/ac	48	816
W94-1	9	Corn	120	Bu/ac	68	612
W94-2	9	Corn	120	Bu/ac	68	612
	1377			Avg rem	51.1	70297

Table 7. 2001 crop plan for MSU farm fields. Crops grown and respective expected yield goals for that crop are indicated in this table. P-rem is the P_2O_5 removed by the crop per acre. Total P is the Total phosphorus removed per field (P-removed/acre *number of acres in field)

Ext.- extensively bu/ac= bushels per acre

Int- intensively Ton/ac= ton per acre yield

TABLE 8. NUTRIENT PRODUCTION FOR 2001 USING 1985 MWPS-18 VALUES

1985 MWPS-18						Yearly Nutrient Production		
Nutrient Production			N	P_2O_5	K_2O	Tot N	P_2O_5	K_2O
Livestock	Wt.	No.	lb/d	lb/d	lb/d	lbs	lbs	lbs
Beef Feeder (HE)	1100	179	0.37	0.28	0.32	24173	18293	20907
Beef Feeder (HE)	750	235	0.26	0.19	0.22	22301	16297	18870
Beef Feeder (HE)	500	186	0.17	0.13	0.15	11541	8825	10183
Beef Feeder (HF)	1100	243	0.37	0.28	0.32	32817	24834	28382
Beef Feeder (HF)	750	28	0.26	0.19	0.22	2657	1941	2248
Beef Feeder (HF)	500	173	0.17	0.13	0.15	10734	8208	9471
0-18 months Dairy	500	18	0.213	0.09	0.17	1399	591	1116
D-Lact Cow	1400	178	0.595	0.24	0.48	38657	15592	31185
D-Heifer	750	178	0.319	0.13	0.255	20725	8446	16567
D-dry cow	1400	2	0.595	0.24	0.48	434	175	350
Cull Cows	1000	6	0.425	0.17	0.34	930	372	744
Horse*	1000	95	0.3	0.161	0.301	10402	5582	10437
Chickens	2	190	0.0017	0.0009		117	62	0
Poultry-Layer	4	1165	0.0029	0.0025	0.0014	1233	1063	595
Poultry-Turkey*	20	790	0.0116	0.01	0.0056	3344	2883	1614
Quail/Pheasants	3	509	0.0023	0.0017	0.0007	427	315	130
8wk turkey	4	9	0.0029	0.0025	0.0014	9	8	4
Mink/Ferrets	4	791	0.0029	0.0025	0.0014	837	721	404
Sheep*	100	400	0.042	0.02	0.039	6132	2920	5694
Sows	275	369	0.07	0.05	0.05	9427	6734	6734
Swine boar	350	22	0.09	0.064	0.064	722	513	513
Mixed Nursery	50	572	0.025	0.017	0.0175	5219	3549	3653
Swine-Grow/finish	100	211	0.04	0.03	0.032	3080	2310	2464
125-200# Feeder	163	289	0.075	0.058	0.058	7911	6118	6118
200# + Feeder	250	185	0.085	0.06	0.065	5739	4051	4389
Pavilion	1000	37	0.3	0.161	0.301	4051	2174	4065
		7060				225018	142577	186837

*All animals for these species assumed as adults at respective weights.

TABLE 8. Shows Nutrient production of nutrients based on Mid West Plan Service (MWPS) 18, 1985 edition values for livestock manure production. Yearly production levels were calculated by multiplying the number of animals by the daily nutrient production by 365 days per year. Yearly nutrient production values were totaled.

Wt=Weight, D-= Dairy; HE= High Energy; HF= High Forage; lb/d= pounds per day nutrient production; No.=Number

TABLE 9. NUTRIENT PRODUCTION FOR 2001 USING 2000 MWPS-18 VALUES

2000 MWPS-18						Yearly Nutrient Production		
Nutrient Production			N	P_2O_5	K_2O	Tot N	P_2O_5	K_2O
Livestock	Wt	No.	lb/d	lb/d	lb/d	lbs	lbs	lbs
Beef Feeder (HE)	1100	179	0.54	0.21	0.32	35263	13720	20907
Beef Feeder (HE)	750	235	0.38	0.14	0.22	32430	12008	18870
Beef Feeder (HE)	500	186	0.14	0.1	0.11	9486	6789	7467
Beef Feeder (HF)	1100	243	0.61	0.21	0.36	53946	18625	31930
Beef Feeder (HF)	750	28	0.41	0.14	0.25	4172	1430	2555
Beef Feeder (HF)	500	173	0.14	0.1	0.11	8823	6314	6945
0-18 months Dairy	500	18	0.155	0.045	0.145	1008	295	952
D-Lact Cow	1400	178	0.82	0.42	0.48	53222	27287	31185
D-Heifer	750	178	0.23	0.07	0.22	14774	4547	14293
D-dry cow	1400	2	0.5	0.2	0.4	364	146	292
Cull Cows	1000	6	0.36	0.11	0.28	786	240	613
Horse*	1000	95	0.28	0.11	0.23	9690	3814	7975
Chickens	2	190	0.0023	0.0014	0.0011	0	97	76
Poultry-Layer	4	1165	0.0035	0.0027	0.0016	1165	1148	680
Poultry-Turkey	20	790	0.0126	0.0108	0.0054	3160	3114	1557
Quail/Pheasants	3	509	0.0029	0.00205	0.00135	509	380	250
8wk turkey	4	9	0.0035	0.0027	0.0016	9	8	5
Mink/Ferrets	4	791	0.0035	0.0027	0.0016	791	779	461
Sheep*	100	400	0.04	0.02	0.04	5600	2920	5840
Sows	275	369	0.05	0.04	0.04	6642	5387	5387
Swine boar	350	22	0.05	0.04	0.04	396	321	321
Mixed Nursery	50	572	0.0367	0.02	0.015	7436	4175	3131
Swine-Grow/finish	100	211	0.07	0.04	0.025	5275	3080	1925
125-200# Feeder	163	289	0.085	0.055	0.04	8959	5801	4219
200# + Feeder	250	185	0.09	0.06	0.05	5920	4051	3376
Pavilion	1000	37	0.28	0.11	0.23	3774	1485	3106
		7060				273600	127961	174318

*All animals were assumed adults at respective weight

TABLE 9. Shows Nutrient production of nutrients based on Mid West Plan Service (MWPS) 18, 2000 edition values for livestock manure production. Yearly production levels were calculated by multiplying the number of animals by the daily nutrient production by 365 days per year. Yearly nutrient production values were totaled.

Wt=Weight, D-= Dairy; HE= High Energy; HF= High Forage; lb/d= pounds per day nutrient production; No.=Number

TABLE 10. MANURE SPREADERS USED ON FARM

Spreader ID	Description	Type	Capacity	Units
JD 785	John Deere Push Off	Solid	350	ft^3
JD 455	John Deere Small	Solid	230	ft^3
Houle	4300 Houle Tank	Liquid	4200	gallons
Nuhn	3600 Nuhn Tank	Liquid	3600	gallons
IME	IME (Better Built)	Liquid	3000	gallons
H&S 175	Horse Barn H&S	Solid	125	ft^3
680 NH	Poultry	Solid	280	ft^3
8014 Knight	Dairy Slinger	Solid	220	ft^3
329 NH	Vet Farm Spreader	Solid	100	ft^3
1802 H&S	Dairy V-Bottom	Solid	300	ft^3
GR Truck	483,321 Grain Trucks	Solid	405	ft^3
Dump Truck	642 Dump Truck	Solid	135	ft^3

TABLE 10. Lists manure spreaders available for use on MSU farms. Spreaders are classified as either liquid or solid and available capacity of each is given. Also listed are trucks used to transport manure to piles. Ft^3 = cubic feet

TABLE 11. 2001 MANURE TOTALS HAULED

	Solid Manure		Liquid Manure	
Facility	**Loads**	**Total Tons**	**Loads**	**Total Gallons**
BCRC	314	1413	124	496000
Cow/Calf	193	772		
Dairy	1087	4424.5	491	1991600
Horse	190	340		
Pavilion	863	3069		
Poultry	30	67	1	3000
Sheep	77	269.5		
Veterinary	194	667		
Reloads	264	918		
Totals	**3,212**	**11,940**	**616**	**2,490,600**

TABLE 11. Manure Totals Hauled. The loads of manure taken from each facility were counted and periodically weighed. Total gallons hauled were based on capacity of the spreader and approximate level in the tank to get total liquid hauled from each facility.

TABLE 12. MANURE ANALYSIS

Manure ID	Species	Manure Type	Description	Total-N	Avail-N	P_2O_5	K_2O	Units
BCRC L	Beef	anaerobic liq	BCRC slotted floor	40	24	27	34	lbs/1000 gal
BCRC Lots	Beef	sol w/o bed	BCRC East Feed Lot	11	4	7	10	lbs/wet ton
BCRC Met	Beef	anaerobic liq	BCRC Metabolism	40	24	27	34	lbs/1000 gal
BCRC S	Beef	sol w/ bed	BCRC Wings	21	8	18	26	lbs/wet ton
BCRC Wgh	Beef	Comp. sol	BCRC Weigh Back	12	0	10	14	lbs/wet ton
C/C S	Beef	solid w/ bed	Cow/Calf Barn S	21	8	18	26	lbs/wet ton
C/C Wgh	Beef	Comp. sol	Cow/Calf Weigh Back	12	0	10	14	lbs/wet ton
Dairy C	Dairy	Comp. sol	Dairy Compost Pad	12	0	10	14	lbs/wet ton
Dairy H	Dairy	solid w/ bed	Dairy South Heifer	9	5	4	10	lbs/wet ton
Dairy HL	Dairy	anaerobic liq	Dairy Heifer Liquid	40	24	27	34	lbs/1000 gal
Dairy Met	Dairy	anaerobic liq	Dairy Metabolism	24	12	18	29	lbs/1000 gal
Dairy NL	Dairy	anaerobic liq	Dairy North Slotted	24	12	18	29	lbs/1000 gal
Dairy PL	Dairy	flushed liq	Dairy Parlor Liquid	4	2.5	4	5	lbs/1000 gal
Dairy S	Dairy	solid w/ bed	Dairy Gutters	9	5	4	10	lbs/wet ton
Dairy SL	Dairy	anaerobic liq	Dairy South Slotted	34.3	18.7	10.9	29.6	lbs/1000 gal
Dairy Wgh	Beef	Comp. sol	Dairy Waste Feed	12	0	10	14	lbs/wet ton
Elsessen	Dairy	solid w/ bed	Dairy Stock Pile	9	5	4	10	lbs/wet ton
Gravel Pit	Dairy	solid w/ bed	Dairy Stock Pile	9	5	4	10	lbs/wet ton
HB S	Horse	solid	Horse Barn Shavings	14	4	4	14	lbs/wet ton
Hort Pad	Horse	solid	Vet Manure Stockpile	14	4	4	14	lbs/wet ton
Misc Pile	Beef	solid w/ bed	Temp Piles	21	8	18	26	lbs/wet ton
Pavilion	Horse	solid	Pavilion Shavings	14	4	4	14	lbs/wet ton
Poultry	Poultry	solid w/ litter	Poultry Solid Pile	56	36	45	34	lbs/wet ton
Poultry L	Poultry	deep pit	Turkey Pit	68	44	64	45	lbs/1000 gal
Sandhill	Horse	solid	Pavilion Stockpile	14	4	4	14	lbs/wet ton
Swine Pile	Swine	fresh (solid)	Swine Stockpile	10	6	9	8	lbs/wet ton
Sheep	Sheep	solid	Sheep Barn Pens	14	5	9	25	lbs/wet ton
Swine 4	Swine	anaerobic liq	Old Swine MOF	36	26	27	22	lbs/1000 gal
Swine C	Swine	fresh (solid)	Swine Compost	10	6	9	8	lbs/wet ton
Swine Endo	Swine	anaerobic liq	Swine Endocrine	36	26	27	22	lbs/1000 gal
Swine S	Swine	fresh (solid)	Old Swine Solid	10	6	9	8	lbs/wet ton
Swine SL	Swine	anaerobic liq	Swine Slurry Tank	36	26	27	22	lbs/1000 gal
Swine 1,2,3	Swine	anaerobic liq	Individual Old Sw pits	36	26	27	22	lbs/1000 gal
Vet Clinic	Horse	solid	Veterinary Clinic	14	4	4	14	lbs/wet ton
Vet Farm	Horse	solid	Veterinary Farm	14	4	4	14	lbs/wet ton

TABLE 12. Manure analysis values from grab samples of the various manure storage facilities. Liquid or slurry manure was taken after agitation during pumping. Solid manure samples were taken midway through hauling manure from storage facilities. Analysis values and units are given for each facility.

*sol= solid, liq=liquid, bed=bedding, comp=composted, Temp=Temporary, Sw=Swine

TABLE 13. NUTRIENT PRODUCTION: MANURE ANALYSIS

				lbs/wet ton			lb/1000 gal		Totals		
			Tot N	P_2O_5	K_2O	Tot N	P_2O_5	K_2O	N	P_2O_5	K_2O
Manure	Ton	Gallons	-----	solid analysis	----	===	liquid analysis	===		Total	
BCRC pit		496000				40	27	34	19840	13392	16864
BCRC Lots	464		11	7	10				5098	3244.5	4635
BCRC-Met		76000				40	27	34	3040	2052	2584
BCRC S	464		21	18	26				9733	8343	12051
BCRC-wbk	486		12	10	14				5832	4860	6804
C/C S	764		21	18	26				16044	13752	19864
C/C wbk	8		12	10	14				96	80	112
D-C	469		12	10	14				5628	4690	6566
D-H/S	3767		9	4	10				33898	15066	37665
D-HL		424000				40	27	34	16960	11448	14416
D-metab		30000				24	18	29	720	540	870
D-NL		308000				24	18	29	7392	5544	8932
D-PL		789600				4	4	4	3156	3158	3156
D-SL		440000				34.3	10.9	29.6	15092	4796	13024
D-wbk	189		12	10	14				2268	1890	2646
Horse	340		14	4	14				4760	1360	4760
Pav	3069		14	4	14				42966	12276	42966
Poultry-S	67		56	45	34				3752	3015	2278
Poultry-L		3000				68	64	45	204	192	135
Sheep	270		14	9	25				3773	2425	6737
Sw-old sol	82.5		10	9	8				825	742.5	660
Sw-comp	217		10	9	8				2170	1953	1736
Sw pits1-4		78000				36	27	22	2808	2106	1716
Sw-Endo		24000				36	27	22	864	648	528
Sw-Slurry		1240000				36	27	22	44640	33480	27280
Vet farm	667		14	4	14				9338	2668	9338
									260897	**153721**	**248323**

Table 13. Manure analysis of manure sources and total nutrient production for each and as a whole. Liquid/Slurry analysis is in Lb/1000 gal (pounds per thousand gallons), Solid analysis is in lbs/wet ton (pounds per wet ton). D=dairy, Sw=swine, comp=compost, Endo=Endocrine, sol=solid, wbk=weighback, PL=parlor liquid, SL=south liquid, NL=North Liquid, Tot= Total, metab=metabolism, HL=Heifer liquid, H/S=heifer solid, C/C=cow/calf, D-C=Dairy Calf, BCRC=Beef Cattle Research Center, BCRC-S=Beef Cattle Research Center solid, Pav=pavilion.

TABLE 14: CROP NUTRIENT REMOVAL

Nutrient Removal			lb/ac	lb/ac	lb/ac	Total Nutrient Removal/Crop		
Crop	**Acres**	**Yield**	**N**	**P_2O_5**	**K_2O**	**N (lb/ac)**	**P_2O_5**	**K_2O**
ACP Grass/Leg	40	3	82	26	78	3280	1040	3120
Alf topdress	204	6	350	60	330	71400	12240	67320
Corn Grain	142	120	172.5	70	167.5	24495	9940	23785
Corn Silage	338	18	135	47.3	103.2	45630	15987	34881
Grass Maint	107	2	112.5	20	80	12037	2140	8560
Orchard Grass	18	3	300	100	375	5400	1800	6750
Pasture-Int Graz	122	3	200	55	180	24400	6710	21960
Pasture-Gen Graz	254	3	225	40	160	57150	10160	40640
Soybeans	5	50	257	48	120	1285	240	600
Trefoil-Hay prod	43	3	250	90	200	10750	3870	8600
Wheat	104	70	155.5	52	136	16172	5408	14144
	1377					271999	69535	230360

TABLE 13. Shows the crops grown in 2001 and the number of acres that were planted to each crop. Using the 1985 version of Mid West Plan Service-18 the nutrient removed by each crop based on yield was used to measure the total nutrient removal for MSU farms in 2001.

Leg.=Legume; Alf= Alfalfa; Main= Maintenance; Int. Graz= Intensive Grazing; Gen. Graz= General Grazing; prod.= production. Lb/ac = pounds per acre.

TABLE 15. NUTRIENT BALANCE

1985 MWPS-18	**N**	**P_2O_5**	**K_2O**
Total nutrient production	225018	142577	186837
Total nutrient removed	271999	69535	230360
Excess Produced		**73042**	
Additional Nutrients Needed	**46981**		**43523**

2000 MWPS-18	**N**	**P_2O_5**	**K_2O**
Total nutrient production	273600	127961	174318
Total nutrient removed	271999	69535	230360
Excess Produced	1601	58426	
Additional Nutrients Needed			56042

Manure Analysis	**N**	**P_2O_5**	**K_2O**
Total nutrient production	260897	153721	248323
Total nutrient removed	271999	69535	230360
Excess Produced		84186	17963
Additional Nutrients Needed	11102		

Table 15. A comparison of nutrient balance between the three methods of nutrient production used. Total nutrient removed is the level of nutrients that would be removed based on MWPS-18, 1985. This level is the same for all three calculations.

*All values are in pounds

TABLE 16. PHOSPHORUS CHANGE

Soil Test P By M III	Adding P	Removing P
lb P/acre	---lb P_2O_5/ acre ---	
10	12.5	20.5
15	10.2	16.8
20	8.9	14.5
25	7.9	13
30	7.2	11.8
35	6.7	11
40	6.3	10.3
45	5.9	9.7
50	5.6	9.2

Table 16. Initial STP (soil test phosphorus level) as indicated by the Melich III soil phosphorus test. The lower the initial soil test phosphorus level the more P that has to be added or removed to change the STP level of this Belknapp soil in Western Kentucky by 1lb/ac (P_2O_5). Higher STP levels (50 lbs P_2O_5 / acre) require a smaller addition or removal amount to change the STP by 1 lb/acre P_2O_5.

This data comes from derivatives of equations that were developed using addition data and removal data.

Added P 39.6/sq rt Pst Pst= P soil test

Removed P 64.9/sq rt Pst Pst= P soil test

(e-mail conversation on 10/27/00 with Gary Pierzynski, Professor, Soil and Environmental Chemistry Department of Agronomy, 2004 Throckmorton Plant Sciences Center, Kansas State University, Manhattan, KS 66506-5501

TABLE 17. SOIL TEST PHOSPHORUS LEVELS (1992-2002)

Soil Test Phosphorus All Levels are in Lbs/ Ac

Field	Acres	1992	T * A	1993	T*A	1994	T*A	1995	T*A	1996	T*A	1997	T*A
E14	6		0	140	840	140	840	117	702	251	1506	193	1158
E27-2	5	699	3495	593	2965	568	2840	693	3465	433	2165	463	2315
E27-1	5	600	3000	529	2645	514	2570	848	4240	422	2110	415	2075
E30	22	324	7128	338	7436	224	4928	331	7282	233	5126	233	5126
E32	5												
E34	14		0		0	240	3360	192	2688	233	3262	214	2996
E36	20	600	12000	663	13260	445	8900	534	10680	433	8660	373	7460
E40	4	80	320	54	216	97	388	80	320		0	65	260
E42	12	230	2760	207	2484	200	2400	255	3060	281	3372	267	3204
E44-1	13	132	1716	178	2314	227	2951	248	3224	156	2028	165	2145
E44-2	13	200	2600	160	2080	272	3536	185	2405	233	3029	175	2275
E44-3	0	124	0	155	0	215	0	150	0	167	0	124	0
E46	4		0		0		0		0		0		0
E47	4		0		0		0		0		0		0
E48	3		0		0		0		0		0		0
E49	4		0		0		0		0		0		0
E50	22	124	2728	120	2640	120	2640	120	2640	97	2134	133	2926
E51	24	46	1104	60	1440	46	1104	78	1872	76	1824	54	1296
E52-1	12	111	1332	102	1224	82	984	85	1020	76	912	143	1716
E52-2	18	49	882	136	2448	166	2988	214	3852	94	1692	149	2682
E53	10		0		0	166	1660	145	1450	144	1440	340	3400
E54	7		0	76	532	83	581	101	707		0	124	868
E55	12		0	87	1044	76	912	87	1044	48	576	107	1284
E56	12		0	90	1080	72	864	85	1020	60	720	120	1440
E57	12		0	41	492	41	492	45	540	39	468	48	576
E58	12	89	1068	128	1536	166	1992	172	2064	156	1872	193	2316

Table 17 (contd)

Field	Acres	1992	T * A	1993	T*A	1994	T*A	1995	T*A	1996	T*A	1997	T*A
E59	12	114	1368	200	2400	136	1632	255	3060	182	2184	220	2640
E61	16	51	816	40	640	46	736	45	720	91	1456	51	816
E62	16	25	400	60	960	64	1024	87	1392	123	1968	78	1248
E64	7	74	518	140	980		0	155	1085	148	1036		0
E65	7	97	679	74	518		0	155	1085	116	812		0
E66	9		0	136	1224		0	166	1494		0		0
E67	9	40	360	124	1116		0	95	855		0		0
E68	11	66	726	98	1078		0	166	1826		0		0
E70-1	12	104	1248	60	720	73	876	90	1080	83	996	76	912
E70-2	11	47	517	118	1298	71	781	110	1210	85	935	93	1023
E73	13		0	58	754	45	585	49	637		0		0
E72-P	4		0	92	368		0	78	312	83	332	69	276
E74-1	22	146	3212	160	3520	94	2068	117	2574	109	2398	113	2486
E74-2	23	146	3358	124	2852	107	2461	120	2760	116	2668	82	1886
E75-1	11	160	1760	160	1760	184	2024	150	1650	148	1628	181	1991
E75-2	11	151	1661	172	1892	178	1958	145	1595	160	1760	175	1925
E75-3	11	117	1287	160	1760	129	1419	166	1826	134	1474	107	1177
E75-4	11	208	2288	200	2200	116	1276	192	2112	174	1914	62	682
E75-5	11	310	3410	407	4477	133	1463	290	3190	282	3102	214	2354
E76	8		0		0	50	400	40	320	22	176	27	216
E77	10		0		0	30	300	19	190		0	31	310
E78	3		0		0	28	84	31	93		0		0
E79	12	57	684	83	996	51	612	69	828		0		0
E82-1	17	66	1122	80	1360	117	1989	67	1139	69	1173	56	952
E82-2	17	66	1122	98	1666	87	1479	124	2108	109	1853	90	1530
E84	26		0		0	145	3770	63	1638		0	76	1976
E85	16		0		0	91	1456	124	1984	152	2432	165	2640

Table 17 (contd)

Field	Acres	1992	T * A	1993	T*A	1994	T*A	1995	T*A	1996	T*A	1997	T*A
E86	20		0		0	97	1940	145	2900		0		0
E87	16		0		0	62	992	113	1808		0		0
E90-1	45		0		0		0		0		0		0
E90-2	40		0		0		0		0		0		0
E90-3	10		0		0	297	2970	253	2530	182	1820	258	2580
E90-4	5		0		0	171	855	191	955	131	655	334	1670
E92	8		0	530	4240	213	1704	523	4184	393	3144	384	3072
E116	20	25	500	88	1760	40	800	39	780	37	740	54	1080
E124	12	40	480	50	600	48	576	85	1020	49	588	48	576
E126	32	30	960	39	1248	50	1600	50	1600	27	864	110	3520
W24	12		0	178	2136	138	1656	110	1320	125	1500	120	1440
W30	18	61	1098	60	1080	59	1062	58	1044	69	1242	80	1440
W31	7	61	427	40	280	30	210	22	154	35	245	51	357
W33	17	225	3825	213	3621	232	3944	178	3026	191	3247		0
W34	17	300	5100	263	4471	192	3264	214	3638	160	2720		0
W35	20	45	900	50	1000	64	1280	65	1300	62	1240	46	920
W36-1	20	57	1140	80	1600	62	1240	87	1740	50	1000	58	1160
W40	9	17	153	17	153	28	252	65	585		0		0
W41	6	30	180	44	264	31	186	26	156		0		0
W42	9	20	180	52	468	48	432	36	324		0		0
W44-1	8	36	288	52	416	43	344	25	200		0		0
W44-2	8	28	224	31	248	46	368	33	264		0		0
W46	12	46	552	59	708	71	852	43	516	36	432		0
W47	15	47	705	50	750	53	795	53	795	53	795		0
W48	25	47	1175	57	1425	62	1550	70	1750	63	1575	63	1575
W50	5		0		0	95	475		0		0		0
W51	32		0		0		0	104	3328		0		0

Table 17 (contd)

Field	Acres	1992	T * A	1993	T*A	1994	T*A	1995	T*A	1996	T*A	1997	T*A
W52	16	25	400	37	592	57	912	98	1568	56	896	82	1312
W53	16	36	576	40	640	45	720	82	1312	49	784	45	720
W54	6	110	660	166	996	48	288	51	306	60	360	60	360
W56-1	9	130	1170	192	1728	89	801	132	1188	91	819	113	1017
W56-2	9		0		0	129	1161	145	1305	80	720	117	1053
W57	3		0		0	67	201		0		0		0
W58-1	3		0		0	51	153		0		0		0
W58-2	2		0		0	45	90		0		0		0
W59-1	4		0	62	248	80	320		0		0		0
W59-2	4		0		0	178	712		0		0		0
W59-3	4		0	107	428	166	664		0		0		0
W59-4	4		0	166	664	99	396		0		0		0
W59-5	4		0	98	392	185	740		0		0		0
W59-6	4		0		0	105	420	120	480	73	292		0
W60	8	84	672	100	800	69	552	107	856	100	800		0
W70	14	142	1988	53	742	80	1120	51	714	51	714	63	882
W71	12	72	864	76	912	61	732	95	1140	78	936	93	1116
W72-1	14	82	1148	68	952	51	714	67	938	62	868	73	1022
W72-2	14	24	336	70	980	51	714	98	1372	40	560	101	1414
W73-T	3		0		0		0		0		0		0
W75-1	5	20	100	28	140	49	245	40	200	67	335	93	465
W75-2	11	20	220	36	396	24	264	37	407	39	429	71	781
W75-3	11	41	451	32	352	21	231	45	495	36	396	54	594
W75-4	11	24	264	29	319	17	187	31	341	28	308	46	506
W75-5	11	27	297	37	407	34	374	29	319	41	451	54	594
W76	11	27	297	36	396	18	198	51	561	45	495	37	407
W77	15		0	66	990	17	255	18	270	22	330	35	525

Table 17 (contd)

Field	Acres	1992	T * A	1993	T*A	1994	T*A	1995	T*A	1996	T*A	1997	T*A
W78	10		0		0		0	60	600		0		0
W80-H	7		0		0	155	1085	178	1246	128	896	214	1498
W80-J	7		0		0	92	644	110	770	80	560	107	749
W90-1	16	66	1056		0	105	1680	104	1664	60	960	104	1664
W90-2	17	62	1054		0	83	1411	98	1666	58	986	90	1530
W90-3	17	151	2567		0	124	2108	192	3264	51	867	107	1819
W94-1	9	52	468		0	65	585	78	702	182	1638	85	765
W94-2	9	41	369		0	80	720	71	639	73	657	113	1017
		*sum(t*A)*	99513		120757		126067		153278		112057		115758
		avg STP	72.1632		87.569		91.419		111.15		81.26		83.943
		970	102.591	1043	115.78	1297	97.199	1324	115.77	1081	103.66	1001	115.64
		Acres tested	avg P/ac	ac tested	avg P/ac	ac tested	avg P/ac	ac tested	avg P/ac	ac tested	avg P/ac	ac tested	avg P/ac
		Mean	102.591		115.78		97.199		115.77		103.66		115.64

Table 17 (contd)

Field	Acres	1998	T*A	1999	T*A	2000	T*A	2001	T*A	2002	T*A	Average
E14	6	402	2412	248	1488	247	1482	181	1086			685.9444
E27-2	5	627	3135	497	2485	756	3780	679	3395	636	3180	1718.579
E27-1	5	413	2065	620	3100	463	2315	560	2800	618	3090	1552.842
E30	22	283	6226	297	6534	270	5940	290	6380	217	4774	3081.526
E32	5									543	2715	
E34	14	225	3150	185	2590	200	2800	181	2534		0	1324.471
E36	20	498	9960	386	7720	393	7860	464	9280	471	9420	4804.684
E40	4	113	452	160	640	160	640	200	800	69	276	235.8333
E42	12	240	2880	225	2700	288	3456	340	4080	275	3300	1518.368
E44-1	13	247	3211	308	4004	262	3406	310	4030	275	3575	1433.263
E44-2	13	233	3029	240	3120	200	2600	300	3900	224	2912	1414.316
E44-3	0	174	0	225	0		0		0		0	78.47059
E46	4		0		0		0	264	1056	224	896	26.4
E47	4		0		0		0	325	1300		0	32.5
E48	3		0		0		0		0		0	0
E49	4		0		0		0		0		0	0
E50	22	150	3300	154	3388	181	3982	187	4114	148	3256	1461.263
E51	24	55	1320	70	1680	64	1536	89	2136	60	1440	727.0526
E52-1	12	106	1272	205	2460	149	1788		0		0	764.8333
E52-2	18	212	3816	192	3456	240	4320	200	3600	143	2574	1462.526
E53	10	301	3010	497	4970	360	3600	386	3860		0	1286.412
E54	7	113	791	96	672	85	595	116	812	138	966	325.8824
E55	12	116	1392	129	1548	99	1188	165	1980	105	1260	550.1111
E56	12	123	1476	172	2064	139	1668	109	1308	128	1536	627.8889
E57	12	109	1308	93	1116	64	768	80	960	43	516	351.1111
E58	12	247	2964	225	2700	190	2280	255	3060	174	2088	1084.895
E59	12	174	2088	233	2796	262	3144		0		0	1282.667
E61	16	57	912	85	1360	78	1248		0		0	513.7778

Table 17 (contd)

Field	Acres	1998	T*A	1999	T*A	2000	T*A	2001	T*A	2002	T*A	Average
E62	16	120	1920	297	4752	149	2384		0		0	947.2778
E64	7		0		0		0		0		0	318.1538
E65	7		0		0		0		0		0	272
E66	9		0		0		0	217	1953		0	269.75
E67	9		0		0		0	69	621		0	204.5385
E68	11	42	462		0		0		0		0	343.3846
E70-1	12	94	1128	85	1020	80	960	69	828	46	552	513.3684
E70-2	11	106	1166	91	1001	116	1276	83	913	69	759	533
E73	13	55	715	91	1183	96	1248	51	663	55	715	347.9375
E72-P	4	109	436	99	396	73	292	145	580	86	344	185.8824
E74-1	22	88	1936	78	1716	109	2398	140	3080	86	1892	1234.842
E74-2	23	55	1265	93	2139	93	2139	140	3220	124	2852	1189.684
E75-1	11	219	2409	172	1892	166	1826	148	1628	300	3300	980.4211
E75-2	11	174	1914	120	1320	135	1485	160	1760	108	1188	898.9474
E75-3	11	116	1276	143	1573	120	1320	136	1496	190	2090	760
E75-4	11	134	1474	133	1463	78	858		0		0	864.6667
E75-5	11	212	2332	99	1089	262	2882		0		0	1472.667
E76	8	32	256	46	368	67	536	98	784	62	496	156.1176
E77	10	20	200	24	240	38	380		0		0	118.8
E78	3		0		0		0		0		0	21.45455
E79	12	42	504	66	792	67	804	49	588	112	344	335.5294
E82-1	17	75	1275	192	3264	116	1972		0			838
E82-2	17	123	2091	212	3604	154	2618		0			1063
E84	26	174	4524	148	3848	139	3614		0			1341
E85	16	182	2912	199	3184	254	4064		0			1239.938
E86	20	45	900	116	2320	131	2620		0		0	801

Table 17 (contd)

Field	Acres	1998	T*A	1999	T*A	2000	T*A	2001	T*A	2002	T*A	Average
E87	16	155	2480		0	181	2896		0		0	668.2308
E90-1	45		0		0		0		0		0	0
E90-2	40		0		0		0		0		0	0
E90-3	10	191	1910	276	2760	288	2880	320	3200	217	2170	1147.941
E90-4	5	174	870	276	1380	181	905	150	750	248	1240	523.4118
E92	8	826	6608	480	3840	370	2960	494	3952	428	3424	1886.944
E116	20	97	1940	59	1180	71	1420	116	2320	76	1520	569.7895
E124	12	57	684	55	660	52	624	58	696	57	684	334.2105
E126	32	21	672	47	1504	36	1152	37	1184	60	1920	714.0526
W24	12	109	1308	99	1188	109	1308	112	1344	69	828	719.7778
W30	18	80	1440	83	1494	53	954	40	720	39	702	605.1053
W31	7	48	336	70	490	46	322	40	280	40	280	171.7895
W33	17	253	4301	320	5440	254	4318		0			1975.765
W34	17	260	4420	267	4539	247	4199		0			2014.941
W35	20	16	320		0	34	680	69	1380	33	660	449.5
W36-1	20	63	1260	53	1060	53	1060	36	720	50	1000	624.1579
W40	9		0		0		0		0			97.69231
W41	6		0		0		0		0			70.53846
W42	9		0		0		0		0			120
W44-1	8		0		0		0		0			108
W44-2	8	43	344		0	64	512	83	664	66	528	143
W46	12		0		0		0		0		0	236.7857
W47	15		0		0		0		0		0	292.5714
W48	25	73	1825	72	1800	76	1900	48	1200	57	1425	800.3158
W50	5	109	545	124	620	135	675	120	600		0	207
W51	32	39	1248	52	1664	60	1920	46	1472	43	1376	604.3571

Table 17 (contd)

Field	Acres	1998	T*A	1999	T*A	2000	T*A	2001	T*A	2002	T*A	Average
W52	16	59	944	74	1184	50	800	33	528	43	688	483.1053
W53	16	78	1248	52	832	34	544	56	896	64	1024	415.4211
W54	6	37	222	83	498	66	396	62	372	80	480	254.1579
W56-1	9	155	1395	106	954	131	1179	165	1485	154	1386	608.1579
W56-2	9	113	1017	78	702	90	810	170	1530	160	1440	452.3529
W57	3		0		0		0		0		0	26.8
W58-1	3		0		0		0		0		0	20.4
W58-2	2		0		0		0		0			13.5
W59-1	4		0		0		0		0			64.54545
W59-2	4		0		0		0		0			89
W59-3	4		0		0		0		0		0	124.0909
W59-4	4		0		0		0		0		0	120.4545
W59-5	4		0		0		0		0		0	128.6364
W59-6	4		0		0		0		0		0	124.1667
W60	8	150	1200	172	1376	123	984	112	896	128	1024	458.7222
W70	14	97	1358	88	1232	85	1190	124	1736	108	1512	567.0526
W71	12	150	1800	138	1656	200	2400	255	3060	224	2688	672.3158
W72-1	14	150	2100	205	2870	247	3458	187	2618	224	3136	803.2632
W72-2	14	167	2338	124	1736	139	1946	150	2100	190	2660	650.5263
W73-T	3		0		0		0	140	420	95	285	14
W75-1	5	127	635	70	350	120	600	73	365	86	430	197.7368
W75-2	11	78	858	103	1133	112	1232	102	1122	95	1045	333.7895
W75-3	11	85	935	72	792	112	1232	109	1199	73	803	320.2632
W75-4	11	52	572	60	660	112	1232		0		0	266
W75-5	11	75	825	70	770		0		0		0	259.0588
W76	11	43	473	68	748	131	1441		0		0	304
W77	15	35	525	22	330	32	480	29	435	20	300	221.1667

Table 17 (contd)

Field	Acres	1998	T*A	1999	T*A	2000	T*A	2001	T*A	2002	T*A	Average
W78	10		0	88	880	116	1160	112	1120		0	232
W80-H	7	123	861	192	1344	160	1120	150	1050	167	1169	550
W80-J	7	103	721	103	721	93	651	73	511	66	462	328.0588
W90-1	16	134	2144	129	2064	99	1584	116	1856	167	2672	762.9444
W90-2	17	85	1445	88	1496	82	1394	78	1326	148	2516	650.3333
W90-3	17	150	2550	85	1445	93	1581	120	2040	88	1496	959.6667
W94-1	9	109	981	113	1017	88	792	98	882	64		434.3333
W94-2	9	80	720	103	927	73	657	128	1152	78		359.3333
			151642		157091		155620		129766		108279	
			109.97		113.92		112.85		94.102		78.52	
		1170	129.61	1117	140.64	1136	136.99	824	157.48	834	129.83	
		ac tested	avg P/ac	ac tested	avg P/ac	Ac tested	avg P/ac	ac tested	avg P/ac	ac tested	avg P/ac	
			129.61		140.64		136.99		157.48		129.83	

Table 17. Analysis of Soil Test phosphorus (STP) levels for previous ten years (1992-2002). Every field was not tested every year, some fields have not been tested at all in the last ten years, thus the STP levels were weighted to account for those fields that were tested and those that were not. Each year that a soil test was taken, the soil test was multiplied by the number of acres of that field (T*A), this number was totaled for each year and then divided by the total acres tested for that year. The result is an average STP level per acre for that year.

Ac tested= total acres tested for that year; avg P/ac= Average Phosphorus level per acre for that year.

TABLE 18. DIFFERENCES BETWEEN MSUNM AND PURDUE MMP IN DEVELOPMENT OF A CNMP.

Differences	
●Purdue	●MSUmn
–Planning Tool	–Record keeping
–Mid West region	–Michigan
–1-5 years planning	–No predetermined limit
– Specific for Nutrients	–Whole farm record sys
–Nutrients reported as pounds/field	–Nutrients reported as pounds/acre
	–Decimal Error in Nutrient Balance

Personal Likes and Dislikes

●Purdue	●MSUmn
–Does not like old soil test data	–MSU Fertilizer Recs could not be run-error
–Non restrictive yield goals	–Able to use last available soil test
–No Sub field required-uniqueness	–Ability to estimate fertilizer cost/benefit of manure
–Application Dates	–Download STP data
–Update Version-via web	–Nutrient Balance Report
–No Charge	
–Manure section	

FIGURE 1. PHOSPHORUS CYCLE

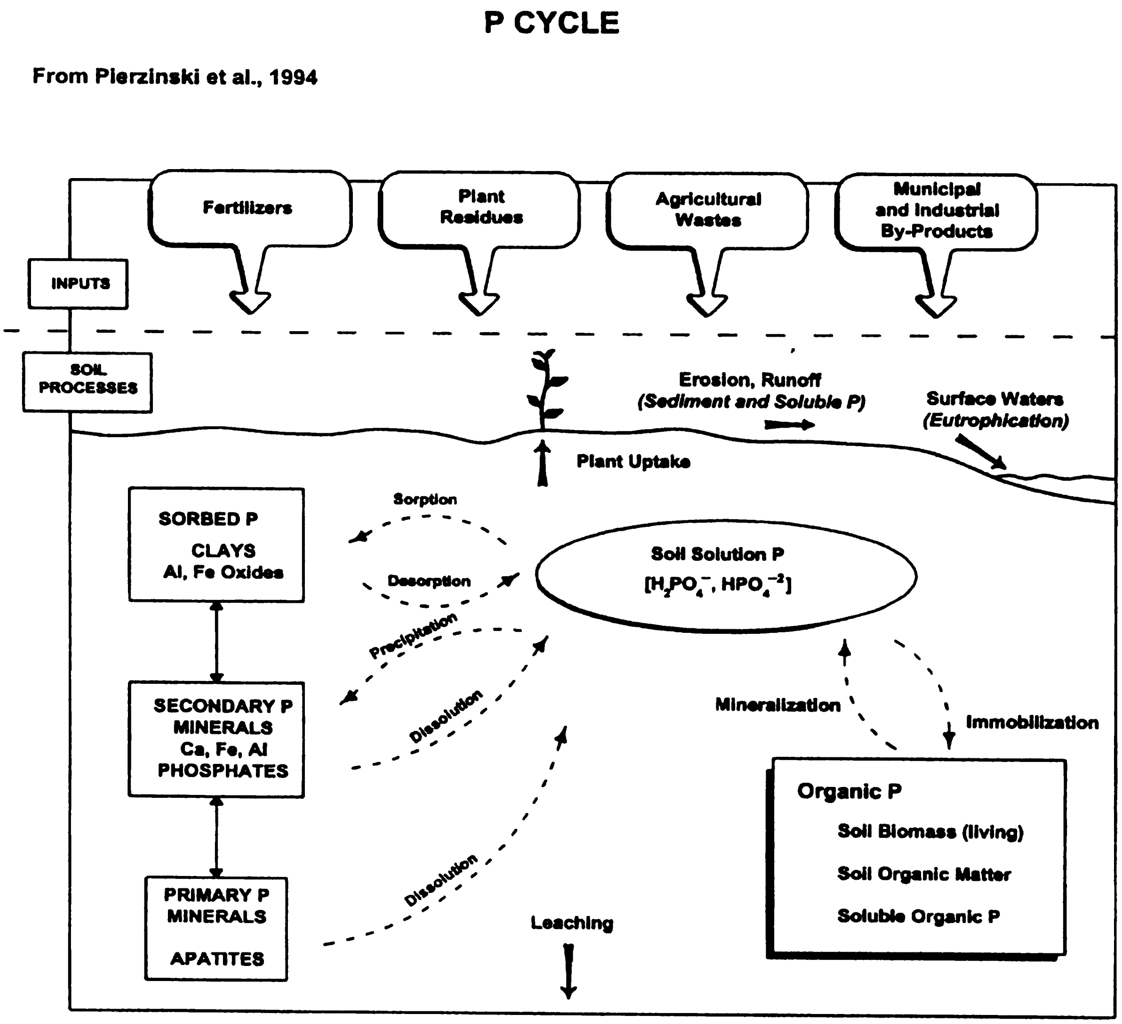

Figure 1. Phosphorus Cycle reveals the movement of phosphorus through the environment. Weathering of phosphate from rocks becomes a nutrient in the soil, from which plants take up P. Plants are ingested by animals, and returned to the soil as an organic waste product.

FIGURE 2. NITROGEN CYCLE

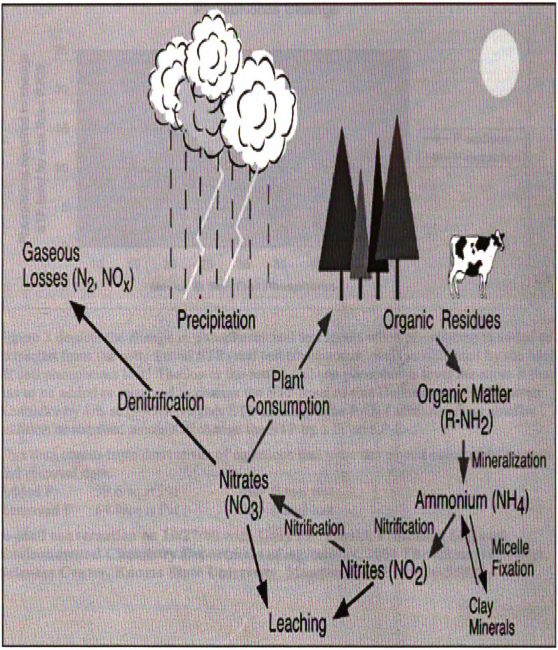

Figure obtained from: http://www.geog.ouc.bc.ca/physgeog/contents/9s.html
Figure 2. The Nitrogen Cycle, nitrogen movement through the environment in various phases and physical states.

FIGURE 3. PHOSPHORUS CHANGE

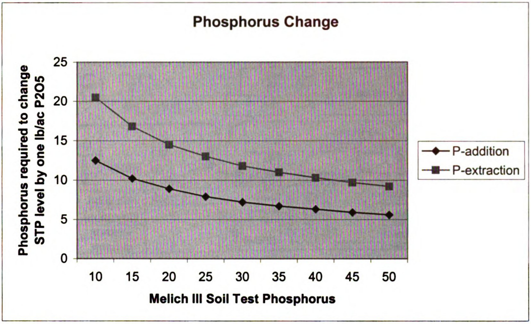

Figure 3 depicts the change in phosphorus soil test levels when phosphorus is added or extracted from the soil. Initial STP (soil test phosphorus level) as indicated by the Melich III soil phosphorus test. The lower the initial soil test phosphorus level the more P that has to be added or removed to change the STP level of this Belknapp soil in Western Kentucky by 1lb/ac (P_2O_5). Higher STP levels (50 lbs P_2O_5 / acre) require a smaller addition or removal amount to change the STP by 1 lb/acre P_2O_5.

This data comes from derivatives of equations that were developed using addition data and removal data.

Added P	39.6/sq rt Pst	Pst= P soil test
Removed P	64.9/sq rt Pst	Pst= P soil test

(e-mail conversation on 10/27/00 with Gary Pierzynski, Professor, Soil and Environmental Chemistry Department of Agronomy, 2004 Throckmorton Plant Sciences Center, Kansas State University, Manhattan, KS 66506-5501)

FIGURE 4. UNIVERSITY FARM FIELDS

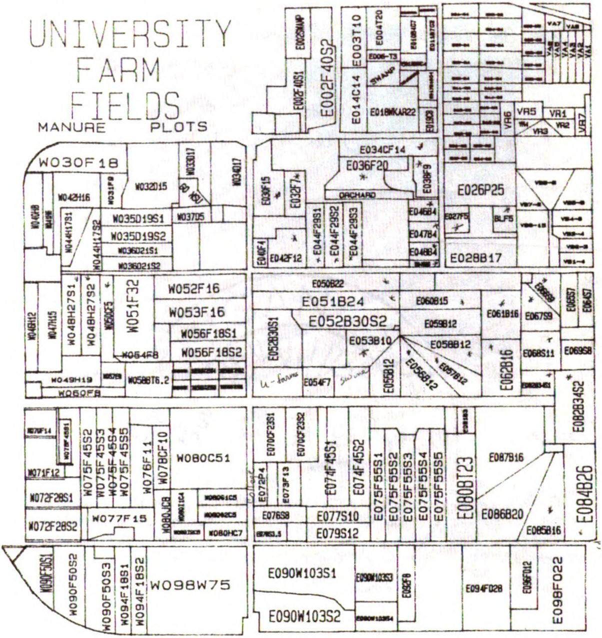

Figure 4. MSU farm fields, location and boundaries and the farm facilities respective locations on MSU farms.

FIGURE 4A. CHANGE IN ACRES

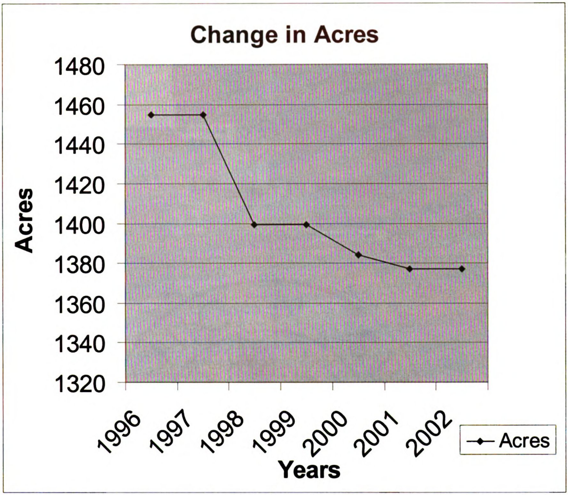

Figure 4a is the change in acres from 1996 to 2002. Reduction in acres available for MSU farms manure applications and crop production is not a predictable trend. Acres change due to development of farmland, and research necessities. MSU farms land available for manure application and crop production has decreased over 60 acres in the seven-year period.

FIGURE 5. AERIAL PHOTOGRAPH OF MSU FARM FIELDS.

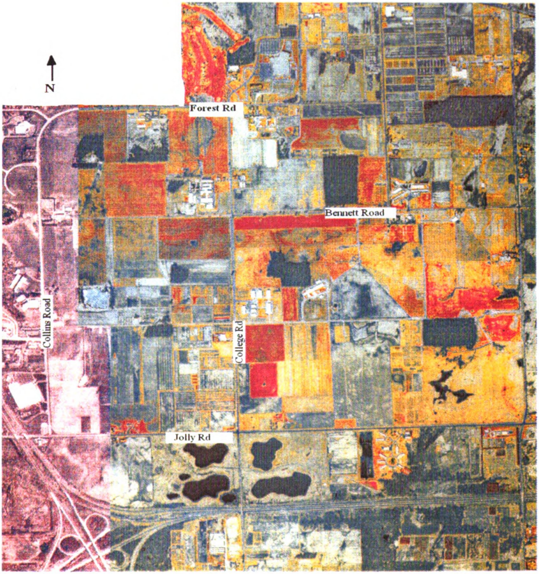

FIGURE 5. Aerial photograph of Michigan State University south campus farms. Most of the land is utilized for crop and feed production; some is used solely for the purpose of research to achieve better crop yields and varieties.

FIGURE 6. TOPOGRAPHY MAP OF MSU FARMLAND

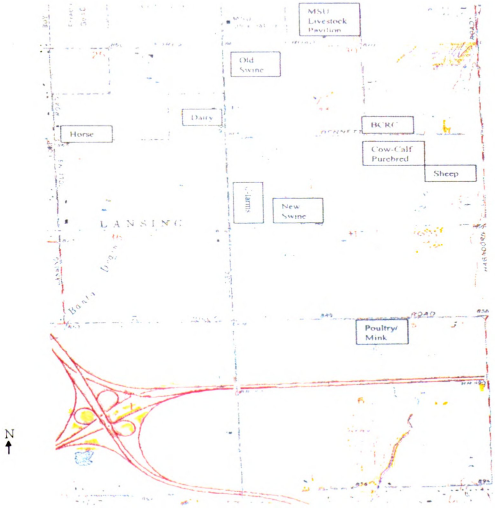

Figure 6. The topography of MSU farmland reveals various elevation heights as well as water resources.

FIGURE 7: SOILS MAP OF MSU FARMLAND AREA

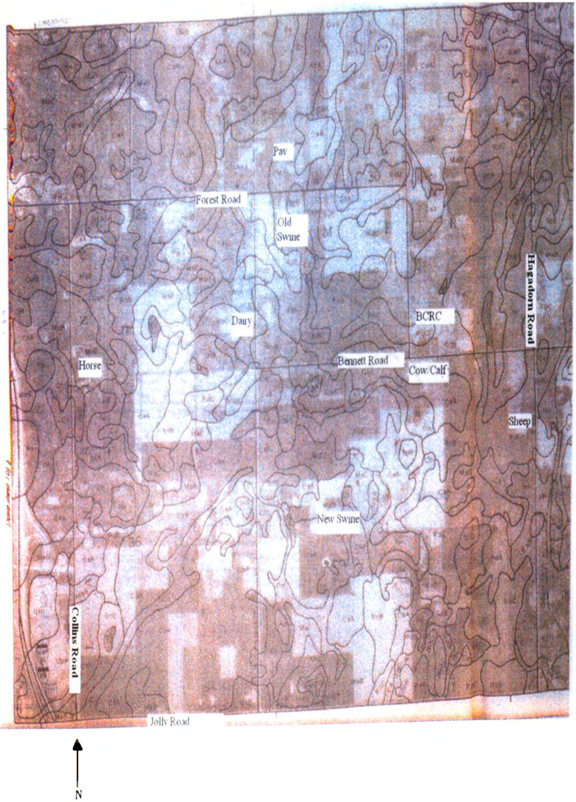

FIGURE 7: (contd)

Figure 7: Spatial relation of various soil types on MSU farms. Slopes range from 0-6%, predominant soil types include Capac, Riddles and Marlette.

FIGURE 8. ANIMAL UNITS GRAPH

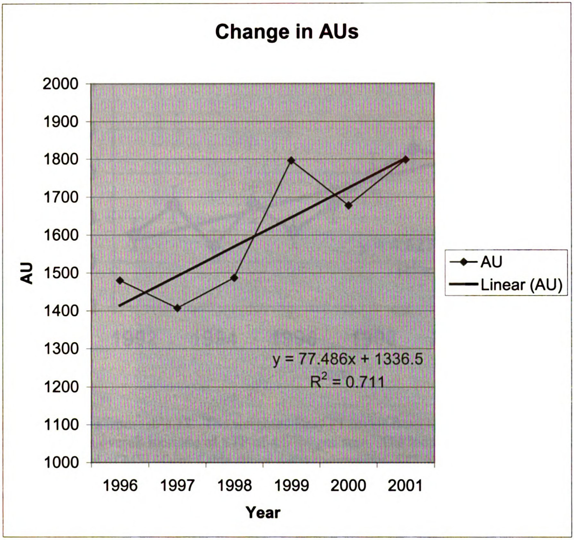

Figure 8 graphs the change in animal units over time. The increasing trend of animal units will require an increased land base to balance the farm system or a higher level of management to maintain a balance. The equation shows an increase of approximately 77 animal units per year. Data in graph is from Table 2.

FIGURE 9. SOIL TEST ANALYSIS GRAPH

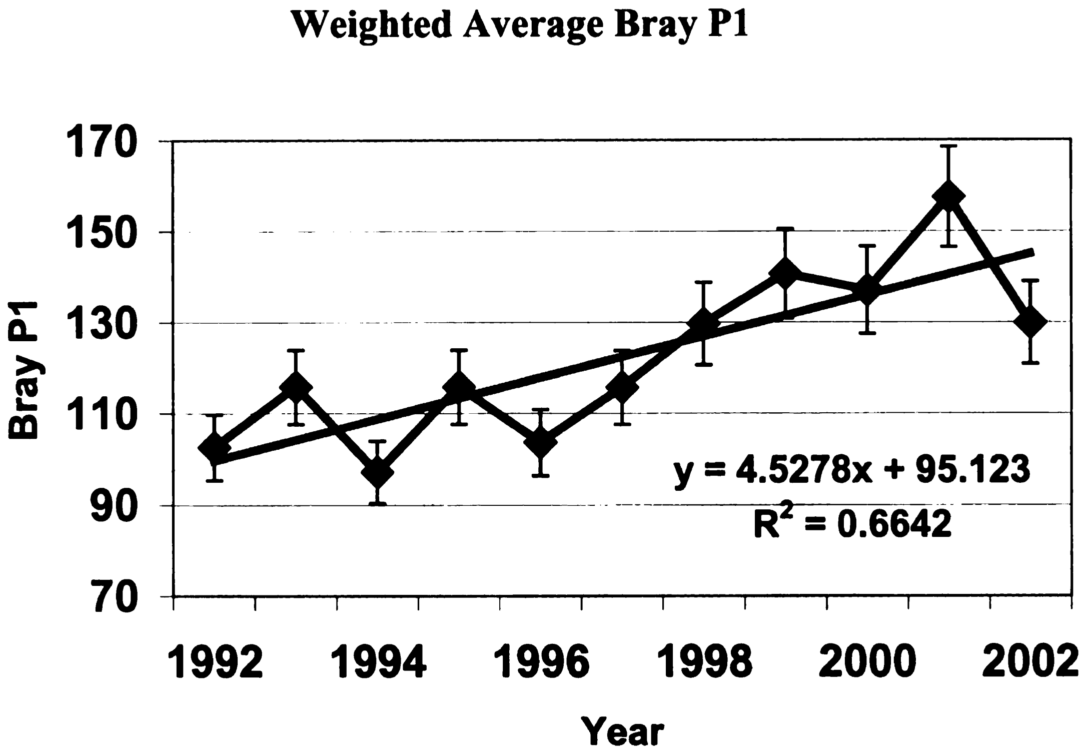

Figure 9 data is from table 17. The weighted Bray P1 levels from MSU farm fields over time reveals an overall increase of STP of 4.5 lbs per acre. The increase predicts an eventual P level of MSU farm fields above the recommended STP level for which manure application can take place according to Generally Accepted Agricultural Management Practices for manure application, GAAMMPs

FIGURE 10. MAP OF FARM FIELDS CODED BY PHOSPHORUS LEVEL

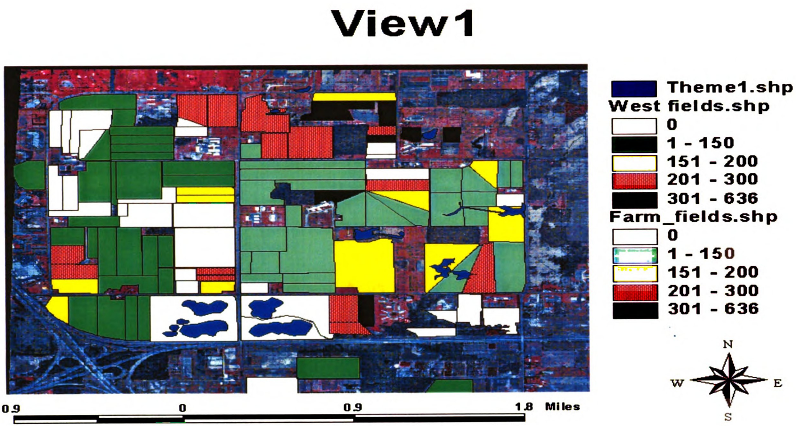

Figure 10. MSU farm fields color-coded by elemental P soil test phosphorus, pounds per acre.

FIGURE 11. DAIRY NORTH AND SOUTH PITS, DIMENSIONS AND CAPACITY

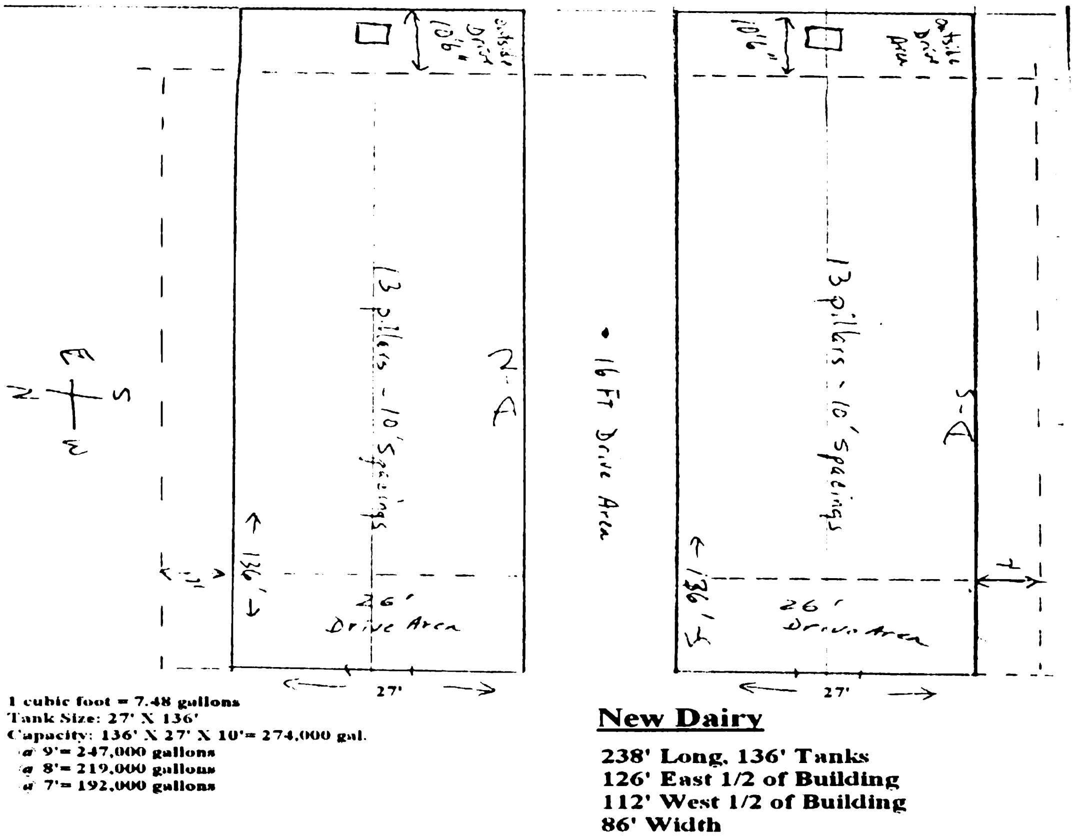

Figure 11. The Dairy North and South pits are each 136' long X 27' wide and 10' deep with a volume of 274,000 gallons each.

FIGURE 12. DAIRY HEIFER PIT, DIMENSIONS AND CAPACITY

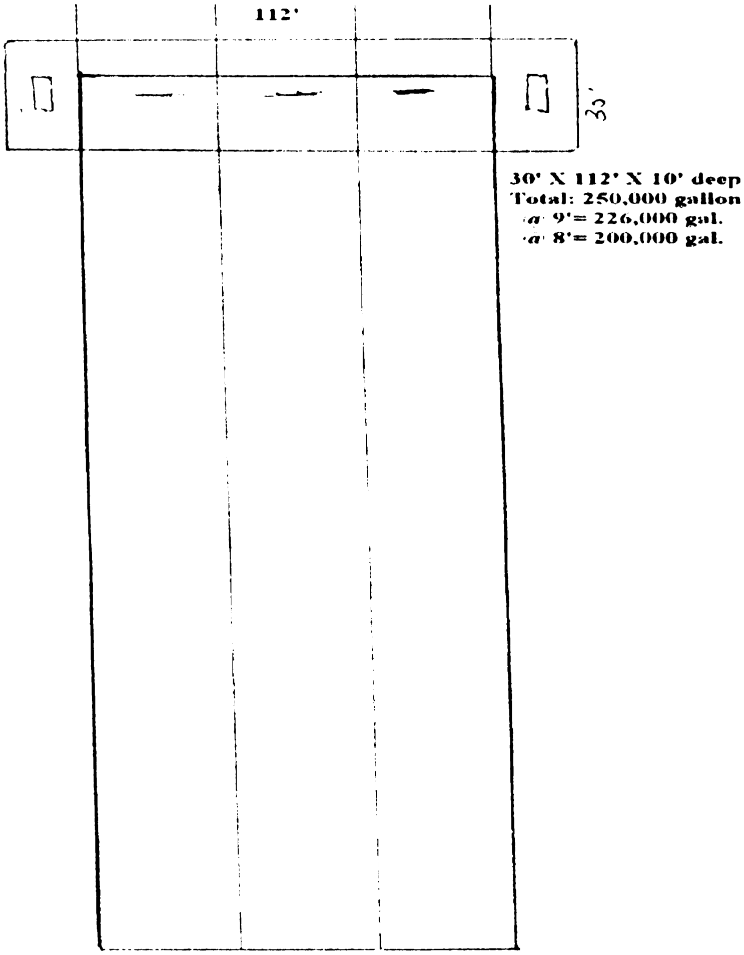

Figure 12. Dairy Heifer pit is 112' long, 30' wide, and 10' deep, resulting in a total volume of 250,000 gallons.

FIGURE 13. DAIRY PARLOR AND MILKHOUSE PITS, DIMENSTIONS AND CAPACITY

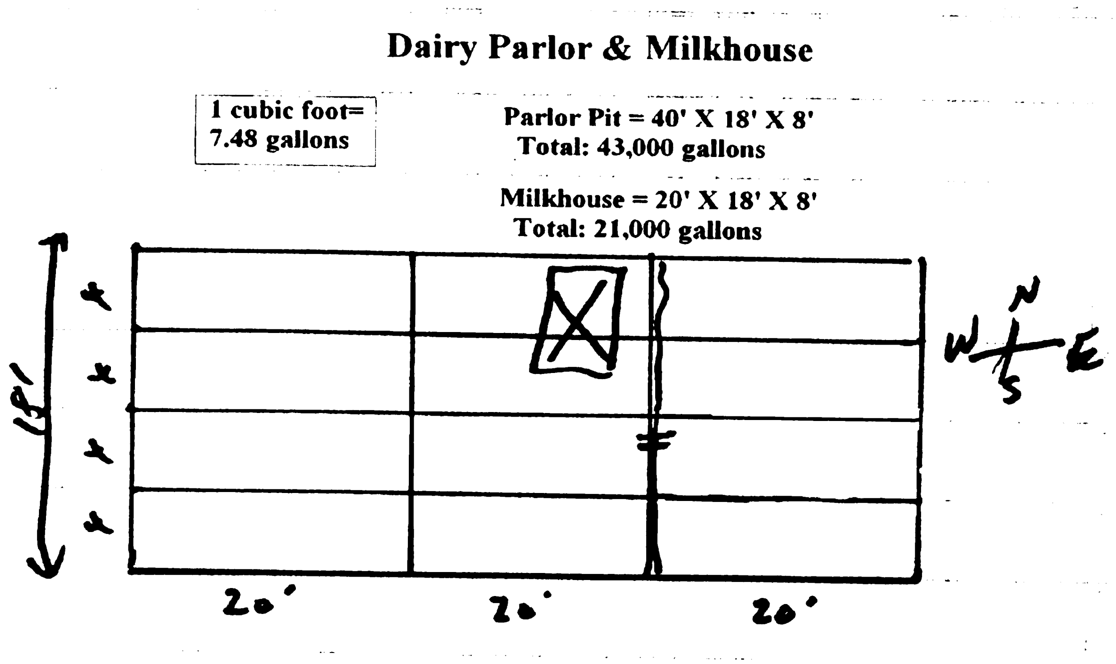

Figure 13. The dairy milk house has dimensions of 40' long, 18' wide and 8' deep, resulting in a volume of 43,000. The Dairy Parlor has dimensions of 20' long X 18' wide and 8' deep with a total volume of approximately 21,000 gallons.

FIGURE 14. BEEF CATTLE RESEARCH CENTER PIT, DIMENSIONS AND CAPACITY

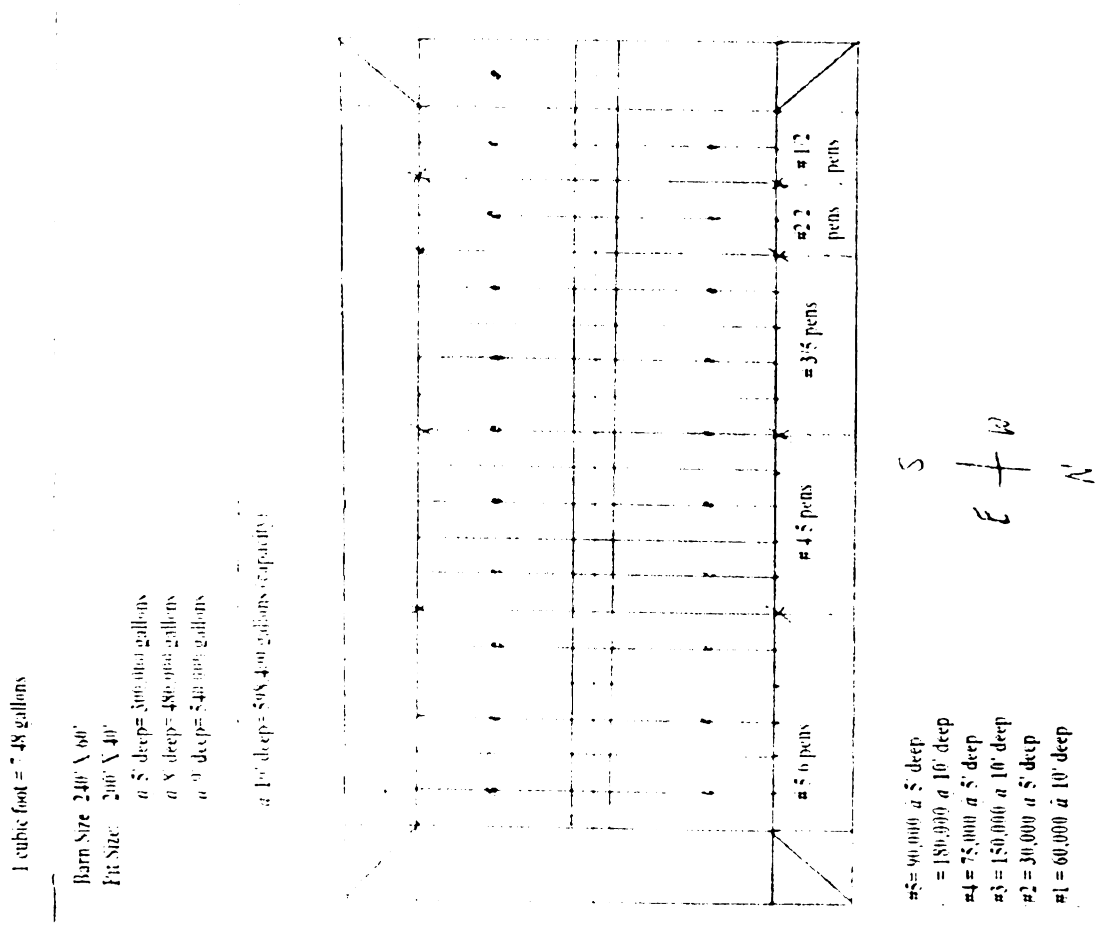

Figure 14. Beef Cattle Research pit has dimensions of 200’ long, 40’ wide, and 10’ deep. Total volume of BCRC pit, 598,400 gallons.

FIGURE 15. OLD SWINE FARM PITS, DIMENSIONS AND CAPACITY

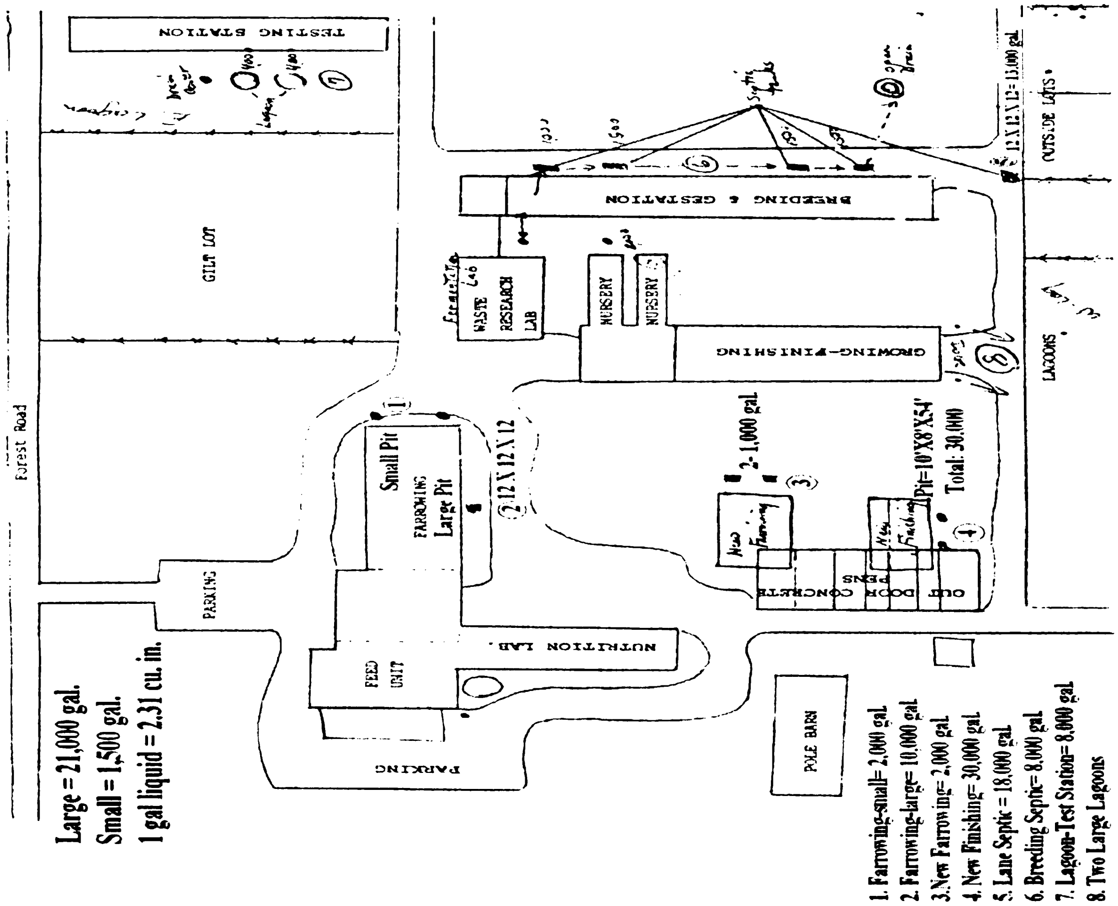

Figure 15. Pit 1, small farrowing pit, capacity of 2,000 gallons; pit 2 large farrowing, dimensions, 12' long, 12' wide, 10' deep, capacity of 10,000 gallons. Pit 3, new farrowing, capacity of 2,000 gallons; new finishing pit dimensions of 54' long, 10' wide and 8' deep, total volume of 30,000 gallons. Lane Septic, dimensions, 12'long X 12' wide X12' deep, 13,000 gallons, pit 6, breeding septic, total capacity of 8,000 gallons. Test station lagoons, 4,000-gallon capacity for each, and total of 8,000 gallons.

FIGURE 16. NEW SWINE FARM, SLURRY TANK, DIMENSIONS, CAPACITY AND FACILITY LAYOUT

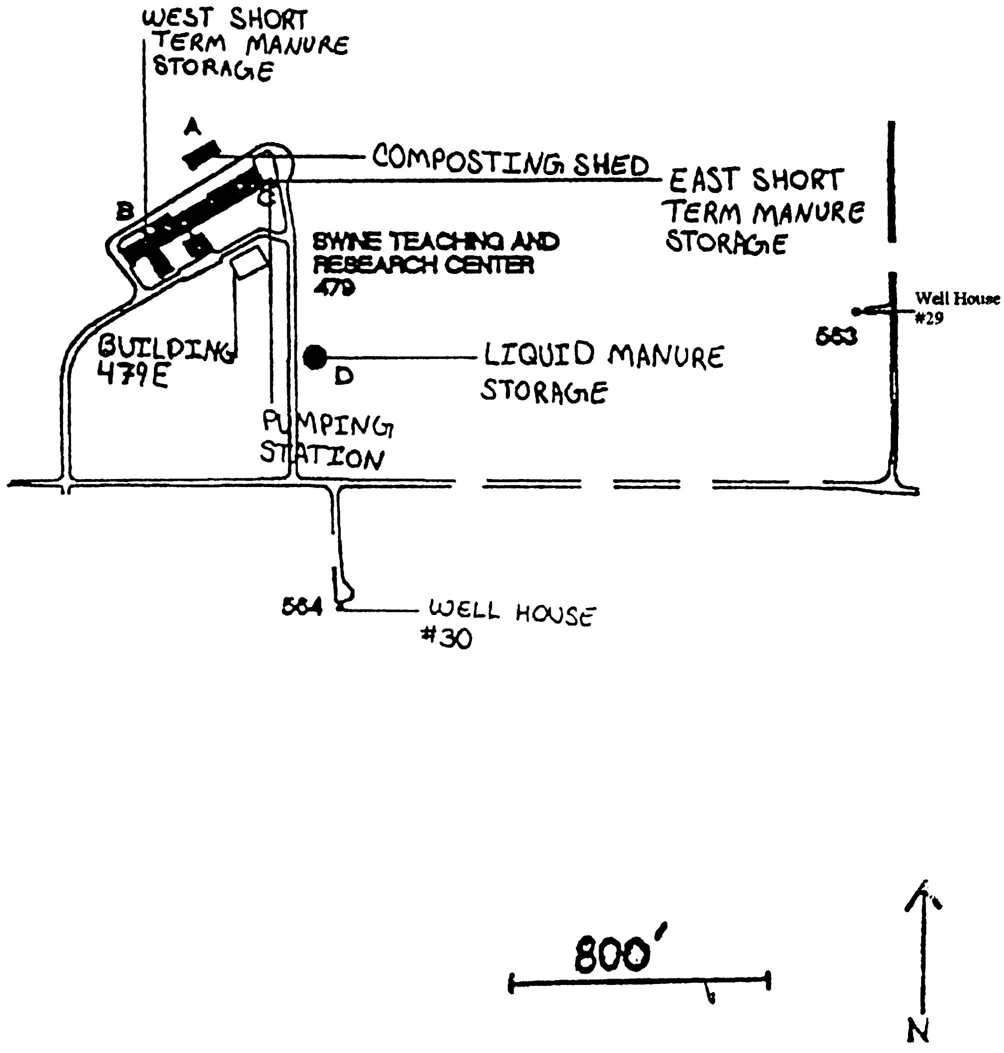

Figure 16. The new or south swine farm has one large slurry storage tank with the capacity to hold up to a half a million gallons of slurry manure.

FIGURE 17: EMERGENCY PHONE LIST

IMPORTANT INFORMATION

Complete this page, make copies and post next to each telephone on the farm.

Local Emergency Assistance Telephone Numbers:

Fire Department:	911
Local Police:	911
County Sheriff:	664-1654
State Police:	332-3521
Ambulance:	911
Emergency Management Coordinator:	719-2153

Farmstead Information:

Name of Farm:	**MSU Farms**-Sheep, Swine, Dairy, Beef Cattle Research Center, Purebred Farm, Horse, Poultry
Address of Farm:	South of MSU Campus, Between Hagadorn and Collins (East and West borders) and Jolly and Forest Road (North and South borders), Dependant on which farm.
County:	Ingham

Directions to Farmsite. Help can come from any direction. Be sure to write down exact, simple and accurate directions to the farmstead:

State and Federal Agency Telephone Numbers:

MDA Agricultural Pollution Emergency Hotline: 1-800-405-0101

EPA National Response Center: 1-800-424-8802

MDEQ Pollution Emergency Alerting System (PEAS): 1-800-292-4706

Michigan Poison Control System: 1-800-464-7661 (1-800-POISON-1)

Figure 17: Emergency contact phone numbers in case of a spill or breach of storage facilities.

FIGURE 18. BEEF CATTLE RESEARCH CENTER FACILITY LAYOUT AND FLOW DIRECTION

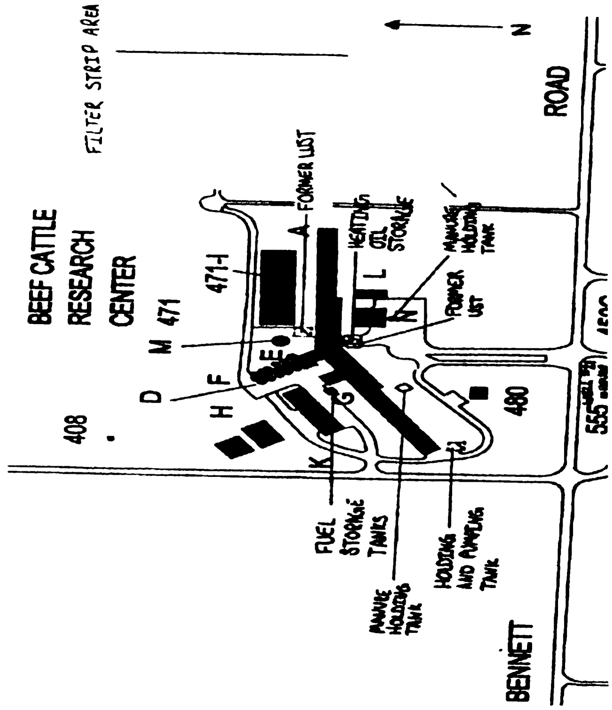

Figure 18. In the event of a spill at the BCRC, manure waste would flow to the south and east.

FIGURE 19: DAIRY FARM FACILITY LAYOUT AND FLOW DIRECTION

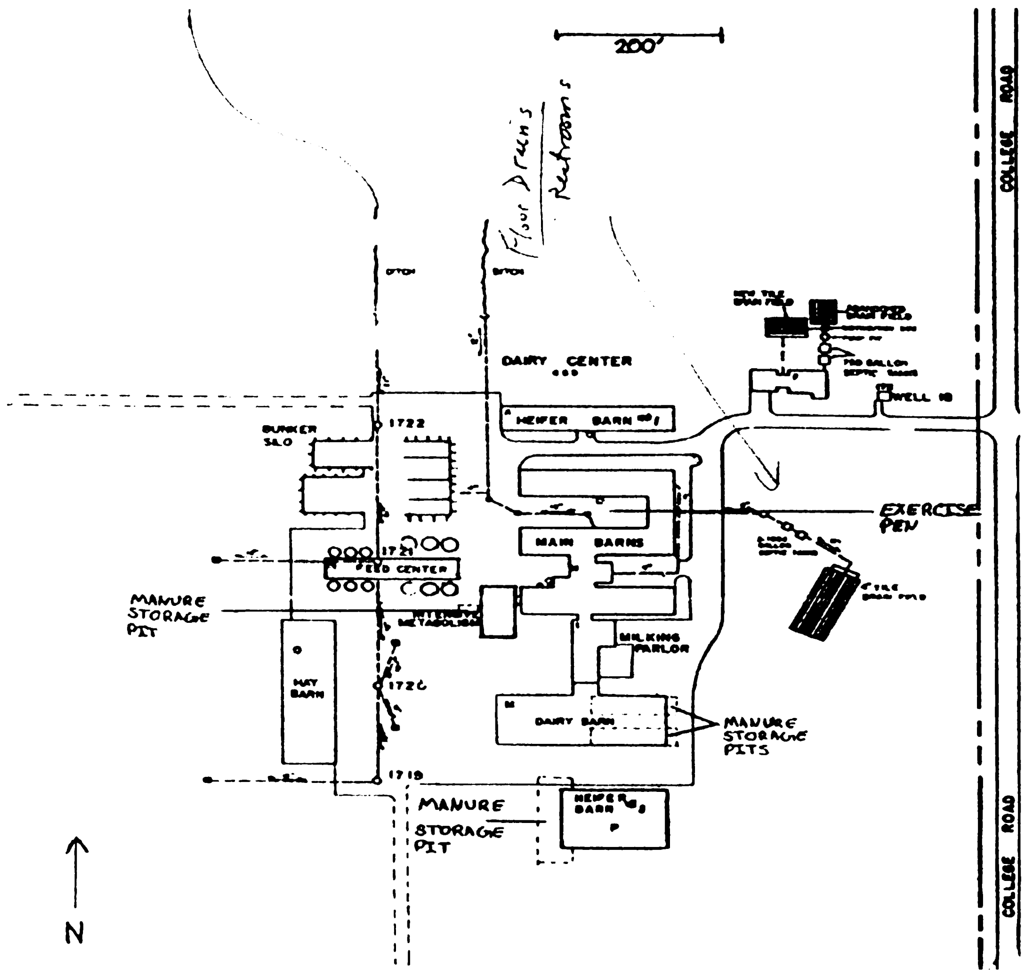

Figure 19. In the event of a spill at the Dairy farm, manure would flow to the east and north.

FIGURE 20: HORSE RESEARCH FACILITY LAYOUT

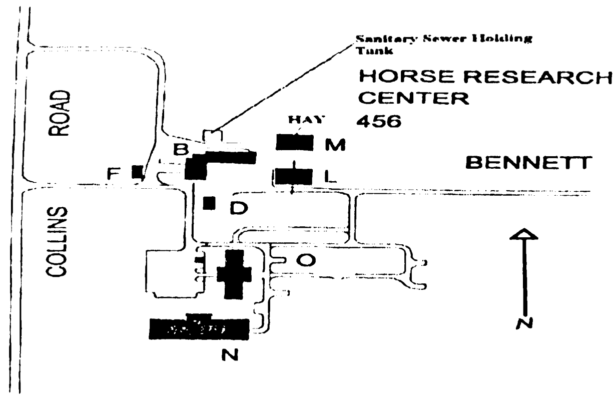

Figure 20. Horse facility layout, all manure is handled as a solid.

FIGURE 21: PAVILION FOR AGRICULTURE AND LIVESTOCK EDUCATION

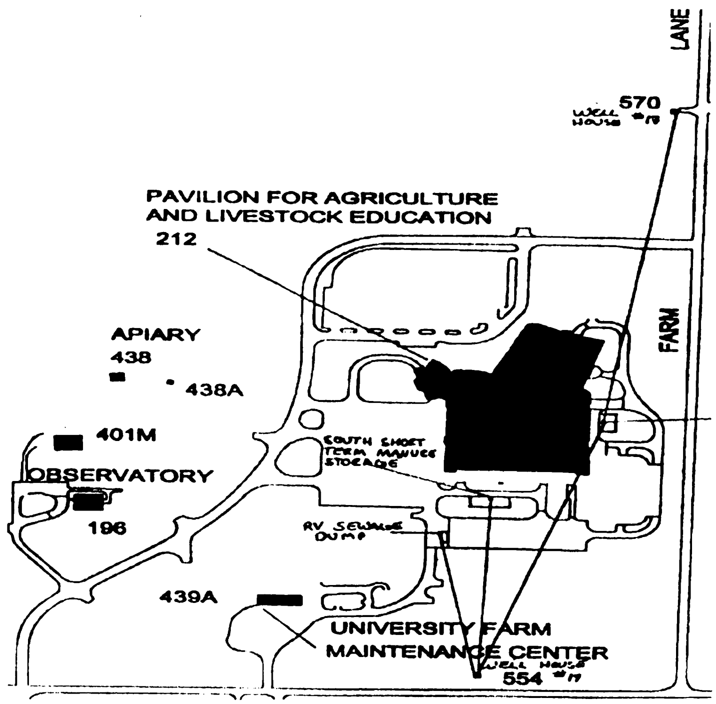

Figure 21. Pavilion facility layout, all manure is handled as a solid.

FIGURE 22: POULTRY RESEARCH CENTER

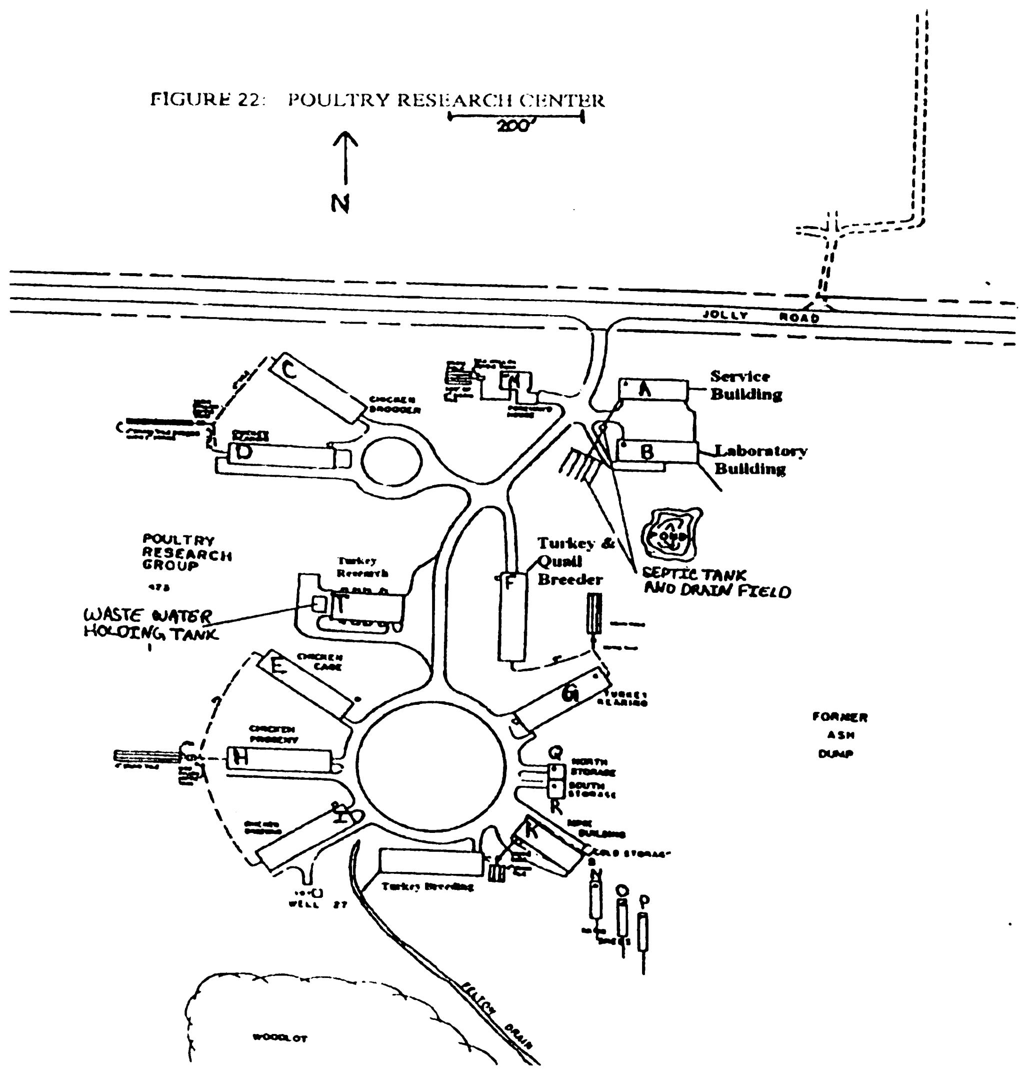

Figure 22. Poultry manure is primarily handled as a solid; if the one turkey collection tank were to breech it would flow to the south. Total capacity of Turkey pit is 3,000 gallons.

FIGURE 23: SHEEP RESEARCH CENTER

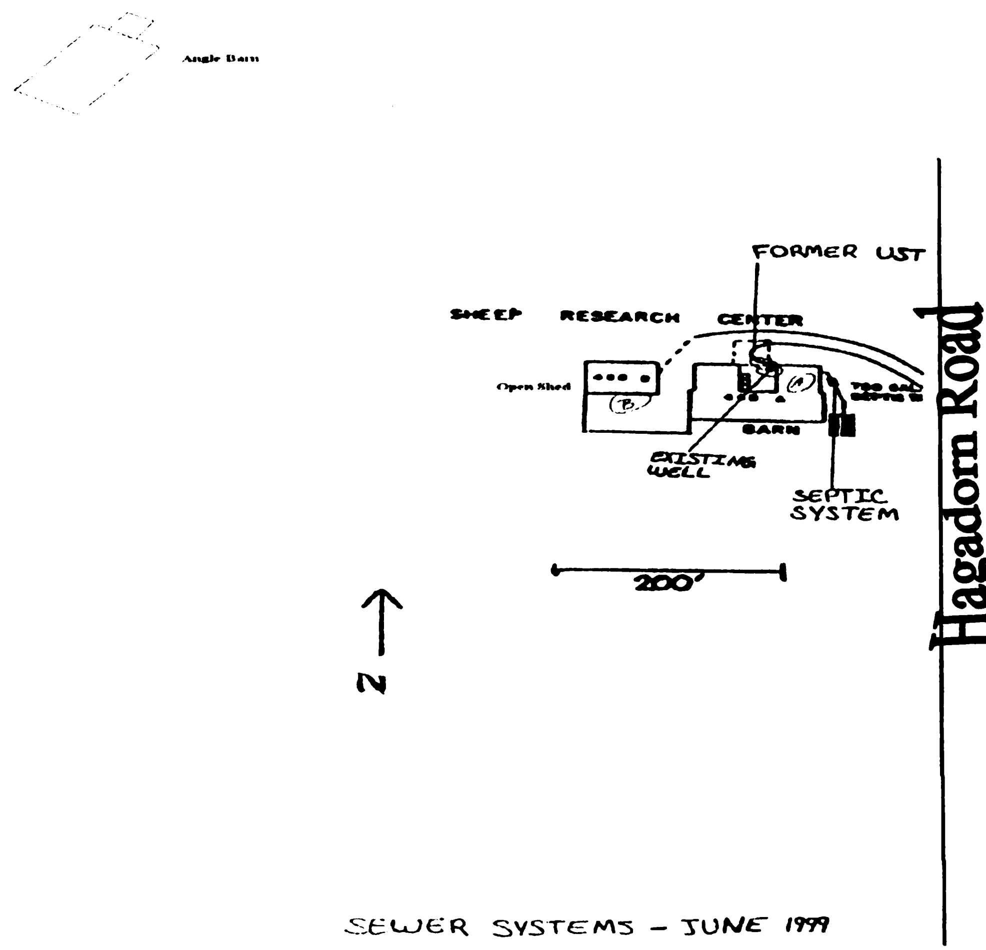

Figure 23. Sheep facility layout, all manure is handled as a solid.

FIGURE 24: OLD SWINE RESEARCH CENTER

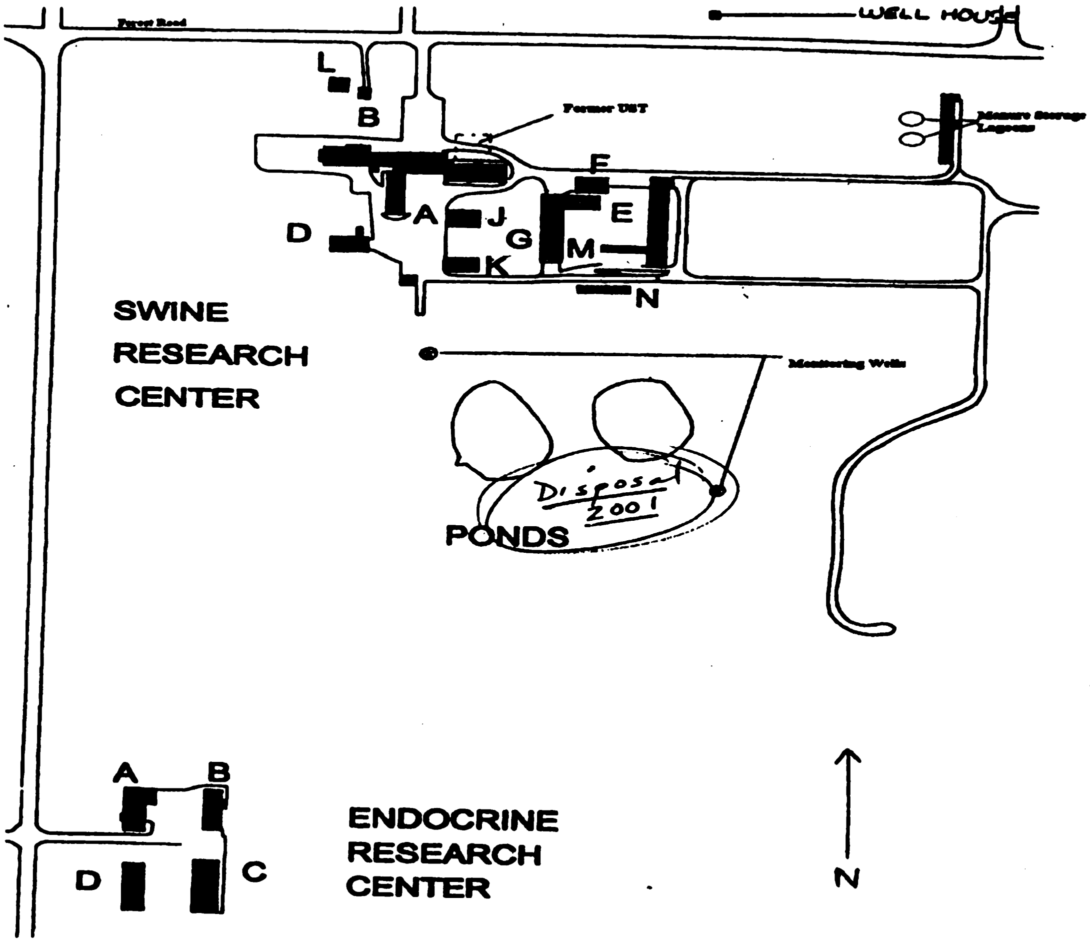

Figure 24. In the case of a breech at the old or north swine facility manure would flow to the east and north. The Endocrine Research Center, manure would flow to the west and north.

FIGURE 25: PUREBRED BEEF FACILITY OR COW –CALF FACILITY

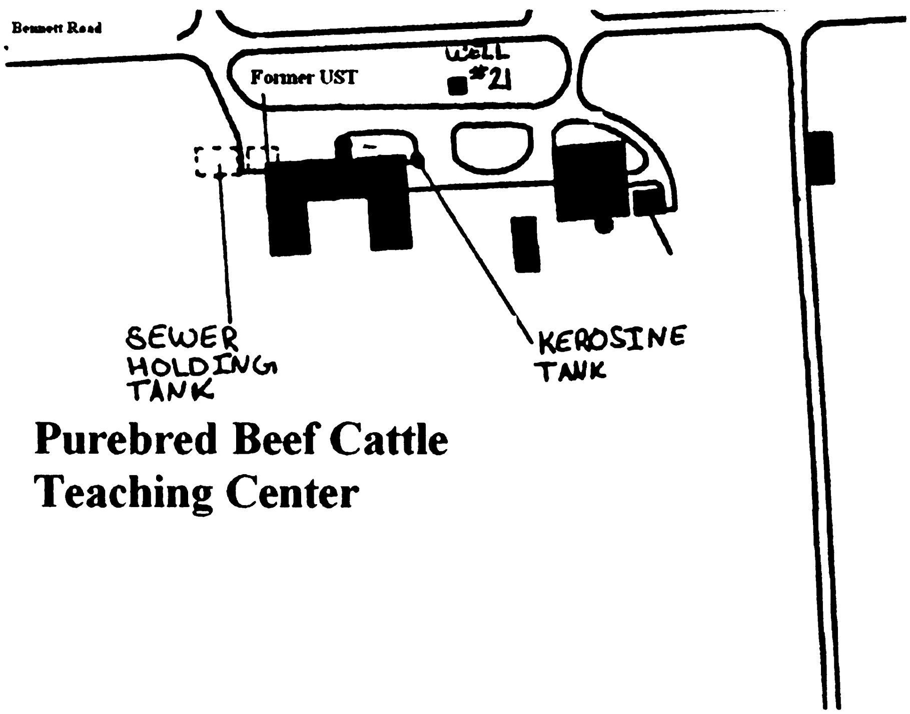

Figure 25. Purebred beef facility, all manure is handled as a solid.