Environmental Work Plan
Year 2

Premium Standard Farms
&
ContiGroup Companies

November 1, 2000

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS

Acronym	Definition
ASAE	American Society of Agricultural Engineers
BEI	Baumgartner Environics Inc.
BMP	Best Management Practices
BOD_5	Biochemical Oxygen Demand
BTU	British Thermal Unit
Ca	Calcium
$CaCO_3$	Calcium Carbonate
CGC	ContiGroup Companies
CLEAN	Citizens Legal Environmental Action Network
COD	Chemical Oxygen Demand
CPF	Crystal Peak Farms
CWT	Changing World Technologies
D/T	Dilutions to Threshold
EC	Electrical Conductivity
F&EA	Function and Equipment Analysis
gpd	Gallons per day
gpm	Gallons per minute
H_2S	Hydrogen Sulfide
IRS	Internal Recirculation System
ISU	Iowa State University
K	Potassium
L	Liter
MDNR	Missouri Department of Natural Resources

Acronym	Definition
min	Minute
mL	milliLiters
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
N	Nitrogen
N_2	Nitrogen Gas
NH_3-N	Ammonia Nitrogen
NO_3-N	Nitrate Nitrogen
P	Phosphorus
ppb	Parts per billion
ppm	Parts per million
PSF	Premium Standard Farms
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
RFP	Request for Proposals
SBR	Sequencing Batch Reactors
SCFM	Standard Cubic Feet per Minute
SES	Sustainable Environmental Solutions, Inc.
SRT	Solids Retention Times
TDP	Thermal Depolymerization and Chemical Reforming Process
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TS	Total Solids
TSS	Total Suspended Solids
VOC	Volatile Organic Compounds
VS	Volatile Solids
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge

EXECUTIVE SUMMARY

This updated Work Plan describes the Capital Improvement Program in place at Premium Standard Farms (PSF) Missouri operations. The Capital Improvement Program was started as part of a Consent Decree with the State of Missouri dated August 3, 1999. A three-member Expert Team (Team) reviews expenditures under the Capital Improvement Program. The Work Plan identifies activities proposed for the following six months, including technologies to be evaluated, pilot projects to be initiated, and construction activities. The Work Plan process has evolved to the point that it is more appropriate to evaluate progress every six months, as opposed to every year. The decision was made in part to allow sufficient time to evaluate systems as they are put in place, while still providing the opportunity to implement or test new technology in the same year. As a result, the Work Plan will be updated in approximately six months. Most activity in the next six months will focus on monitoring the systems installed during year one and in testing, designing and permitting systems that may be installed in the next year.

To date, the Expert Team has approved the following projects:

- Phytase addition
- Installation of 38 permeable covers
- Whitetail treatment project
- Internal Recirculation System
- Crystal Peak Farms process
- Changing World Technologies process
- Water Reuse Pilot plant
- Consulting and monitoring expenditures

PSF has identified several substantial goals for new technology investigation and implementation. These goals include source reduction and risk reduction, improved manure treatment, beneficial reuse of waste products (creation of value-added products) and water reuse.

The following is a summary of future projects described in this Work Plan based on the goals listed above:

- **Source Reduction**
  - University research to remove fiber from raw feedstuffs
  - On-site nutrition research to further lower nitrogen and phosphorus levels
  - Test of an essential oil air treatment system on several barns
  - An investigation into the feasibility of oil sprinkling for dust suppression
  - An investigation of slat pH adjustment to reduce ammonia generation
- **Release Prevention**
  - A study to optimize agronomic utilization of current manure and land resources
  - Continued implementation of the findings of a Function and Equipment Analysis for land application
- **Improved Manure Treatment**
  - Install permeable lagoon covers on all remaining grow/finish lagoons before November 2001
  - Complete aerial photography and contour mapping of all grow/finish sites
  - Conduct a biological pilot test of the Whitetail system
  - Start-up and monitoring of the full-scale Whitetail wastewater treatment system
  - Design the Homan farm with a treatment system similar to Whitetail
- **Beneficial Reuse (Value-added Products)**
  - Construct a second generation Internal Recirculation System
  - Complete a marketing and a feasibility study on the Crystal Peak Farms process
  - Design the South Meadows farm using the Internal Recirculation and Crystal Peak processes
  - Complete pilot testing and a feasibility study on the Thermal Depolymerization and Chemical Reforming Process
- **Water Reuse**
  - Start-up and monitoring of the pilot water reuse project
  - Conduct a small-scale pilot test of other innovative water reuse processes

During the next twelve months, PSF should determine the technology to be implemented on a widespread basis. The technology evaluation is proceeding along a parallel path of evaluating both "baseline" and "value added" processes simultaneously. PSF will meet with the Team and update the Work Plan in approximately six months in order to expedite final technology selection.

1 Introduction

This updated Work Plan describes the Capital Improvement Program in place at Premium Standard Farms (PSF) Missouri operations. The Capital Improvement Program was started as part of a Consent Decree with the State of Missouri dated August 3, 1999. PSF has been implementing the Capital Improvement Program as described in the original Work Plan, which was submitted on November 1, 1999 and in revised form on April 19, 2000. Expenditures under the Capital Improvement Program are reviewed and approved by an Expert Team (Team) pursuant the Consent Decree. Currently, Team members include Dr. Larry Jacobsen of the University of Minnesota, Dr. John Sweeten of Texas A&M University, and Dr. C. Michael Williams of North Carolina State University. Dr. Joe Engeln of the Missouri Department of Natural Resources (MDNR) serves as an ex-officio member. Regarding this updated Work Plan the Consent Decree provides:

> Prior to the end of each year of the [Capital Improvement] Program, Defendants shall submit to the Team and the State a revised Work Plan that presents a summary of the activities conducted during the preceding year of the Program, including a discussion of alternatives considered, the results of any pilot projects conducted, and a reasonably detailed itemization of expenditures made. The revised Work Plan shall also identify activities proposed by Defendants for the following year of the Program, including technologies proposed to be evaluated, pilot projects proposed to be initiated, and proposed construction activities.

To date, the Team has approved the expenditures related to the following:

- Phytase addition (Section 2.1);
- Installation of 38 permeable covers (Section 3.1);
- Whitetail (Section 3.2);
- Internal Recirculation System (Section 4.1);
- Crystal Peak Farms process (Section 4.2);
- Changing World Technologies process (Section 4.3);
- Water Reuse Pilot (Section 5.1;) and
- Consulting and monitoring expenditures, including a research proposal from Iowa State University (Sections 6 and 7).

1.1 Capital Improvement Program Goals

PSF has identified several substantial goals for new technology investigation and implementation. Our goals far exceed the existing regulatory requirements for animal feeding operations. We believe our goals may be obtainable, but the question of economic viability remains to be proven. PSF's goals for the capital investment in new technology are as follows:

- Source reduction and release prevention;
- Improved manure treatment;
- Beneficial reuse of waste products; and
- Creation of value-added products.

Achieving these goals is expected to produce many environmental benefits, including reduction in air emissions and reduction in the amount of land required for land application. These goals will be achieved through a systems approach. A systems approach addresses the entire production process, from the feed provided for the animals through the final land application of manure. PSF believes that this systems approach will result in substantial reductions in air emissions and land requirements.

1.2 Overview of Premium Standard Farms

PSF is a leading pork producer with operations located in the northwest Missouri counties of Daviess, Gentry, Mercer, Putnam and Sullivan. PSF also has operations in Texas and North Carolina. Headquartered in Kansas City, Missouri, PSF is the nation's second largest pork producer and the first pork producer that has achieved true vertical integrating. PSF began operations in 1988. In 1998, Continental Grain Company, now ContiGroup Companies (CGC), bought a controlling interest in PSF. CGC is a private, family-owned, international agri-business. CGC has been involved in pork production since 1985. CGC also owns the farms in Daviess and Gentry counties. These farms are operated by PSF. For purposes of this Work Plan, the term "PSF" will refer to both the farms owned by PSF and the farms owned by CGC.

1.3 Missouri Facility Description and Locations

PSF has approximately 107,000 sows and 800,000 finishing spaces on company-owned farms in Missouri. All breeding, gestation and farrowing facilities are isolated from the grow/finish facilities. In some locations, off-site nurseries have been constructed but, for the most part, the nurseries are located with the sow farms and share a common lagoon. The farm locations are shown on the location map included in Appendix 1. Appendix 1 also contains detailed maps of the Whitetail and Homan farms. The farm types and names are as follows:

Multiplier Farms
Brantley
Denver Miller
Hedgewood
GIF
Overlook

Sow Farms
Badger/Wolf
Hickory Creek
Peach/Perkins
Scott Farm
Sharp
Terre Haute
Wade/Webster
Wiles

Mega Nurseries
Badger/Wolf
Cypress Creek
Terre Haute
Summers

Grow/finish Farms
Green Hills
Homan
Locust Ridge
Ruckman
Somerset
South Meadows
Valley View
Whitetail

Each farm listed above consists of multiple sites, with each site having its own lagoon system. The sow sites were constructed in three standard sizes: 1,100-, 2,200- and 2,500-head facilities. The grow/finish sites are either 8,000-head or 8,800-head facilities (8 barns per site) each with an individual lagoon. With few exceptions, the lagoons are single-stage anaerobic systems for treatment and storage. The total number of lagoons in the Missouri operation is 163, with 95 lagoons located at grow/finish sites and the remainder at sow/nursery sites.

Most PSF production buildings including all grow/finish sites are tunnel-ventilated. The sow units are all mechanically ventilated in the breeding, farrowing and nursery barns. Most gestation barns are naturally ventilated.

All but a few production barns are flush type with fully slatted floors and shallow gutters beneath the slats. Lagoon effluent is continuously recycled to the barns for flushing purposes 24 hours per day seven days a week. Multiple flushing reservoirs containing between 800 and 1,600 gallons are located in each production building. Periodically, a flush valve releases the contents of a reservoir to flush individual lanes within the building. A small pit at the low end of each building collects the drainage from the flushing lanes and has a single outlet connected to a gravity sewer system. The gravity sewer system connects a series of production barns and has a single outlet pipe to the farm's lagoon.

Each production facility is surrounded by secondary containment structures sized to hold 24 hours of flow from the recycle pumping system. Each secondary containment structure has an outlet pipe with a valve that is opened, after testing, only to release rainwater. Should there be a release of effluent from the recycle or gravity sewer systems or the barns themselves, the effluent is fully contained by the secondary containment structures. Any release or discharge to a secondary containment structure results in all effluent in the containment being pumped back to a lagoon or land applied and flushing the containment structure with freshwater.

Effluent from each lagoon is land applied using primarily high-pressure traveling gun applicators. In recent years, PSF has committed significant capital investment dollars toward alternative low-pressure application systems, including center pivots, subsurface injection, and Aerway incorporators. These newer systems lessen the risk of spills and the likelihood of odor complaints during land application.

1.4 Selection of Technologies

PFS reviews technology from two viewpoints, referred to as "baseline" and "value-added". Baseline technology projects are focused on finding processes that make marked improvements in performance toward stated environmental goals (Section 1.1) and do so without product export and revenue. Although PSF does not initially reject baseline technology due to capital and/or operating cost, PSF must be responsible in selecting technologies that are economically feasible. Value-added projects achieve the same environmental goals but allow for higher capital and operating expenditures due to an offsite export and sale of a product (fuel, fertilizer, etc.). Value-added concepts may expand the definition of what is affordable for the pork industry.

Over the past three years, hundreds of baseline and value added proposals have been evaluated. In addition, several internally developed engineering concepts have been assessed. The best methodology for reviewing technology has been requiring vendors to provide detailed cost and process design information in order to give them serious consideration. For the vendor to be in a position to propose a detailed system, it is necessary to give them a model farm specification. In Missouri, the base case used as an example is a farm (e.g., Homan) consisting of multiple finishing sites with single cell anaerobic lagoons at each site. Each vendor is provided with specific data on existing structure sizes, wastewater quantity and quality, and company goals for "next generation" technology. PSF has generally used the Homan farm as the example because it is the primary research site.

Vendors are asked to design their system to the model scale. They also are asked to report on capital and operating costs, land requirements, a description of how their technology will meet the company technology goals, and other characteristics specific to their system. This model farm concept keeps all proposals consistent, thereby making them easier to compare. This process also separates those companies that have serious intent from those that have not spent the time to understand the industry. It seems that the higher the level of detail that is communicated by the vendor through the model farm concept, the final product quality has been better.

Vendor, entrepreneur and academic concepts and proposals have been a greater benefit to the PSF research and development effort in Missouri. There is one general problem though with a majority of the proposals PSF has received. They typically address only one aspect of operations. Some of these technologies may have advantages for isolated parts of the PSF system, but may not be advantageous (and may even be disadvantageous) to the system as a whole. Thus, most proposals only partially meet the diverse goals that have been established for next generation systems. The viability of any one proposal can not be evaluated in a vacuum. It is important to look at technologies on a systems level where "the answer" may very well be a combination of several university or vendor concepts. To develop a systems approach, PSF uses basic engineering feasibility principles to assist in evaluating technology.

Engineering feasibility studies are organized to provide the basis for a prudent technical decision. Major study components include:

- A complete description of the total integrated operation, including farm operations, waste management processes, environmental goals and economics;
- A technical review of the proposed technologies and test work used as a basis for the proposal;
- A review of budgetary projections for capital and operating costs;
- A review of the timeline necessary to implement the project; and
- A risk analysis that details potential technical, operational, organizational, environmental and/or investment risk.

1.5 Project Team

PSF and CGC have dedicated considerable staffing resources to its environmental systems and research for the future. To supplement PSF's engineering resources, PSF has retained HDR Engineering, Inc. (HDR) of Omaha, Nebraska; Sustainable Environmental Solutions, Inc. (SES) of Lenexa, Kansas; and Nofsinger, Inc. (Nofsinger), a Burns & McDonnell company based in Kansas City, Missouri.

In addition, PSF has made or will make arrangements with researchers from several universities to assist in research related to the Capital Improvement Program. Dr. Dwayne Bundy from Iowa State University leads a team of researchers and graduate students that is providing sample collection and analysis for olfactometry and other odor-related parameters. PSF also will solicit proposals from university researchers for conducting research about the environmental benefits of dietary changes. Further, PSF will solicit assistance from masters or graduate level students with the collection and analysis of other monitoring data.

1.6 Public Participation

The Consent Decree includes provisions designed to ensure meaningful public participation in the Work Plan process. To provide another means of public participation, the United States and Citizens Legal Environmental Action Network (CLEAN) have entered into a written agreement with PSF. This agreement allows the United States and CLEAN to participate in the ongoing technical discussions with PSF and the State of Missouri on the selection and implementation of environmental practices and measures at PSF's Missouri facilities. The United States has, in fact, participated in the process by submitting comments to the Team on the technologies proposed by PSF.

1.7 Organization of Remaining Sections

The following four sections of this updated Work Plan are organized based on the goals listed in Section 1.1. Each section will detail the activities undertaken in the last year to address the stated goal and the activities planned for the next year. In general, more detail is provided when describing past activities compared to future planned activities. Following those sections is a segment describing the statistical and analytical methods for the technology evaluation program in place at PSF. The final section describes the budget for the Capital Improvement Plan.

2 Source Reduction and Release Prevention

Source reduction and release prevention are environmental improvement strategies that address environmental concerns at the point of generation. Source reduction activities result in either reduced amounts or reduced strength of waste products. Release prevention refers to practices that focus on preventing the unintended release of manure. Source reduction practices that are discussed in this Work Plan are nutritional changes, which reduce the amount of waste produced by animals or change the characteristics of the waste produced, and activities that change the barn environment to reduce the amount of exhaust air or improve the quality of exhaust air. The major release prevention activities described in this Work Plan are the Function and Equipment Analysis conducted on PSF's land application processes, and a study to optimize the agronomic use of existing manure resources.

2.1 Phytase

The phytase enzyme reduces the excretion of phosphorous (P) by the animals by making more of the P found naturally in available corn. This reduces the amount of inorganic P (currently added in the form of dicalcium phosphate) added to the feed and reduces the total mass of P passing through the PSF system. In turn, this leads to smaller amounts of P being land applied, which reduced the risk that this P could negatively impact water quality.

The cost of installing the phytase application equipment was underestimated in the previous work plan. The original plan was to install spray-applied phytase equipment in PSF's feedmills that produce grow/finish rations (Coffey and Lucerne). Once design work on the application system began, PSF identified unanticipated, but minor, modifications of the Coffey feedmill that would be required. The final remaining design details are mainly associated with the control system. This phytase application system should be operational by April 1, 2001. The Lucerne feedmill presents a larger challenge in that there is not sufficient room between the pellet screener and the load-out bins to allow spray application prior to the feed entering the load-out bins. PSF is experimenting with a heat stable phytase enzyme that can be directly added to the feed prior to the pellet mill. Assuming successful testing, this alternate phytase application method would be installed at Lucerne by April 1, 2001.

2.2 Defibered/Degermed Corn

Recent research has shown that feedstuffs processed to remove fiber greatly improve the energy and protein digestibility of the feed, while yielding a reduced quantity of feces. Processed feedstuffs not only have a higher digestibility (in terms of metabolizable energy content), but they also are easier to digest. This means that the animal has to expend less energy to digest the feedstuff, which should result in an even larger increase in net (productive) energy and a reduction in nitrogen excretion with urine (catabolic losses associated with endogenous secretions). Improving digestibility and reducing endogenous losses is expected to reduce odor emission because odors are produced during the fermentation of remnants from the digestive process. The indigestible fraction and the endogenous losses are both lowered due to the removal of fiber from the feed ingredients. The reduction in fecal mass (60% reduction in unpublished research by North Carolina State University) would likely produce a corresponding reduction in biochemical oxygen demand (BOD_5), total solids (TS) and volatile solids (VS). The potential for a dramatic reduction in these waste characteristics could have major impacts on any subsequent waste treatment processes.

PSF plans to fund research into diets based on defibered/degermed corn during the next year. PSF will issue a Request for Proposals (RFP) soliciting research into the benefits of defibered/degermed corn in diets. The RFP will be submitted to the Team for review and approval before being issued. The objectives of the research will be:

1. Establish the ileal amino acid and energy digestibility of processed feedstuffs as compared to their conventional counterparts;
2. Formulate a diet using processed ingredients and a control diet using conventional ingredients and to assess growth performance in a conventional performance trial and waste production in a conventional (fecal) energy and nitrogen retention and digestibility trial; and
3. Assess effects of the alternative diet on air quality in production buildings.

2.3 Off-site Studies

The genetic combination PSF has chosen is unique. Understanding this pig's nutritional requirements is vital for feeding these pigs more closely to their requirements and thereby reducing manure and nutrient excretion. Many nutritional areas, through both formulation and/or feed additives, offer the potential for nutrient reduction. PSF will issue RFP's soliciting research involving amino acid requirements for our animals. This will determine if there is potential for nitrogen reduction within the system. In addition, we will attempt to determine the order of limiting amino acids and evaluate the cost of improving amino acid balance. An RFP will also be issued to assist PSF in identifying more efficient sire lines. The use of superior sire lines will reduce nutrient excretion. The benefits of off-site testing as compared to an on-site facility are more rapid results, more controlled environment, input from broader nutritional perspectives, the ability to maximize genetic potential, and the opportunity for modeling.

2.4 PSF On-Site Research Facilities

In addition to funding university research, PSF also plans to conduct on-site feeding trials to investigate source reduction potential. Using the results taken from the pilot studies, implementation of these solutions will be demonstrated within PSF's production system. This will provide validation of the results observed from the University studies. The three studies described below are examples of research that will be conducted.

Lysine Titration Study: Premium Standard Farm's grow/finish pigs will be fed diets with varying lysine levels at each stage of growth to determine the lysine levels that optimize feed gain during each phase.

Crude Protein Reduction Study: Previous research has demonstrated that reducing dietary crude protein may result in less ammonium and total N in manure. However, the limiting amino acid sequence must be known to maintain performance when crude protein is replaced by synthetic amino acids. A study will be conducted to determine the dietary methionine and threonine levels needed for optimal growth performance during the finishing phase.

Calcium and Phosphorus Study: PSF grow/finish pigs will be fed diets with lower Ca and P levels to determine the minimum levels of Ca and P that can be fed without hindering growth performance.

PSF proposes converting two existing grow/finish barns to conduct these studies. The facility improvements and equipment needed to conduct this research include additional feeders, an electronic feed tracking system, pen scales, pig scales, a scan machine and a pig tracking system.

2.5 Slat pH Adjustment

PSF barns are constructed with concrete slotted floors (slats) that are suspended above shallow, sloped concrete pits. Manure solids and urine excreted by the animals fall to the slotted floors and eventually to the pit beneath. Flush water then washes the pit floor carrying the manure solids and urine to the building's end where it enters a gravity sewer line leading to the wastewater lagoon. Urine and feces that do not immediately fall through the slates coat the concrete and begin to dehydrate/evaporate.

PSF plans to investigate the feasibility of modifying the physical and chemical characteristics of the surface of the slotted floors. PSF will generally look at the impact of adjusting the pH and/or moisture levels found on the concrete surface. If a modification to this interface is significant in reducing odor and/or gas emission rates, PSF will then look at the feasibility and practicality of modifying the conditions on a sustainable basis. Examples of possible delivery systems include depressed pH water solutions applied through a misting system and a dry alum broadcasting system.

PSF will begin by developing an experimental protocol for review and approval by the Team. It is likely that the protocol will include measurement of ammonia concentrations six inches above the slats in control pens and those that have been pH and/or moisture adjusted. Several concentrations of acid and the acid type will be assessed. Animal and human health considerations will be an important element of this work. Frequency of application and amount of moisture delivered per square foot per unit time also will be evaluated. If promising results are obtained from the initial small-scale tests, larger scale delivery methods will then be investigated.

2.6 Essential Oil Misting

Misting with essential oils is a source reduction technology that has the potential to reduce air emissions from production buildings. A version of this technology is being tested by PSF that mists a water-based solution of essential oils into the air of the production building and distributes it through the building with mixing fans. Misting with essential oils potentially reduces air emissions in two ways including improving the quality of the ventilated air and reducing the amount of air that needs to be ventilated. The removal of dust from the air and the neutralization of certain odorants improve the quality of the exhaust air. Dust removal occurs because the water-based mist comes into contact with dust particles as it settles to the floor, removing some particles from the air. Odorant neutralization reportedly occurs because of chemical reactions between the essential oils and ammonia and other odorous volatile organic compounds. These reactions produce compounds that have reduced odor, or an odor with a less offensive character. The amount of air needed for ventilation is potentially reduced because the misting system cools the indoor air, resulting in a reduced need for ventilation to meet the animals' needs. This results in a net reduction in air emissions from the buildings, because less air is exhausted.

2.6.1 Accomplishments to Date

PSF installed two different versions of the essential oil system into south-facing finishing barns at Homan 23. One version is purely designed for odor control, and comes on periodically. The other version is a combined cooling and odor control system that is thermostatically controlled during warm weather and comes on periodically for odor control during cooler weather. Another south-facing barn at Homan 23 has been used as a control. PSF also has installed the cooling system at a naturally ventilated sow barn at the Peach site.

Air samples have been collected inside the finishing barns since February 11, 2000. Sampling data from this test (and all other air quality testing) is contained in Appendix 2. In addition, some scentometry monitoring has been conducted outside the buildings since June 8. So far, there has been no observed reduction in ammonia or hydrogen sulfide (H_2S) concentrations in the test barns for either system compared to the control. Scentometry results from outside of the buildings have been inconsistent. This is partly due to the fact that it is difficult to make scentometry observations outside of one building that are not influenced by the other buildings. Qualitatively, it appears that the odor from the test buildings is less offensive than the odor coming from the control building. On some occasions, it has been possible to see and smell mists of the essential oil product outside the buildings.

2.6.2 Plans for Coming Year

PSF will install the cooling version of the essential oil system in all four south-facing barns at Homan 23. The four south-facing barns at Homan 22 will be used as a control. Scentometry observations will be made inside and outside the barns once per week for the first month after installation. After this, observations will be made every other week until the summer months. Sampling also will be conducted weekly during the month of July. In addition to these scentometry observations, olfactometry samples will be collected monthly. Ammonia and H_2S samples will be collected inside the barns on a monthly basis. These data will be collected and analyzed as described in Sections 6 and 7.

In addition, data will be collected to determine the effect of the misting system on the production environment at PSF. These data include temperature and relatively humidity (inside and outside), respirable dust concentrations (inside), wind speed, animal death loss, average daily weight gain, and ventilation system use.

2.7 Oil Sprinkling for Dust Reduction

Oil sprinkling is similar to essential oil misting (Section 2.6). In this case, however, undiluted vegetable oil is misted inside the buildings instead of a dilute aqueous solution of essential oils. Oil sprinkling is not expected to have the same cooling and odorant neutralization benefits of essential oil misting. While there is no chemical neutralization of odorants, there is some odor reduction from the suppression of dust. Published research has shown dust reductions of 50 to 80 percent from oil sprinkling. PSF plans to investigate the feasibility of oil sprinkling through literature review and site visits. If this investigation is promising, PSF will install an oil sprinkling pilot system at one of the Homan sites. PSF will report to the Team the results of the initial investigation and the feasibility evaluation by April 1, 2001.

2.8 Land Application Function and Equipment Analysis

A Function and Equipment Analysis (F&EA) was performed for PSF's land application program prior to the start of the 2000 land application season. F&EA is an assessment and optimization tool for the recognition, evaluation and control of work tasks and risks. The analysis process is based on a detailed task-oriented review of operations (functions) resulting in an inventory of past experience, known potential risks and consideration of external conditions and factors (weather, seasonal variations, equipment, etc.) that may impact or influence how a particular work assignment or task should be executed. The review is facilitated by a third party (i.e., an individual or team that is not directly involved in the specified functions), but draws upon the experience of persons involved with the specified function at multiple levels of operations and/or management.

PSF requested that Mr. Steven E. Kroon, Manager of Safety & Loss Prevention for CGC facilitate the F&EA. Mr. Kroon has 23 years of experience in Loss Prevention activities and a general familiarity with agribusiness and concentrated animal feedlot operations. An independent consultant, Mr. Robert L. Sholar, of Compass Environmental, Inc. (Compass) was contracted to audit the F&EA process, assist with report preparation, and review applicable procedures and practices. Table 1 shows the list of items considered in the F&EA.

Table 1. Initial F&EA evaluation list

EQUIPMENT	TASK/FUNCTION
Aboveground Pipe	Application Monitoring
Aerway & Injector	Distribution System
Center Pivot	Emergency Response
Hose	Field Conditions
In-Line Pumps	Lagoon Transfer
Pumps	Land User Communications
Traveling Gun	Radio Communication
	Road Bores
	Site Information
	Site Preparation

The checklist items were divided into groups for discussion with crew leaders and technicians from the Land Application Group (January/February 2000). Typically, group size was 8 to 10 persons (in some cases supervisors or superintendents participated in the group discussions). Approximately 60 hours of discussion time led by Mr. Kroon and 600 person-hours were dedicated to this phase of the F&EA, including physical inspection of many of the equipment items under discussion. During this phase of the F&EA, Mr. Sholar audited group discussions and field inspections.

The results of Equipment and Task/Function discussions are documented in the F&EA Summary Report (Appendix 3). The information in the Summary Report was the basis of a group review session by supervisors, area superintendents and the land application group manager (February 2000). This final review session served to peer review the 'Management Inventory' of the F&EA and to add the value of the comprehensive review process to experience base for the upcoming land application season. For continued function enhancement, the F&EA information has been provided as a training support document to PSF's Training Farm Manager. The F&EA appears to have resulted in comparative environmental improvement. This improvement is demonstrated by the fact that no spills from PSF's land application activities have occurred during the 2000 application season.

2.9 Agronomic Optimization of Existing Resources

PSF plans to work with SES to study agronomic optimization of the existing manure and land resources available to PSF. This is a release prevention strategy because it may result in less acreage being required to utilize all of the manure produced by PSF. Reduced acreage requirements lessen the risk of spills and odor complaints during land application.

SES will begin this research by conducting a literature review of various agronomic crops and cropping strategies that may be suitable to northern Missouri. This review will consist of a library literature review, an Internet literature review, and discussions with technical experts. These technical experts will include university professors and Extension personnel from nearby universities (Missouri, Iowa State, Nebraska, and Kansas State) and other crop industry experts. This research will focus on the following topics:

1. *Suitability of plant species or cropping sequence to northern Missouri*. If PSF is to modify its cropping strategy, the first issue is whether a particular plant species or variety is suited for northern Missouri and what realistic yields can be expected. SES will evaluate new crops and modified varieties of crops currently grown. SES will examine the crops adaptability to the climate (precipitation, temperature, humidity and growing degree-days) and soils (texture, structure, drainage, nutrient content, pH, etc.) of northern Missouri. In order to determine if

nutrient utilization of these alternative crops is superior to current cropping strategies, realistic yields will be estimated.

2. *Nitrogen and phosphorus utilization by the various plant species*. After SES has identified those alternative crops that are suitable to northern Missouri, the firm will determine if the nutrient uptake (nitrogen and phosphorus) will exceed that of the traditional crops based on realistic yield goals. In addition, PSF will examine higher yielding or higher nutrient uptake varieties of current crops including corn (high available phosphorus corn, high oil corn), soybeans, wheat, oats, alfalfa, and clover; alternative cropping sequences to maximize use of the growing season (winter cover crops); improved haying strategies for both legumes and grasses; and improved grazing strategies on pasture land.

3. *Cost of production and value and marketability of the agronomic product*. SES will examine the cost, in terms of dollars and labor, to introduce and implement a new cropping strategy. SES also will evaluate the potential market for the product and the value of the product. Unlike the grain and hay that PSF currently produces primarily for livestock feed, many of these alternative products will have non-traditional markets. Timber and grass sod may be directly marketable to urban areas. Oil seeds may be used for human consumption (cooking), in manufacturing processes as ingredients or lubricants, or as a renewable feedstock for alternative energy processes (see CWT in Section 4.3).

These three factors are analogous to practicability, technical considerations, and economic considerations commonly used in feasibility studies. SES will generate a matrix table to perform a feasibility study based on the three factors above to rank the alternative agronomic strategies. Based on the results of the literature review and feasibility study, PSF may perform field demonstration trials to verify its preliminary findings. Some of the alternative crops that will be evaluated include: (1) forages including corn silage, sorghum silage, sudan, and millet; (2) other grains like grain sorghum, barley, and rye; (3) other grasses for hay production or grazing, including Bermuda grass and blue grass or improved varieties of brome, fescue, or orchard grass; (4) oil seed production from plants like sunflowers, rapeseed (canola), flax, or safflower; and (5) timber production; and (6) sod production.

3 Improved Manure Treatment

Improved manure treatment will yield many environmental benefits, including reduction of air emissions and nutrient reduction. PSF has begun to install permeable covers and implement an advanced manure treatment system known as the Whitetail project. In addition, PSF and it's consultants have researched and considered many other advanced manure treatment systems, including (but not limited to):

- Partial lagoon aeration;
- Solids separation (many types and configuration of screens, and physical-chemical separation);
- Impermeable lagoon covers (partial and fully covered);
- Anaerobic digesters (covered lagoon digester, heated and mixed digesters, both mesophyllic and thermophyllic);
- Biological treatment including nitrification/denitrification (i.e., activated sludge processes, and SBRs); and
- Constructed wetlands (surface flow, subsurface flow, and reciprocating).

In the coming year, PSF will continue to evaluate alternative and innovative wastewater treatment processes by monitoring university research, attending conferences on the subject, visiting on farm demonstrations and entertaining vendor proposals (Section 1.4). PSF also will begin pilot-scale and full-scale operation and evaluation of the Whitetail project. In addition, PSF will obtain contour information for design of future manure treatment of value-added processes. Detailed contour information is needed during design of any project for new technology implementation at PSF. The most efficient way of preparing contour maps is by aerial photography and aerotriangulation. Aerial photography for these purposes is best done during late fall through winter when tree canopy and vegetative cover is less likely to obstruct view of the ground surface. In order to expedite future design work, PSF will have topographic mapping performed at all grow/finish sites during the coming year. The work will include field photogrammetric control. The maps will be produced at a one-foot contour interval. The area of contouring will be approximately 50 acres around each site.

3.1 Permeable Covers

Permeable covers can be a component of an integrated waste treatment system. Permeable covers provide cost-effective emissions reduction from existing anaerobic lagoons. Anaerobic lagoons perform similarly to impermeable covered anaerobic digesters with respect to BOD_5, COD, TS and VS removal, and can perform better with respect to TKN, ammonia and phosphorus removal (Cheng, et al., 2000). Thus, anaerobic lagoons covered with permeable covers are a reasonable means of wastewater pretreatment.

A recent study was performed in Colorado (Zahn and Baumgartner Environics Inc., 2000) to evaluate the effectiveness of a permeable cover for reducing the emission of ammonia, hydrogen sulfide, and total volatile organic compounds from a swine lagoon. Emission comparisons were performed between treatment areas that were covered with the same permeable cover used by PSF and an opening in the cover on the same lagoon. The emission tests showed that the permeable cover achieved an average reduction for hydrogen sulfide, ammonia, and total VOCs of 81%, 96%, and 90%, respectively during the December 1999 sample collection period. Reductions of hydrogen sulfide, ammonia, and total VOCs during the April 2000 period were 98%, 74% and, 88%, respectively and 97%, 61% and, 79%, respectively for the June 2000 period. These results indicate that the emissions reduction performance of the permeable covers appears to be independent of seasonal conditions.

Unlike impermeable covers, permeable covers provide odor control for an anaerobic treatment cell without causing a buildup of odorous compounds or nitrogen in the treated wastewater. A permeable cover on a surface reduces odor in two ways: by physically limiting the emission of odorous chemicals from the lagoon (including elimination of wind and wave action) and by creating an aerobic, biologically active zone on top of the cover where odorous chemicals emitted from the lagoon are oxidized by microorganisms. Permeable covers represent an effective emission reduction option for lagoons.

3.1.1 Accomplishments to Date

A permeable cover was installed on lagoon 24 at the Homan Farm during the fall of 1999. The lagoon has since developed significant algal growth. A cover also was put on lagoon 26 at the Homan Farm as an element in the water reuse pilot plant on May 25, 2000. Similar to the results at lagoon 24, algae growth developed during the warm months of the year. At the Whitetail Farm, all nine existing anaerobic lagoons were covered in the spring of 2000.

PSF has been evaluating the odor control effectiveness of permeable covers using ambient scentometry H_2S measurements as described in Sections 6 and 7. Data from these measurements are found in Appendix 2. In addition, PSF has worked with Baumgartner Environics Inc. (BEI), the manufacturer of the covers currently in use; Sustainable Environmental Solutions, Inc.; and Iowa State University to evaluate the odor emission rates from covered lagoons. The results from the BEI study are currently being analyzed.

Results from the ambient monitoring show a significant improvement in ambient odor and hydrogen sulfide measurements from the covered lagoon compared to the control lagoon. The permeable cover test site is Homan 24; the control site is Homan 20. Twenty-five pairs of scentometry observations were made between October 7, 1999, and October 6, 2000. The scentometry data were analyzed in terms of the frequency of observations that fall into certain classes. Two classes were defined as: observations of two dilutions to threshold (D/T) or below detection, and observations of seven D/T or greater. The scentometry data show that observations of 2 D/T or less were significantly more frequent at the covered lagoon than at the control lagoon ($p=0.0002$). Twenty out of 25 observations (80 percent) at the covered lagoon were minimal compared to seven out of 25 at the control lagoon (28 percent). On all 25 sampling days, the odor observed at the covered lagoon was either less than or equal to the odor observed at the open lagoon.

Sixteen pairs of hydrogen sulfide measurements were made. Fewer hydrogen sulfide measurements were made (compared to scentometry) as a result of maintenance and repair to the hydrogen sulfide analyzer. The average hydrogen sulfide concentration at the control lagoon was 35 parts per billion (ppb), while the average hydrogen sulfide concentration at the test lagoon was 10 parts per billion. This difference is significant when tested with a paired *t*-test ($p = 0.02$). The covered lagoon did not always have lower H_2S concentrations; on two sampling days, the hydrogen sulfide measurements at the covered site were higher than at the control site. Overall, there is substantial variability within the two groups. For both groups, the coefficient of variation (the ratio of standard deviation to mean) was greater than 100 percent (102 percent and 131 percent for the control and the cover, respectively).

Research at the Whitetail farm has been conducted to evaluate the effectiveness of covered lagoons and air dams, installed on a site-wide basis, as an odor control option. Between June 2 and October 16, 2000, 27 sampling visits were made to the Whitetail site. Scentometry observations were made at the property line following the protocol described Section 7. Odor was below detection on 21 out of 27 sampling events (78%).

There has been some concern that covering a lagoon, even with a permeable cover, may cause a buildup of odor-causing chemicals or nitrogen compounds in the lagoon liquid. To evaluate this possibility, manure samples have been collected from the recycle pump system from the covered and control. There was no significant difference between the two lagoons in terms of oxygen demand (biological or chemical), volatile solids, nitrogen content (total Kjeldahl nitrogen and ammonia nitrogen), or concentration of odorous organic compounds (volatile fatty acids and phenolics). Both the covered lagoon and the control lagoon showed the same basic seasonal patterns in terms of the wastewater quality indicators listed above, with concentrations increasing through the winter and spring months and then decreasing in the summer. Generally, the peak concentrations for the covered lagoon were slightly higher than the peak concentrations for the control lagoon. In addition, there appears to be a short lag between the time that concentrations in the control lagoon begin to decrease and the time that concentrations in the covered lagoon begin to decrease. These data show that the manure in the covered lagoon is not significantly different from the manure in the uncovered lagoon in terms of nutrient content and odor potential.

3.1.2 Plans for Coming Year

PSF proposed (and the Team approved on October 18, 2000) installation of 38 additional permeable covers in the original Work Plan. Nine of those covers were approved earlier in the year for installation at Whitetail. Before March 31, 2001, PSF will install the remaining 29 covers (see November 1, 1999 Work Plan for locations). PSF proposes to install permeable covers on the remaining grow/finish lagoons between April 1, 2001, and November 1, 2001.

PSF will continue to test the odor reduction benefits of the permeable covers at Homan 24 and Whitetail. There is an opportunity to evaluate a thicker permeable cover (up to ½ inch thick) that would have the ability to retain more aerobic bacteria, including nitrifying microorganisms to more effectively oxidize gasses that would be emitted from the large lagoon. The oxidized gasses would include hydrogen sulfide, mercaptans, ammonia and other gases. With nitrifying microorganisms oxidizing ammonia to the nitrate form, the resulting nitrates would be in the liquid form in the moist cover. The nitrates in liquid form return to the anaerobic environment of the large lagoon and are denitrified. This would significantly reduce the ammonia emissions to the atmosphere from the large lagoon. There have been samples taken from the covered lagoon in North Carolina to determine if aerobic bacteria are growing in the permeable cover. The results have shown that there is a significant population of aerobic bacteria growing in the permeable cover.

Two manufacturers have expressed interest in supplying a thicker permeable cover on an existing anaerobic lagoon. These covers will be evaluated to determine which one would have the most likely chance of increasing the population of nitrifying organisms in the cover. One or more alternative cover materials will then be selected for installation on lagoons at the Homan site where the performance can be compared to the covers on sites 24 and 26 and the control site (20). The Team will be consulted prior to selecting alternate cover materials for testing.

3.2 Whitetail

The Whitetail project was proposed in the initial Work Plan as a comprehensive system to accomplish improved manure treatment for an entire finishing site consisting of nine finishing farms. Expected benefits from the project include odor reduction at the barns, lagoons, and land application areas, as well a reduction in the effluent nutrient content and acres required for land application. This reduced land application acreage and use of low-pressure center pivots is expected to reduce the risk of spills. The project controls barn odor through two methods including the use of air dams downwind of the exhaust fans and improved quality of recycled flush water. Other wastewater treatment and air quality improvements are accomplished by a combination of other technologies.

3.2.1 Whitetail System Description

A summary of the design data and predicted effluent quality is provided in Appendix 4. Each of the existing nine anaerobic lagoons at Whitetail has been covered with the permeable cover, which may affect the fate of ammonia nitrogen within the lagoon. With the covers, there should be improved air quality as described in Section 3.1. Further, with the use of aeration basin effluent as flushing water, there should be a drop in the pH of the existing lagoons that also could reduce the volatilization of ammonia from the lagoons.

An aeration basin was constructed adjacent to each of the nine existing anaerobic lagoons. The design detention time for the basins was two days at 0.60 million gallons per day (gpd). Effluent from the aeration basin is used all year as recycle make-up for flushing the barns. Between April and November, effluent (30,000 gpd for six months) also is discharged to the subsequent settling and nutrient reduction cells. This change should improve air quality in the barns and from the ventilation exhaust due to the aerobic nature of the recycle flow. Additionally, the reduction in pH expected during aeration also should reduce the volatilization of ammonia in the barns. Sulfides that could produce hydrogen sulfide emissions from the barns should be minimal due to their oxidation to sulfates during aeration.

A 40-horsepower blower and a retrievable course, bubble-diffused air grid meet the oxygen requirements for the aeration basin. The concentrations of BOD_5 and TSS for the aeration and settling basin effluent were derived using Dr. Ross McKinney's equations for aerobic treatment along with an estimate of the effectiveness of the settling cell. Ammonia stripping is not expected from the aeration basin because of a pH reduction during aeration to approximately 7.1.

A settling cell follows the aeration cell for removal of settlable solids. The settled solids are returned back to the existing anaerobic lagoons for storage and further biodegradation. Flow out of the settling cell goes to the nutrient reduction cells.

Three nutrient reduction cells are under construction at Whitetail. The purpose of the cells is to produce an aerobic effluent with low odor for land application. Nitrogen also will be significantly reduced in these cells so that much less acreage is needed for land application. The cells are designed to function with moderate to low organic loading rates. When designed with a shallow depth, these cells are expected to have good light penetration, develop diverse algae populations, and have little or no odor. Nitrogen compounds are reduced through seasonal nitrification/denitrification and volatilization. The depth of the nutrient reduction cells will be approximately six feet (not including freeboard).

The nutrient reduction cells were designed using predicted removal efficiencies for municipal wastewater stabilization ponds. The area of each nutrient reduction cell is two acres for each set of eight grow-finish barns. This results in a BOD_5 loading during the April to November period of 12.5 to 19 lbs. BOD_5/acre/day. The nitrogen losses were calculated using Middlebrook's equations in "Wastewater Stabilization Ponds – Nitrogen Removal" (EPA, 1985). Middlebrook's formulas are empirical and do not identify what the form of nitrogen is when lost.

Nitrogen removal is likely a combination of volatilization and nitrification/denitrification. In a recent paper authored by Lowry A. Harper and Ron R. Sharpe of the ARS-USDA Office in Watkinsville, Georgia, a statistical model was presented that found a substantially greater loss of N as N_2 gas rather than as ammonia (Harper et al., 2000). The study was based on flux measurement data collected from the surface of three hog lagoons in North Carolina and Georgia. In addition, there are likely some losses of N to the sludge that would include algae cells and microbiological cells. There also should be a significant amount of nitrification of the ammonia N because the lagoons are loaded a fairly low rate and there is adequate alkalinity for nitrification. Oxygen will be available from algae.

The wastewater irrigated from the nutrient reduction cells should be in an aerobic state due to the oxygen provided by algae. Odor from irrigation operations should be substantially reduced after treatment by this comprehensive system.

3.2.2 Accomplishments to Date

Permeable covers were installed on all lagoons at the Whitetail facility during March and April of 2000. The construction permit application for the Whitetail project was submitted to the Missouri

Department of Natural Resources on February 10, 2000. Upon receipt of the construction permit on June 20, 2000 and receipt of the land disturbance permit on June 30, 2000, construction began on July 12, 2000. Excavation of the north and south nutrient reduction cells was completed in early September and barrel testing is currently underway. Excavation of aeration basins has been completed at sites 1, 4, 5, 6, 7, 8, and 10 and liner material has been installed in the aeration basin at sites 1 and 6.

An unusually high amount of precipitation during August and September has resulted in a delay in liner installation and a consequent delay in equipment installation. Upon completion of the settling basin excavation and lining, aeration equipment, manholes, and pumps will be installed, and electrical service will be connected.

The proposed completion date for the project has been moved from October 31, 2000, to November 30, 2000, due to weather-related delays. Operation start-up is scheduled for Spring of 2001 and will include implementation of air and water quality monitoring.

3.2.3 Plans for Coming Year

Future work on the Whitetail project includes a biological pilot project (Section 3.2.3.1), start-up and monitoring of the full-scale Whitetail system (Section 3.2.3.2), and design activities for possible future installations of similar systems (Section 3.2.3.3).

3.2.3.1 Biological Pilot

Construction of the Whitetail Project is nearing completion. The purpose of this pilot is to simulate the start-up and operation of the Whitetail aeration system to verify a few key theoretical assumptions. This effort should assist PSF in optimizing the start-up of the full-scale facility in the coming months.

The biological pilot will entail constructing a relatively small-scale model of the Whitetail aeration process. The proposed scale is approximately 0.5% full scale. Through this pilot test, PSF expects to learn the following:

- Information about the effect of aeration on pH;
- Start-up considerations for suppressing nitrification so that target BOD reductions are met; and
- Observation of the biological processes at start-up.

The biological pilot will be constructed using existing research vessels. These vessels were previously used for the other pilot operations at Homan Farm 25 (Sections 4.1 and 4.2). The scale information is contained in Table 2 below:

Table 2. Design scale for biological pilot.

Design Consideration	Pilot Scale	Full Scale (Whitetail)
Aeration Cell (gallons)	7,500	1,200,000
Aeration (pounds per hour)	0.55	88
Flow (gallons per day)	625	100,000
Sludge Settling Cell (gallons)	189	30,000

PSF will use air-operated diaphragm pumps to control flow rates for feeding the pilot aeration tank and for withdrawing sludge from the settling tank. A fine bubble air diffuser connected to an air compressor through a metering valve (200 SCFM) will be used to provide oxygen. A mixer will be placed in the aeration tank to assure that mixing is adequate. PSF expects the pilot to last for two months.

Before beginning the pilot, PSF will write a detailed test protocol. In general terms, the protocol will look at influent and effluent water quality, sludge settling characteristics and nitrification inhibiting agent effectiveness. Monitoring targets (for both influent and effluent) are:

- Alkalinity (2 times/week);
- Temperature (Daily);
- Chemical Oxygen Demand (Daily);
- BOD_5 (2 times/week);
- NH_3-N (2 times/week);
- Dissolved Oxygen (Daily);
- pH (Daily);
- Total Suspended Solids (2/week including sludge sample)

3.2.3.2 Full-Scale Operation and Testing

The general procedures for starting up the Whitetail project are as follows:

- Fill the aeration basins and check all operations affected by the flow of water, including the piping, weirs, and pumps.

- Check the dissolved oxygen control system.
- Check the aeration system, including the blowers and aeration piping.
- Place the recycle flush lift station in operation with overflow from the existing lagoon after the dissolved oxygen control system begins reducing the flow rate into the aeration basin.
- After the aeration basin is operating under stable conditions, introduce treated wastewater into the settling basin and check the sludge draw-off manhole, recycle sludge pump and the floating pump discharging to the nutrient reduction cell.
- The nutrient reduction cells will have at least two feet of lake water before flow from the settling basins at each site pump flow to the nutrient reduction cells.

As the system comes into operation, PSF will begin a program of wastewater monitoring. The purpose of this monitoring will be to evaluate the effectiveness of the Whitetail system. Table 3 describes the samples that will be taken from each part of the system.

3.2.3.3 Design for Future Installations

In the next six months PSF proposes to complete design documents and a permit application for the Homan farm using the same type of treatment as at Whitetail. This work will be done in advance of a decision on implementing the technology. This is necessary to expedite the permitting and construction process, should this technology be selected for further installation. PSF will meet with the Team in approximately six months to review progress on determining the technical and economic feasibility of the Whitetail system. Construction will not commence nor will the documents be submitted for permits before meeting with the Team.

Table 3. Sampling program for Whitetail system.

Parameter	Sample	Frequency
LOCATION #1: Covered Large Lagoon Effluent (Each of the nine Whitetail sites)		
BOD_5	Grab	Weekly
TSS	Grab	Weekly
VSS	Grab	Weekly
TDS	Grab	Monthly
TKN-N	Grab	Weekly
pH	Grab	Weekly
Alkalinity ($CaCO_3$)	Grab	Weekly
EC	Grab	Monthly
LOCATION #2: Aeration Basin Effluent (Each of the nine Whitetail sites)		
MLSS	Grab	Weekly
MLVSS	Grab	Weekly
LOCATION #3: Settling Basin Effluent (Each of the nine Whitetail sites)		
Flow	----	Daily
BOD_5	Composite	Daily (First 2 weeks, except Sunday, then 3 times/week)
TSS	Composite	Daily (First 2 weeks, except Sunday, then 3 times/week)
TKN-N	Composite	Daily (First 2 weeks, except Sunday, then 3 times/week)
NH_3-N	Composite	Daily (First 2 weeks, except Sunday, then 3 times/week)
NO_3 N	Composite	Daily (First 2 weeks, except Sunday, then 3 times/week)
Alkalinity ($CaCO_3$)	Composite	Daily (First 2 weeks, except Sunday, then 3 times/week)
Phosphorous	Composite	Daily (First 2 weeks, except Sunday, then 3 times/week)
LOCATION #4: Sludge Draw-off Control Manhole No. 1 (Each of the nine Whitetail sites)		
TSS	Grab	Weekly
WAS Flow	----	Daily estimate
LOCATION #5: Nutrient Reduction Cell Effluent (Each of the three NRC sites)		
BOD_5	Grab	Weekly
TSS	Grab	Weekly
TKN-N	Grab	Weekly
NH_3-N	Grab	Weekly
NO_3-N	Grab	Weekly
NO_3-N	Grab	24 hourly once every 2 weeks
Alkalinity ($CaCO_3$)	Grab	Weekly
Phosphorous	Grab	Weekly

4 Beneficial Reuse (Value Added Processes)

Value-added processes are those that produce and export a product like fertilizer or fuel off of the farm. These projects achieve the environmental goals identified for the Capital Improvement Program (Section 1.1). The revenue stream from the sale of these products may allow for higher capital and operating expenditures. PSF has evaluated numerous value-added technologies. The technologies discussed in this section are those with the highest potential for commercial success at the scale of PSF's Missouri operations. PSF will continue evaluating other alternative processes during the next year while work progresses on the options described in this section.

4.1 Internal Recirculation System (IRS)

The Internal Recirculation System (IRS) (patent pending) is a practical means to concentrate dilute wastewater flows to concentrated slurry. The IRS itself does not produce a value-added product, but the volume reduction of the waste stream it can achieve is essential to minimize the capital and operating costs of any downstream advanced waste treatment process. Without the IRS, the dilute nature of the waste stream flushed from PSF's barns would prohibit consideration of value-added technologies.

4.1.1 The IRS Process

The IRS is designed to condition and concentrate hog waste slurries produced in confinement barns. Depending on water conservation measures used in the farm operation, the IRS can consistently produce concentrated waste slurries of up to 8% Total Solids (TS). This is roughly an increase of 40 times the solids content (from 0.2% TS to 8% TS) from the discharge slurry typically produced by a high volume recycle flush system using lagoon supernatant.

A pilot IRS system was installed at Homan site 25. A flow diagram is included in Appendix 5. Flow from eight 1,000-head grow/finish barns entered a large partially submerged tank used as a wet well. The temporary tank was used due to a potential delay with getting a permit modification for excavation. Although operation was somewhat ungainly, the tank worked well with the exception of the long pump suction required for the pickup pump. The tank overflowed directly into the lagoon in the event of an IRS failure. A more conventional wet well would be a buried vessel or vault equipped with a chopper-type submersible pump. Excess fluid would overflow to an adjacent lagoon. A simple means to detect an overflow condition should be included in the permanent design.

Flow from the wet well was pumped to a single-deck, 60-inch circular screen that was equipped with an 80-mesh screen. The purpose of the screen is to remove coarse solids that may cause sludge accumulation problems if recycled to the barns. During the test period, the coarse fraction accounted for 17% of the total solids produced by the farm. The coarse fraction contained almost all of the hair, spilled feed, corn hulls, and other fibrous material present in the waste stream. The screen undersize fraction (i.e., flow and material passing through an 80-mesh screen) was used as recycle fluid. During steady state operating conditions, the screen undersize slurry averaged 3.94% TS. The undersize fraction contributed 83% of TS to the IRS product. Additional testing is necessary to verify these values over a broader range of animal ages and diets.

During initial operation, the capacity of the screen deck was marginal. Screen flooding occurred on prolonged operation, and frequent cleaning was required. A slightly larger (50-mesh) second screen deck would help by removing the hair and coarse fiber material first to prevent plugging of the finer second screen. This configuration was successfully tested during the second pilot operation. The addition of a chopper pump at the wet well and elimination of wood chips in the circuit also would help in future systems.

Sulfuric acid was added to the recycle flow to control the pH in the desired range of 7.5 to 8.0. During the test period, little ammonia was detected in the barns or process building at pH levels of 8.4 or lower. The pH of the recycle flow was measured at least once a day and the acid delivery rate was adjusted to correspond to the pH trend. Given the volume of the circuit (roughly 20,000 gallons), the system took several hours to respond to changes in the addition rate. The average daily use of 17.4 gallons showed only slight correlation to waste generation. A design rate of 20 gallons per day seems reasonable.

During the test period, the coarse and undersize fractions were recombined to produce what is labeled as IRS product. Production of IRS product averaged 1.32 lbs/day/pig or 5.77 lbs/day/1000lbs live weight (dry basis). The calculated waste production rate is approximately 82.5% of ASAE tabulated data. The difference may in part be attributable to the feed conversion ratios attained by PSF. At least some of the difference is attributable to recurring overflows from the wet well to the lagoon and sludge accumulation in the barns and process vessels. The IRS Product slurry averaged 8.38% TS. Flow rate averaged 6.9 gpm during the test period with a peak of 7.7 gpm. The suggested design would be 15 gpm to account for the maximum potential animal inventory for which the farm is designed.

4.1.2 Accomplishments to Date

An IRS unit was installed at Homan 25. Two pilot runs occurred during 2000, producing five months of operating experience with the system. The system IRS performed very well. The problems that were encountered can be remedied with straightforward design changes.

Operationally, the IRS should require only a daily walk-through to address any problems. The volume of the system buffers any rapid changes. Both of the value-added processes described in Sections 4.2 and 4.3 use the IRS to produce feedstock. In addition to producing a concentrated feedstock, the IRS is expected to produce a recycle liquid that has a lower odor (because it is aerobic) than the recycled lagoon water currently used.

The extended test program was run in conjunction with pilot scale testing of the Crystal Peak Process (Section 4.2). The concentrated slurry produced was used to feed downstream testing of fertilizer and fuel production technologies. The concept and performance of the IRS was excellent. The test program generated sufficient data to proceed with the design and construction of the first commercial IRS units.

Impacts from IRS operation on environmental conditions in and around the affected hog barns were consistently beneficial. The controlled high volume recycle of conditioned slurry provided equal or better cleaning of flush gutters in the barns. As compared to the use of dilute solutions from lagoons, the high concentration of fine solids in the IRS recycle slurry (2 to 4% TS) is believed to improve solids removal from waste pits in operating barns.

Aerobic conditioning of the recycle slurry provided by IRS operation produced a distinct, but at this point, subjective improvement in odor emitted from barn exhaust fans. Qualitatively, the difference was the elimination of the anaerobic (or lagoon) smell from the exhaust.

The concentrated slurry produced by the IRS is very consistent in terms of concentration and physical characteristics. This consistency is essential to effective downstream processing of the waste stream to value-added products. Depending on the type of farm (i.e., finishing, nursery, breeding) and volume of water used in farm operation, the concentration of TS in the IRS product can range from 3 to 8%.

4.1.3 Plans for Coming Year

The focus during the next year will be the implementation of the IRS on a fully operational basis. Planned development efforts include:

1. Test work is planned to confirm design assumptions made about pumping the IRS product slurry to a central processing facility. No work has been completed to date on determining the friction loss of IRS recycle and product fluids, which will need to be pumped through relatively long pipelines to a central processing facility. The comparatively easy manner in which the slurries were pumped during the test program suggests that friction losses may be

significantly less than book values derived largely from municipal sources. These values must be established prior to the design of the first commercial facility.

2. Further testing is planned to determine if these coarse components have an adverse affect on subsequent production of granular fertilizers.

3. Complete preliminary design of a compact commercial IRS for a grow/finish unit. The design of the commercial unit will emphasize ease of operation and effective process control to prevent overflows and other process upsets. The IRS will be designed to operate during the building clean-outs. It is expected that the volume of waste recovered from the cleaning operations will dictate that normal operation of the IRS will be maintained. With the use of high-pressure equipment, it is not expected that the volume of water used during barn cleaning will exceed the capacity of the IRS.

4. Construct, at a minimum, one IRS unit on a grow/finish site to demonstrate continuous operation. Additional units will be built if a value-added process is judged to be economically feasible and a decision is made to proceed with a full-scale prototype on one of the PSF grow/finish farm complexes.

5. Complete preliminary design work for a sow farm. The modified sow farm design would require much higher internal recirculation rates.

4.2 Crystal Peak Farms Process

The Crystal Peak Farms (CPF) Process (patent pending) was designed to produce a high quality fertilizer product from swine waste. Recent work also has examined the potential role of the CPF Process to provide efficient preparation of feedstock for advanced fuel production technologies (see Section 4.3). Crystal Peak had previously completed bench-scale testing. Pilot testing on the key unit processes was largely completed during the past year at the PSF Homan farm. A study will be conducted in the next year to examine the economic viability of a proposed demonstration plant. Elements required for the success of an integrated value-added process, like the CPF Process, are efficient nutrient recovery, effective containment of waste streams, economically justifiable processing costs, and defining reliable markets for the value-added products. The process appears to consistently provide a 90% reduction of total P and N. If implemented, the required acreage for land application should be significantly reduced as compared to current operations.

The complexity of developing a fully integrated waste process for PSF has been aided by a number of firms. A key element in the potential economic viability of the CPF Process has been the development of the IRS (patent pending) by PSF.

Crystal Peak Farms, PSF, and Nalco Chemical Company conducted the CPF Process Pilot as a joint research project. The participation by Nalco provided both resources and engineering experience. Nalco is a wholly-owned subsidiary of Suez Lyonnalse Des Eaux. Suez is a leading international supplier of waste management engineering, equipment, process chemicals, and construction services. Additional support was provided by Suez Group companies, including United Water Service and Inflico-Degremont. United Water Service specializes in contract operations of municipal and industrial water and waste treatment systems. Infilco-Degremont is a major supplier of equipment, engineering, and construction services in the waste management industry. Feeco International, a major supplier of equipment used in similar facilities, provided test facilities and engineering for the planned fertilizer plant. Chemical Lime conducted a number of process tests related to lime usage and ammonia stripping. Chemical Lime has a major production facility located at St. Genevieve, Missouri.

4.2.1 The CPF Process

The CPF Process uses physical and chemical processes to affect the separation of nutrients from waste produced by livestock operations. Economical use of the CPF Process requires a concentrated feed source. In the projected PSF operations multiple IRS systems will be used to supply a centrally located CPF process plant. PSF grow/finish farm complexes have eight to 16 farms at each complex. Under the proposed system, each farm would have an IRS system. The IRS product slurry from each farm would be pumped to a central process facility. Each 8,000-head grow/finish farm would produce approximately 15 gallons per minute (gpm) of waste slurry at approximately 7% TS. Storage for the waste slurry would be provided at the process plant. Continuous processing of the waste slurry generated by full range of animal ages and diets will minimize variations in nutrient concentrations.

The initial unit process in the CPF Process is the crystallization of struvite (magnesium ammonium phosphate) by the addition of a soluble magnesium salt to the waste slurry. Struvite recovery is enhanced in the subsequent lime stabilization step by staged lime addition. Phosphate recovery as struvite typically exceeds 90%. N recovery as a component of struvite crystallization is approximately 30%. Available phosphate in the CPF product as tested by the industry standard citric acid procedure (AOAC 16 960.02) for plant-available phosphate consistently exceeded 90% of total phosphate. Struvite is an excellent slow release nitrogen and phosphate fertilizer.

The second unit process is lime stabilization. Lime stabilization provides improved solid/liquid separation, pathogen reduction, conversion of various forms of nitrogen to ammonia for the stripping circuit, and increased recovery phosphate recovery as struvite. After lime stabilization, ammonia is removed from the slurry by air stripping. The ammonia was recovered by reacting it with sulfuric acid to form ammonium sulfate. The ammonium sulfate solution will be fed in a controlled manner to the product pellitizer/dryer to provide both necessary fluids for pelletization and recovery of crystalline ammonium sulfate.

The primary slurry exits the air stripper to a specially designed clarifier where a small quantity of flocculent is added. After flocculation, the slurry is continuously wasted to a centrifuge for separation. Extensive work was conducted during the pilot operation to optimize operation of the clarifier and centrifuge. Key considerations were polymer usage and solids recovery. The tests confirmed that effective separation could be accomplished with polymer addition rates in the range of two to four pounds per ton of solids. Twelve polymer samples provided by vendors were tested. Solid recoveries achieved during the pilot run ranged from 60% (no polymer) to 94%. The final design should consistently yield a recovery rate of approximately 90%.

The thickened slurry was fed to a conventional scroll centrifuge supplied by Plerallsi. Extensive test work established key operating parameters. The centrifuge cake is predicted to average 30% TS based on pilot plant operations. The centrate is returned to the clarifier. The clarifier overflow is the process effluent. A number of options have been investigated for either land application or processing of the effluent. Primary alternatives for further processing of the effluent include both water reuse and recovery of remaining nutrients. Ultrafiltration and a proprietary solid/liquid separation process will be studied during the next year as potential alternatives to land application. A review of potential salinity implications of land application also is planned.

The final unit process is the pelletization and drying of the wet cake and ammonium sulfate solution. Several options were tested at both Feeco and CPF. A promising fluidized bed technology was tested at Feeco and failed to produce an acceptable product (product quality is judged by pellet hardness and the amount of dust generated in material handling.) Further testing with a conventional drum pelletizer and rotary dryer produced a high quality product. Product samples have been retained by PSF for use in marketing presentations.

4.2.2 Accomplishments to Date

Two pilot runs were performed during the past year. The results from the pilot runs and the process changes necessitated by these results are included in the process description in Section

4.2.1. Pilot operations produced more than 30 tons of product for testing both thermal depolymerization (Section 4.3) and fertilizer pilot tests.

4.2.3 Plans for Coming Year

For a value-added process, the value of the product produced must support the capital and operating costs incurred. Numerous contacts were made with persons involved in both the commodity and horticultural markets. Based on these discussions, a decision was made that an investment decision would have to be made on a commodity product. Although the pricing available for a CPF product was significantly higher in horticultural markets, the relatively small niche markets with these specialty products would not be sufficient for the volume of CPF product expected to be produced. As a consequence, a market study has been initiated to establish the marketability of the anticipated product to regional farmers. The market study focuses on direct sales to minimize distribution costs. Each large grow/finish complex will produce between 15,000 to 40,000 tons per year of product depending on product analysis and farm size. The ultimate goal is to produce a 10-10-10 NPK (i.e. 10% nitrogen, 10% phosphorous, and 10% potassium) product, although this probably will not occur with the initial demonstration plant. The base process is projected to produce either a 7-6-2 or a 6-6-6 NPK product. The CPF product has many advantages including:

- Consistently high NPK value;
- Fertilizer produced from a "clean" feedstock as compared to municipal sources;
- Addition of organic carbon to soil;
- A good mix of both slow release and readily available nutrients;
- A good source of minor nutrients including magnesium, calcium, sulfur, and iron; and
- Key micronutrients such as zinc, copper and manganese.

Work planned during the next year includes:

1. A feasibility study will be complete by the end of the year. The study will provide the basis for an investment decision on a demonstration plant that would likely be located at the Homan Farm Complex. A recognized engineering company with broad experience with similar projects will conduct the feasibility study. Major elements of the feasibility study will be:

    - Completion of a final process flow sheet;
    - An estimate of capital costs;
    - An estimate of operating costs;
    - Definition of regulatory issues;

- Market Projections;
- Customers;
- Pricing;
- Distribution;
- Project Timetable; and
- Risk and sensitivity analysis of proposed investment;

2. Completion of a feasibility study about CPF Process use to produce a feedstock for fuel production options.
3. PSF proposes to, in the next six months, complete design documents and a permit application for the South Meadows farm using the IRS and CPF technologies. This work will be done in advance of a decision on implementing the technology. This is necessary to expedite the permitting and construction process, should this technology be selected for further construction. PSF will meet with the Team in approximately six months to review progress on determining the technical and economic feasibility of the CPF process. Construction will not commence nor will the documents be submitted for permits before meeting with the Team.
4. Additional development and pilot work on process effluent treatment through land application or water treatment technologies targeted at water reuse.
5. Additional study of possible means to upgrade the nutrient analysis of fertilizer produced by the CPF Process. Pilot studies of the basic process produced a product with an NPK analysis of 7-6-2. New studies will be undertaken to increase the nutrient content to the common commercial 10-10-10 NPK formulation.
6. If the completed feasibility study concludes that a project is economically viable, work will proceed to complete final design engineering and proceed with required regulatory permitting of a prototype plant. On a fast-track basis, construction of the first plant could be initiated during the second half of next year.
7. Completion of a marketing study based on position as a baseline producer of a commodity product.
8. Bench-scale work including study of solubility of potassium and phosphorous salts.
9. Development of process design modifications for thermal depolymerization option.
10. Complete economic review of the use of anaerobic digestion for increasing product analysis and dryer fuel production.
11. Complete testing and economic review of process options related to effluent treatment, land application, and water reuse.
12. Agronomic testing of CPF product performed by University of Missouri Cooperative Extension Service.

4.3 Changing World Technologies Process (TDP Process)

Shortly after publishing the November 1999 Work Plan, PSF learned about a novel organics processing method called Thermal Depolymerization and Chemical Reforming Process (TDP). TDP converts hydrocarbon and organic materials into fuels and fatty acids. Wastes, byproducts, or low-grade organic materials go into the TDP process. Three separate streams come out; including a fuel gas, light organic liquid, and a solid product that can be used as fuel or fertilizer. The process is owned and being developed by Changing World Technologies, Inc. (CWT) of West Hempstead, New York.

The application of this soon to be commercialized process to hog farming seemed impractical when first reviewed, since the organic feedstock solids content necessary for the process to be effective needed to be at least 20 to 30 percent. Flush-type hog farms like those at PSF have a solids content of less than one half of one percent. Further investigation appeared justified based on progress made in waste-thickening methods, including the IRS and CPF processes (Sections 4.1 and 4.2).

After careful consideration PSF decided that an integrated system employing TDP, IRS and CPF could have merit. PSF has invested considerable time and money toward integrating all three concepts. A brief description of the TDP process is included in the next section, followed by a description of the past year's activities and plans for 2001.

4.3.1 The TDP Process

There are five main steps in the TDP process. The first step involves slurrying the organic feed with water. The slurry is then heated under pressure to a specific reaction temperature. After sufficient retention at pressure, the reacted product is flashed to a lower pressure to release the gaseous products. Next, the remaining dense slurry is reheated to drive off water and liquid oil from the solid product. Finally, the system employs physical phase separation of the oils from water.

The process temperatures for the initial slurry phase of processing are between 250^{o} C to 300^{o}C. For the dense slurry processing stage, the temperatures are near 500^{o}C. The individual steps of the TDP process have been well developed in other industries, including oil and gas processing. The TDP plant looks like a small chemical plant.

Fuel gas produced by the TDP is a medium-BTU fuel-gas that is used in gas turbines located near the TDP plant for electric power generation. The oil product is typically a narrow range of light hydrocarbons or organic materials that also can be used for fuel, or converted into higher value products. The solid product either can be a fertilizer that is rich in micronutrients or a fuel, depending on the carbon-forming character of the feedstock.

4.3.2 Accomplishments to Date

The TDP process is very new and only now approaching a stage where commercial implementation (in another industry) might be possible. Thus, progress in assessing its applicability to the hog industry has been cautious. During the past year, PSF has developed a theoretical, but realistic, business model for deploying multiple IRS's at PSF hog farms with CPF plants centrally constructed at each property (multiple IRS's feeding one CPF wet processing plant at each farm site). A CWT plant would then be constructed at a central site to process all of the products produced by multiple CPF plants. Manure solids would be trucked from the farms to the central CWT plant. Manure solids can be economically transported because the CPF process consistently delivers high solids content feedstock. Low nutrient and relatively low organic strength wastewater remains at the individual farm site for crop irrigation.

Using this model PSF has attempted to collect preliminary pilot plant engineering and preliminary cost data. Critical steps in this review include:

- Ongoing research, development and refinement of the IRS and CPF processes;
- Full-scale piloting of our organic feed stock through CWT pilot plant located in Philadelphia;
- Understanding of the basic process chemistry;
- Capital investment projections; and
- Product yield and valuations.

This is a very complicated undertaking given the newness of the CWT process not to mention the newness of the IRS and CPF processes. IRS and CPF pilot results are discussed elsewhere in this report (Sections 4.1 and 4.2). Manure products produced by the IRS and CPF systems have been pilot tested in Philadelphia twice. The first test was in April 2000. The most recent test is ongoing as of this writing. Many materials handling issues have been encountered in these tests. As a result, little quantitative data has been obtained to date. The TDP plant in Philadelphia is a scale up of smaller pilot machines where quantitative data were obtained for animal manure. These pilot data provides some optimism that if a few key engineering obstacles pertaining to materials handling can be overcome, acceptable mass balance data can be obtained. In turn, it is hoped that these data will justify an investment. Qualitative results and observations in April and again in the current test are encouraging.

4.3.3 Plans for Coming Year

Work planned during the next year includes:

1. Completion of pilot testing to confirm product yields and obtain a system mass balance.

2. A feasibility study will be complete by the end of the year. The study will provide the basis for an investment decision on a demonstration plant that would likely be located at the Milan plant. The plant would bring in manure feedstock from one grow/finish farm, all dead animals from PSF farms, and all offal from the plant. A recognized engineering company with broad experience with similar projects will conduct the feasibility study. Major elements of the feasibility study will be:
   - Completion of a final process flow sheet;
   - An estimate of capital costs;
   - An estimate of operating costs;
   - Definition of regulatory issues;
   - Market Projections;
   - Customers;
   - Pricing;
   - Distribution;
   - Project Timetable; and
   - Risk and sensitivity analysis of proposed investment.
3. Additional development and pilot work on process effluent treatment technologies targeted at water reuse or direct discharge.

4. If the completed feasibility study concludes that the project is economically viable, work will proceed to complete final design engineering and proceed with required permitting of a prototype plant.

5 Water Reuse Processes

A Water Reuse Pilot Project was proposed as a new technology in the 1999 Work Plan and is currently under construction at site 26 at the Homan Farm. The concept of the Water Reuse system is to treat and reuse effluent using proven wastewater treatment and water treatment technologies. In addition to further work on this project, PSF also plans to conduct a small-scale pilot test of a microfiltration system for water reuse. Industry and academic representatives have criticized water reuse as being unrealistic or too costly. However, PSF is committed to exploring water reuse processes because PSF is prohibited from discharging treated effluent as a disposal method and is greatly affected by weather patterns in Missouri. PSF relies on rainfall to fill freshwater reservoirs, but depends on dry weather to support wastewater irrigation on heavy clay soils. These factors make water reuse very attractive.

5.1 Site 26 Pilot

PSF proposed a water reuse project for Homan site 26 that was previously approved by the Team. The project goal is to treat wastewater to sufficient water quality to allow reuse via direct consumption by the hogs as their drinking water supply. This project scope is 8,000 finishing spaces and is currently under construction. The system will be placed into operation in the coming year.

5.1.1 Site 26 Process

The process for the site 26 pilot was described in detail in the November 1999 Work Plan. A schematic diagram of the process and other design information is included in Appendix 6.

5.1.2 Accomplishments to Date

The construction permit application for the water reuse pilot plant was submitted to the Missouri Department of Natural Resources on February 2, 2000. The construction permit was issued on June 20, 2000, with the land disturbance permit being issued on June 30, 2000. Staking of new structures began on June 26, 2000, and construction of the water reuse pilot plant began on July 5, 2000, with an anticipated completion date of October 31, 2000.

A permeable cover was installed on the primary lagoon at site 26 in May 2000. Excavation of the aeration basin, settling cell, algae removal cell, nutrient reduction basin, and covered water storage cell was completed on September 14, 2000. The liner installation in the settling cell and in aeration basin was completed on October 4, 2000. The plumbing and manhole installations were completed in mid-October 2 000.

5.1.3 Plans for Coming Year

Start-up of the water reuse pilot plant is scheduled for Spring 2001. As the system is initialized, a program of wastewater monitoring will be implemented. The purpose of the program is to establish the effectiveness of each step in the wastewater treatment process in reducing the organic pollutants and documenting the reduction in nutrients. In addition the effectiveness of the tertiary wastewater treatment processes and the various types of disinfection facilities will be established. Table 4 describes the samples that will be taken from each part of the reuse process.

Table 4. Sampling program for Water Reuse pilot.

Parameter	Sample	Frequency
LOCATION #1: Existing Lagoon Effluent		
BOD_5	Grab	Monthly
TSS	Grab	Monthly
VSS	Grab	Monthly
TDS	Grab	Monthly
TKN	Grab	Monthly
pH	Grab	Monthly
Alkalinity ($CaCO_3$)	Grab	Monthly
EC	Grab	Monthly
LOCATION #2: Aeration Basin Effluent		
MLSS	Grab	Weekly
MLVSS	Grab	Weekly
LOCATION #3: Settling Basin Effluent		
Flow	----	Daily
BOD_5	Composite	Weekly
TSS	Composite	Weekly
TKN-N	Composite	Weekly
NH_3-N	Composite	Weekly
NO_3 N	Composite	Weekly
Alkalinity ($CaCO_3$)	Composite	Weekly
TDS	Composite	Weekly
Phosphorous	Composite	Weekly
EC	Composite	Weekly
LOCATION #4: Sludge Draw-off Control Manhole No. 1		
TSS	Grab	Weekly
WAS Flow	----	Daily estimate
LOCATION #5: Nutrient Control Cell Effluent		
BOD_5	Grab	Weekly
TSS	Grab	Weekly
TKN-N	Grab	Weekly
NH_3-N	Grab	Weekly
NO_3-N	Grab	Weekly
NO_3-N	Grab	24 hourly once every 2 weeks
Alkalinity ($CaCO_3$)	Grab	Weekly
Phosphorous	Grab	Weekly
TDS	Grab	Weekly
EC	Grab	Weekly
Total Organic Carbon	Grab	Weekly
LOCATION #6: Algae Removal Cell Effluent Lift Station		
BOD_5	Grab	Weekly
TSS	Grab	Weekly
VSS	Grab	Weekly
TKN-N	Grab	Weekly
NH_3-N	Grab	Weekly
NO_3-N	Grab	Weekly
Phosphorous	Grab	Weekly
TDS	Grab	Weekly
Ascarid Eggs	Grab	To be determined
EC	Grab	Weekly

Parameter	Sample	Frequency
Total Organic Carbon	Grab	Weekly
LOCATION #7: Sand Filter Effluent Lift Station (Both types of filters)		
pH	Grab	Weekly
BOD_5	Composite	Weekly
TSS	Composite	Weekly
VSS	Composite	Weekly
TKN-N	Composite	Weekly
NH_3-N	Composite	Weekly
NO_3-N	Composite	Weekly
TDS	Grab	Weekly
Ascarid Eggs	Grab	Weekly
EC	Grab	Weekly
Total Organic Carbon	Grab	Weekly
LOCATION #8: Covered Water Storage Cell Effluent Lift Station		
BOD_5	Grab	Weekly
TSS	Grab	Weekly
VSS	Grab	Weekly
TKN-N	Grab	Weekly
NH_3-N	Grab	Weekly
NO_3-N	Grab	Weekly
Total Coliform	Grab	Weekly
Turbidity	Grab	Weekly
Giardia	Grab	Weekly
Ascarid Eggs	Grab	Weekly
pH	Grab	Weekly
LOCATION #9 & 10: Disinfection Facilities Effluent Lift Station and Lake Waters		
Flow	----	Weekly
Total Coliform	Grab	Weekly
Giardia	Grab	Weekly
Ascarid Eggs	Grab	Weekly
TDS	Grab	Weekly
Electric Conductivity	Grab	Weekly
pH	Grab	Weekly
Chlorine Residual	Grab	Weekly (Sodium Hypochlorite Disinfection System only)
LOCATION #11: Hog Drinking Water		
Flow	---	Daily
Total Coliform	Grab	Weekly
Turbidity	Grab	Weekly
Giardia	Grab	Weekly
Ascarid Eggs	Grab	Weekly
TDS	Grab	Weekly
EC	Grab	Weekly
Chlorine Residual	Grab	Weekly (Sodium Hypochlorite Disinfection System only)
pH	Grab	Weekly

5.2 Other Water Reuse Processes

PSF plans to pilot test a technology that consists of an activated sludge biological treatment system integrated with a microfiltration membrane system (membrane bioreactor). The system will be tested at Homan site 25 in conjunction with the biological pilot test (see Section 3.2.3.1).

The goals of the bioreactor pilot test are to generate reuse quality water without the complexity of the system being tested at site 26. The membrane bioreactor system would simply consist of an aeration tank (following the covered anaerobic lagoon) that contains the microfiltration system. Effluent quality should meet the drinking water requirements of hogs with the possible exception of total dissolved solids (TDS). Reverse osmosis may be required if TDS removal is needed.

The microfiltration system replaces the solids separation function of the secondary clarifiers and sand filters of a conventional activated sludge system. The microfiltration membrane has a pore size small enough that ensures no particulate matter is discharged in the effluent. The microfiltration membranes are typically submerged in the aeration tank. A vacuum draws the treated water through the hollow fiber membranes. An airflow is introduced to the bottom of the membrane module producing turbulence which scours the external surface of the hollow fibers transferring rejected solids away from the membrane surface. This airflow also provides a portion of the biological process oxygen requirements; the remainder is provided by a diffused aeration system. Waste sludge is pumped directly from the aeration tank.

The technology offers the following advantages:

- Overcomes the problems associated with poor settling of sludge in conventional activated sludge processes;
- Permits bioreactor operation with considerably higher mixed liquor solids concentrations;
- Typically operated at a mixed liquor suspended solids (MLSS) concentration in the range of 10,000 to 15,000 mg/L;
- With elevated MLSS concentrations, extended solids retention times (SRTs) are readily attainable. The long SRTs allow complete nitrification even under extreme cold weather operating conditions; and
- At extended SRTs, sludge yields can be up to 70% less than conventional aerobic processes, due to endogenous decay.

PSF will use information from this pilot to determine:

- Capital and operating costs associated with the technology;
- If reverse osmosis is required following microfiltration;
- If fouling of the membranes presents and operational problem; and
- Energy requirements for complete nitrification.

6 Technology Evaluation Program

This section describes the technology evaluation program in place at PSF and how it will be used in the future to evaluate environmental technologies. The evaluation of these technologies will follow the general principles set forth in this Section; specific details about testing of individual technologies, including results of testing to date, are contained in the sections above.

PSF contracted with SES to draft a protocol for testing odor reduction and air quality improvement technologies in an objective, scientific fashion. In addition to creating the protocol for testing and evaluation of these technologies, SES has provided support during the field sampling phase of the evaluation. The main sampling phase of the evaluation began in June 1999, and continues at the Homan Farm site near Pattonsburg, Missouri. A PSF Environmental Engineer is the primary person responsible for collecting air and liquid samples as part of this evaluation program. SES accompanies PSF on half of the semi-monthly sampling visits to document the sampling protocol that is being followed and to verify the on-site measurements made as part of the sampling visit. In addition, PSF has accepted (and the Team approved) a proposal from Iowa State University (ISU) to assist with sample collection and analysis. ISU will provide people to assist with sample collection and also will perform analysis of odor by olfactometry. ISU will prepare a detailed set of protocols for monitoring and submit these protocols to the Team for approval before beginning.

Evaluations will be conducted for all technologies involved in the Capital Improvement Program, regardless of intended environmental benefits. These qualitative evaluations are described in Section 6.1. Technologies intended to reduce odor or improve air quality are tested in a controlled evaluation described in Section 6.2. The effectiveness of waste treatment technologies will be evaluated by measurement of wastewater quality parameters as described in Section 6.3.

6.1 General Evaluation

All technologies tested during the Capital Improvement Program will be qualitatively evaluated based on logistical and other factors. These data are just as important as quantitative data on performance, because no technology that is not logistically feasible can be an effective environmental technology. The factors that will be evaluated are:

Technical: Reliability, susceptibility to environmental conditions (ruggedness), implementability, and other logistical requirements.

Environmental: Compatibility with facility conditions, odor transport mechanisms addressed, nutrient reduction, spill risk reduction (especially during land application), beneficial effects (short and long term), and adverse effects (long term, short term).

Institutional: Ease of operation, training requirements, safety, and compliance with federal, state, and local regulations.

Cost: Capital costs (direct and indirect), operation and maintenance costs (labor, material, and energy), licensing, insurance, and other.

All of the qualitative variables listed above will be assessed and recorded. Notes will be recorded over the entire evaluation with regard to the technology's reliability and ruggedness (how many times did it break down or require repairs), maintenance needed, implementability and other logistical requirements, ease of operation, training requirements, safety aspects, and costs (both initial and ongoing costs dealing with maintenance, consumables, energy requirements, and labor requirements). If the technology required significant vendor assistance, then technical service and vendor response also will be evaluated. All the notes taken in the field logbooks will be reduced and summarized as part of the final qualitative evaluation of the technology.

6.2 Odor Reduction and Air Quality Improvement Evaluation

The odor reduction and air quality improvement methods involved in this evaluation will be compared to the performance of controls. Controls are buildings or manure storage areas where no new technologies, best management practices (BMPs), or nutritional changes have been implemented. Although the focus of the evaluation will be the comparison between the odor reduction method and the control, this evaluation also will compare each tested method versus other methods tested as part of this program. This section outlines a basic protocol for the evaluation of an odor reduction method against a control.

6.2.1 Evaluation Site Selection

Two locations are required to test each method: a test site and a control site. To ensure that any observed differences between test and control sites are due to the effects of odor reduction methods and not due to other factors, it is necessary to select control sites that are as similar as possible to the test sites. While it is not possible to find a control site that is identical to the test site, the value of the evaluation will be improved by removing as many confounding factors as possible. PSF has chosen the Homan farm near Pattonsburg, Missouri, to test the majority of its odor-control technologies. This farm is comprised of 10 finishing sites that each have eight 1,000-head finishing barns with a single-cell lagoon. The Homan farm makes a good evaluation site because the 10 sites are all similar and within close proximity to one another (within a one-mile radius). The selection of Homan allows for the following criteria to be satisfied. First, the test site and the control site should be located in the same general area. For tests of building-related methods, the test buildings and the control buildings should be oriented in the same direction and be separated by the same distance. For lagoon sites, the areas should be topographically similar. The lagoons should all have approximately the same surface area and volume, and have approximately the same volatile solids loading rate.

The Homan farm meets these criteria. The buildings and lagoons are all similarly managed at Homan. Management factors relating to the buildings considered were feed, cleaning schedules of buildings, number and weight of pigs in buildings, ventilation, flushing schedule, and quality of flush water. Lagoon management factors considered were freeboard, use of fresh dilution water, and pumpdown frequency. The fact that Homan is an operational finishing site means that the individual sites within the Homan farm will have some differences in operational factors at any one time. However, over the long-term course of the technology evaluation, the individual farms will all be similar enough to use as test or control sites.

At the current time, site 20 is the control lagoon site. This site was chosen as the control because the lagoon is away from the buildings and the building exhaust does not blow over the lagoon. This alleviates the potential confounding factor of the building exhaust with lagoon odor. For the permeable cover, the test is being conducted at site 24. For the essential oils misting test, the test is being performed in the four western-most buildings of site 23. The exhaust fans from each four-building set face west. Sites where the effects of manure treatment changes on building exhaust odor will be studied include site 24 (permeable cover), site 26 (reuse system), and site 25 (IRS). The control barns will be the four western-most buildings of site 22 (essential oils) and the eight barns at Site 17 (other three tests). For all of the building test and control sites, only one building will be used for source sampling (Section 7.1.1). This building will be randomly selected at the beginning of each source sampling event.

Whitetail was selected as a test site for the system-wide project (Section 3.2) for several reasons. First, Whitetail is a finishing farm that is representative (in terms of numbers of animals, site size, location, and topography) of all of PSF's finishing operations. Another advantage of the Whitetail farm is that sufficient land is available to construct the additional earthen basins needed for the project. Finally, the Whitetail farm has been controversial during its operations, and is therefore a high priority site for these capital improvements. Because the performance of the Whitetail system is not being compared to a control site, it was not necessary to evaluate the control-site factors described above to select the Whitetail site.

6.2.2 Evaluation Objectives and Design

The evaluation objectives are as follows:

- Determine if an odor reduction method has the potential to maintain odor below the levels prescribed in Missouri Air Conservation Commission Rules (10CSR 10-3.090);
- Determine if an odor reduction method reduces odor and associated compounds below levels found at control sites;
- Determine the costs associated with the implementation, operation, and maintenance of an odor and nutrient reduction method;
- Determine the reliability and ruggedness of an odor and nutrient reduction method; and
- Determine the logistical needs of an odor and nutrient reduction method (personnel, training, materials, energy).

The evaluation objectives described above provide a basis for identifying meaningful performance measures so a comparison between an odor and nutrient reduction method and a control can be performed. These objectives will be assessed in the following two ways: quantitative, through statistical analysis; and non-quantitative, through the objective reporting and consideration of observed, measured, or reported characteristics. The criteria for evaluation of each performance measure must be clearly stated. The criteria for statistically evaluating performance measures must be clearly stated in the form of a statistical hypothesis that can be tested. This assures that conclusions reached are clear and can be shown to have been supported by the observed data within the stated statistical limits.

Examination of the major functional elements of odor reduction methods indicates that the quantitative measures of performance that are important for comparison may include: (1) the degree to which concentrations in air of hydrogen sulfide (H_2S) and odor by scentometry and olfactometry are changed, as a result of applying an odor control technology; and (2) the degree to which odor-related constituents or parameters in liquids – volatile solids, ammonium, sulfides, phenolics, pH, volatile fatty acids, temperature, and electrical conductivity measurements are changed, as a result of applying an odor reduction technology. Specific performance measures will be determined by the function of a particular odor reduction technology.

To provide clear conclusions about the nature of the comparison points listed above, it is necessary to clearly state the criteria being compared and the exact nature of the comparison in the form of a statistical null hypothesis (H_o). This null hypothesis is then tested and is either accepted or rejected at some level of significance. The general language in the paragraph above used to describe the intermethod comparisons is too imprecise to reach clear conclusions about the comparisons. Therefore, precise null hypotheses are stated below. These hypotheses represent the major conclusions that will be tested using the data collected during the evaluations.

The null hypothesis will be tested at a single level: between an individual odor reduction method and the control. The following null hypotheses, stated both grammatically and mathematically, will be tested in this demonstration:

1) Comparing the measured chemical or odor characteristics for air and liquid samples:

The average difference in concentration between matched pairs of concentrations measured from the control and the test site is zero

H_o: $D_{mean} = 0$

where: D_{mean} = the arithmetic mean of the differences in measured concentrations between the test site and the control site.

2) Comparing scentometry observations:

The proportion of scentometer readings that are greater than 2 dilutions to threshold (D/T) is independent of the use of odor reduction methods.

H_o: $P_{control} = P_{test}$

where: $P_{control}$ = the proportion of readings greater than 2 D/T for the control site.
P_{test} = the proportion of readings greater than 2 D/T for the test site.

6.2.3 Control of Independent Variables

Odor and H_2S emissions from a swine production operation are subject to many influences (independent variables), some of which are major and significantly affect the nature and intensity of the odor released and some of which do not exert a significant effect and are considered minor. Major independent variables are considered to be those factors that are capable of significantly affecting several of the evaluation's performance measures. Significant effects have the potential to cause false acceptance or rejection of the statistical hypothesis, or the biasing of the non-quantitative comparisons. The independent variables that are believed to have the greatest potential to significantly affect the evaluation performance measures described above include:

- Odor reduction technology;
- Production phase;
- Building design and age;
- Management practices;
- Odor source;
- Environmental factors (e.g., weather);
- Operator skill;
- Sampling and field monitoring methodology; and
- Lagoon characteristics (level, location relative to buildings)

The demonstration is designed to allow statistical analysis of the relative influence of the first factor. The last eight factors will be controlled by holding them constant between odor reduction test sites and the corresponding controls to minimize the influence of their fluctuations. The influence of physical characteristics of production will be controlled by using matched pairs of test sites and control sites that have nearly identical management practices, building designs and age, and manure management systems. The influence of environmental variables will be controlled by minimizing the time between the collection of paired samples. The influence of operator skill will be controlled by using similarly trained personnel. The sampling methodology variable will be held constant by using consistent sample handling procedures between all sampling technologies. The field monitoring variable will be controlled by using similar techniques, standard monitoring procedures, and conducting periodic quality control (QC) checks.

Minor factors are considered to be those factors or variables that in their typical range exert limited influence on most of the performance criteria but that outside their typical range are capable of affecting several of the performance criteria and thus of causing false acceptance or rejection of a null hypothesis or biasing conclusions. The minor factors that are believed to most significantly affect the performance criteria described above include:

- Site logistics;
- Analytical laboratory methodology;
- Order in sampling schedule; and
- Decontamination of sampling equipment.

The demonstration has been designed to control the influence of these minor factors by holding them constant or randomizing the testing to minimize the influence of fluctuations. Site logistics will be controlled by selecting pairs of test sites and controls that have similar logistical support. The analytical laboratory and decontamination variables will be controlled by using standard analytical and monitoring procedures, and conducting periodic quality control checks. The order of sampling between a test site and a control will be controlled by randomization.

6.2.4 Sample Size

The basic experimental design of this evaluation is intended to allow the objective evaluation of quantitative and non-quantitative performance measures that will be used to evaluate various odor reduction methods. In order to evaluate the quantitative performance factors statistically with sufficient power to draw meaningful conclusions about the effectiveness of different odor-control technologies, it is necessary to collect a number of samples over an extended time period (months and years). Logistical and economic factors must be considered in determining the sample size for testing each method. Scentometry presents logistical challenges as the number of samples that can be collected on any one sampling day due to odor fatigue.

PSF will take ambient air samples twice per month, source air samples once per month, and liquid manure samples once per month at the Homan farm (Section 7). Over the course of the evaluation, this should provide a sufficiently large sample size for statistical evaluation. At the end of the evaluation, the power of the analysis will be calculated when final statistical analyses are being performed. A discussion of the power of the analysis and any potential impacts of sample size on the conclusions of the evaluation will be included in discussions of the statistical analyses of the evaluation results. In addition to this routine monitoring, more intensive monitoring will be performed at times during the installation and operation of next generation technologies. Specific protocols for these monitoring events will be drafted prior to beginning the monitoring.

6.2.5 Statistical Analysis of Results

Some of the data collected during the evaluation of the odor reduction methods can be effectively assessed through statistical evaluation. These data deal with the objective of evaluating the performance of an odor reduction method against a corresponding control.

The data collected during the methods evaluation will be analyzed to allow statistical tests of the hypotheses. There will be two types of data from these technology evaluations: concentration data and scentometer data. Concentration data will include concentrations of gases in air, olfactometry data, and concentrations of odorous compounds in lagoon liquid. This data will be analyzed using paired observations tests as described in the section below. Scentometer data will be analyzed using contingency tests as described below.

6.2.5.1 Concentration Data

Concentration data will be analyzed using paired comparison tests. For odor concentration data (but not odor emission data) from olfactometry, the data will be log-transformed before analysis. If possible, a paired-observations *t*-test will be used. For this to be possible, concentration data from a test and control site must be simultaneously collected. If for some reason a data point is collected at one site, but a paired data point cannot be obtained from the other site, the data point that is collected will not be usable in the statistical analysis.

The advantage of using a paired observations test is that this type of test reduces the effect of temporal variation (i.e., the variation among different pairs of observations) and therefore allows for a more sensitive testing of the two sets of observations. For a paired comparison *t*-test, the null hypothesis can be stated as follows: the mean difference within each pair of observations is zero. This is different than the null hypothesis for a standard *t*-test, which is: the difference between the means of the two sets of observations is zero. This distinction is subtle but important. Paired comparison tests are typically many times more efficient for distinguishing differences between treatments than standard tests. For the PSF Technology Evaluation Program, the effects of confounding factors, including weather conditions, will be greatly reduced by using paired comparison tests.

It is possible that the distributions of variances within the sets of observations will be so different that a non-parametric test will be required. In general, a *t*-test is not very sensitive to problems with distribution or unequal variances, so this will probably not be necessary. The Wilcoxon signed-ranks test will be used as a non-parametric test for the paired observations if a *t*-test is not appropriate.

6.2.5.2 Scentometer Data

Scentometer data are not continuous and quantitative in the same way that concentration data are. There are only a limited number of values possible from a scentometer, and the readings from a scentometer actually represent ranges of odor concentration, not specific values. For example, a reading of 7 D/T on a scentometer actually means that the odor concentration is equal to or greater than 7 D/T but less than 15 D/T. Because of this, it is not appropriate to analyze scentometer data in the same way that concentration data are analyzed.

For analysis, scentometer data will be separated into classes of readings. The two classes are: 1) readings of 2 D/T or non-detects, and 2) readings of 7 D/T or greater. A technology will be considered effective at odor reduction if its use results in a lower proportion of high readings and a higher proportion of low readings compared to the control.

The differences between these proportions will be statistically tested using contingency tables. The null hypothesis for a contingency table analysis is: the distribution of observations among classes is independent of the treatment. In other words, the proportion of minimal odor readings is independent of whether the readings were collected at a control site or a test site. Statistically, it is not required that these observations be paired; however, to avoid biasing any set of observations it will be necessary to make these readings as close to simultaneous as possible. Another possible confounding variable for this type of observation is the individual taking the scentometer reading. To avoid this kind of bias, it will be necessary to have only one person making scentometer observations for any sampling visit. SES will provide quality control in the form of an observer, who is a certified odor observer, and other quality control measures described in Section 7. People with colds or other nasal problems will not be allowed to take scentometer measurements.

6.3 Waste Treatment Evaluation

The evaluation of waste treatment effectiveness for treatment systems (and for portions of beneficial reuse systems) will not be structured as a comparison between a control and a test site. Instead, the effectiveness of waste treatment systems will be evaluated based on measurements of waste strength parameters and comparison to system-specific target values. The specific parameters to be analyzed will depend on the system being evaluated. Lists of these parameters are contained in the sections describing the waste treatment or beneficial reuse systems (Sections 3.2.3.2 and 5.1.3).

7 Sampling And Analysis

The sampling and analysis plan for this evaluation specifies procedures that will be used to ensure the consistency and integrity of samples, and control within-sample variation. In addition, this plan outlines the sample collection procedures necessary to meet the evaluation purpose and objectives. Careful adherence to these procedures will ensure that samples analyzed from a test site are comparable to samples analyzed from the corresponding control site. The following subsections will discuss the monitoring strategy in terms of methods used, sampling location, frequency, procedures, and quality control checks.

Specific procedures are detailed in this section for the measurements that are, at this time, expected to be the foundation for the technology evaluation conducted as part of this Work Plan. As pilot technologies are improved and evaluations of these technologies begin, additional procedures may be added as an Addendum.

7.1 Odor and Air Quality Sampling Locations and Frequencies

There are two basic types of odor and air quality samples that will be taken as part of this Work Plan: source samples and ambient samples. Source samples are taken directly at an odor source. Ambient samples are taken some distance downwind of a source, at the berm of a lagoon or at a property line. The table below summarizes sampling locations and frequencies.

Table 5. Ambient and source sampling locations for different technologies.

Technology	Ambient Sampling		Source Sampling	
	Locations	Frequency	Locations	Frequency
Permeable Cover	Lagoon Berm	2 times/ month	Building Fan	1 time/ month
	Building Downwind	2 times/ month	Cover Surface	Special Studies
IRS	IRS System Downwind	2 times/ month	Building Fan	1 time/ month
	Building Downwind	2 times/ month		
Whitetail	Property Line	2 times/ month	Building Fan	1 time/ month
	Building Downwind	2 times/ month	Surface of Treatment Cells	Special Studies
Reuse System	Reuse System Downwind	2 times/ month	Surface of Treatment Cells	Special Studies
Essential Oil Misting	Building Downwind	2 times/ month	Building Fan	1 time/ month
Control (essential oils)	Building Downwind	2 times/ month	Building Fan	1 time/ month
Control (buildings flushed with recycled water)	Building Downwind	2 times/ month	Building Fan	1 time/ month
Control (lagoon)	Lagoon Berm	2 times/ month	Lagoon Surface	Special Studies

7.1.1 Source Sampling Locations and Frequency

Source locations are immediately outside of building exhaust fans, and the surface of manure treatment cells. Samples from outside the exhaust fans will be taken from the 48-inch fan with the lowest setpoint (if running) or from the 24-inch minimum ventilation fan. Source samples from manure treatment cells will be taken using a flux hood.

Source samples will be taken once per month and analyzed for odor by olfactometry and hydrogen sulfide, unless the technology is expected to reduce particulate matter, in which case they will be analyzed for odor and particulate matter. Source samples from the surface of manure treatment cells will be taken during special studies to examine seasonal and operational changes in manure treatment. For some building odor evaluations, the expected improvement is due to improved flush water quality. For these evaluations, samples will only be taken while an aisle in the building is being flushed. The flush control will be manually operated if necessary.

7.1.2 Ambient Sampling Locations and Frequency

Ambient sampling locations are on the berms of manure treatment cells, property lines, downwind of production buildings, and in the vicinity of manure handling and treatment locations. For samples collected from manure lagoons, ambient samples will be taken on the downwind berm of the lagoon. For alternative manure treatment and handling systems, ambient samples will be taken approximately 10 yards downwind of the system. For samples collected downwind of production buildings, samples will be taken 10 yards away from the set of buildings, in the direction of the fan exhaust air. Ambient samples will be taken twice per month and analyzed for odor by scentometry and hydrogen sulfide. During each monitoring period, the same person will collect scentometry measurements at all locations within a two-hour time interval. The longer time interval is required because hydrogen sulfide monitoring will be conducted concurrently with the scentometry measurements.

Ambient monitoring also will be used to evaluate the odor associated with the Whitetail site as a whole. This monitoring will take place at the property line of the site. Monitoring will take place in the early morning, before 10 a.m. For purposes of this evaluation, only the part of the property that is south of Missouri Highway 129 will be monitored. Because the monitoring will not be performed at an odor source (i.e. not at the lagoon berm or by a building exhaust fan), additional efforts will be required to locate the center of the odor so that readings can be taken where the odor is greatest. The first step to determine this location will be to determine wind speed and direction with a hand-held anemometer. After a general wind direction is established, the scentometry observer will go to the property line in the direction to which the wind is blowing and begin locating the odor (if any). If the wind speed is below 5 miles per hour, the observer will move to the low-lying areas along the eastern and southern boundaries of the property and attempt to locate an odor in this area. The observer will use qualitative observation to determine where the odor is greatest. After this point is determined, the observer will begin breathing through the scentometer with the odorous air ports closed to check for leaks and resensitize the nose to the odors. After the scentometry reading has been taken, the observer will move approximately 500 feet to each side along the property boundary and take another scentometry reading. If these readings are both equal to or less than the original reading, it will be assumed that the original reading was taken at the proper location. If not, the observer will re-locate the odor (as described above) and perform the procedure again. Hydrogen sulfide measurements will be taken at the location determined to be the center.

The monitoring locations and frequencies described above are designed to produce long-term data on effectiveness. In addition to this routine monitoring, more intensive monitoring will be performed at times during the installation and operation of next generation technologies. Specific protocols for these monitoring events will be drafted prior to beginning the monitoring.

7.2 Scentometry Procedures

Scentometry measurements will be collected with a Barnebey and Sutcliffe scentometer following the manufacturer's instructions. Only the dilutions obtainable through opening of one odorous air intake port will be considered valid readings. The dilutions available, according to the manufacturer, are 2, 7, 15, 31, 170 and 350 dilutions to threshold (D/T).

7.2.1 Scentometry Sample Locations

Scentometry will only be used at ambient sampling locations. Scentometry will not be used for source sampling because it is less suitable than olfactometry for analysis of more concentrated samples (greater than 350 D/T). Scentometry is more suitable for ambient sampling because it has lower detection limits than olfactometry (i.e., readings of 2 D/T are not generally possible with olfactometry). Scentometry also is widely used by regulatory agencies (MDNR) for evaluation of compliance with odor standards.

7.2.2 Scentometry Sampling Procedures

The same person will always collect the measurements at the control site and test site within a biweekly monitoring event. If the person has a cold or other nasal problem, they will not collect measurements. It may be necessary at times to use a second person to collect the measurements, but not within a biweekly monitoring event. This should not cause a problem with the statistical analysis of the results. Because the proportion of scentometer readings taken by any given observer will be equal among technologies and the control sites, this will not bias the statistical tests of proportions.

Prior to collecting the measurements at each location, the observer will record the following information in a bound field logbook: temperature, wind direction and speed, relative humidity, the number of fans operating, and any other pertinent information that may have an influence on the measurements. At the lagoons, the observer also will note the level of the lagoon (depth below the berm), meteorological conditions, and any other information pertaining to loading or pumping of the lagoon when these measurements are collected.

The observer will practice with the scentometer so as to become adept at obtaining a reading with a minimum exposure to the odorant. Before opening any holes, the observer will breathe through the nasal ports to be sure there is no leakage anywhere, either around the nose piece or through the instrument. This testing will be conducted prior to each biweekly monitoring event and will be done in an atmosphere not impacted by hog production operations. Prior to collecting the measurements at each farm, a field blank measurement will be collected by sniffing air with no open sample holes. This will ensure that nothing has collected in the scentometer that will bias the measurements. At each location, the observer will breathe through the instrument for a short period of time (few seconds) with all the odorous air ports closed so as to climatize his nose to a non-odor background. After this, the smallest port will be opened and the observer will sniff two or three times. The observer will progressively open larger ports until an odor is discernible. If the odor is not discernible after opening the largest port, then the concentration of the odor in the air is less than 2 D/T.

7.2.3 Scentometry Quality Control

SES will provide an observer who is a certified odor observer to provide oversight and assistance for scentometry sampling. PSF will also provide odor observation training for PSF employees who take scentometry measurements as part of the technology evaluation program.

One quality control measure that will be used for scentometry is the use of an n-butanol standard as a check on the consistency of the observer's measurements and to gauge the relative sensitivities to odor of persons taking scentometry measurements.

Two solutions of n-butanol will be prepared for each check. Test solutions will be prepared by a different person than the person conducting the scentometry monitoring. These solutions will be prepared within 2 hours of conducting the check. After two hours solutions will be discarded. The solutions will be prepared by adding a measured amount of n-butanol to a pre-measured amount of water in a 1,000-mL plastic beaker (preparation beaker). The water will be filtered, odor-free water, such as Culligan water, and the volume of water will be measured in a 1,000-mL plastic graduated cylinder. The n-butanol will be measured in and dispensed from a plastic pipet. After the solution is prepared, 500 mL of the solution will be dispensed into another 1,000-mL beaker (test beaker). The test beaker will be sealed with aluminum foil, and shaken gently. The additional solution in the preparation beaker will be discarded, and the preparation beaker will be rinsed three times with distilled water before re-use.

Check samples will be delivered to the scentometry monitor on a "single-blind" basis, meaning that the monitor will not know the concentration of the solution. Two solutions will be provided to the monitor as check samples. Each will be labeled with a letter "A" or "B". The solutions will be in a 1,000-mL plastic beaker tightly sealed with aluminum foil. The first check will be conducted without the scentometer, to determine if the monitor can distinguish the relative strength of the two solutions. The monitor will sniff the solutions without the scentometer, and choose either "A" or “B” as the stronger solution. When using the scentometer, the scentometry monitor will shake the solution gently to mix, then peel the foil away and use the scentometer to sniff the headspace within the beaker. The D/T rating from this scentometry will be recorded on a field sheet. Responses from different observers will be tracked and reviewed to ensure consistency and quality in scentometry observations.

7.3 Hydrogen Sulfide Air Monitoring

Hydrogen sulfide (H_2S) will be the primary target gas for air monitoring at both source and ambient locations. This is because H_2S is an odorant and is readily detected at low concentrations with field monitoring equipment

7.3.1 Hydrogen Sulfide Sampling Locations

Samples for H_2S will be taken at all ambient sample locations (Section 7.1.2) and at source locations (Section 7.1.1).

7.3.2 Hydrogen Sulfide Monitoring Procedures

Air monitoring will be conducted for H_2S using a Jerome meter. This will be conducted concurrently with the scentometry measurements. Air samples will be in 10-liter (L) Tedlar bags. Tedlar bags will be used because readings from the bag are expected to be more stable than collecting multiple measurements from the ambient air. A Supelco Model 1062 suitcase-type pump will be used to draw air through tubing fastened to a stake into the Tedlar bags at a flow rate of 1.0 L/minute (min) until the bags are completely full. Measurements with the H_2S meter will be made on aliquots taken from this 10-L air sample. Multiple H_2S meter readings will be taken on each sample. The average value will be used for data analysis.

The 10-L Tedlar bags will not be reused within a monitoring event. However, the Tedlar bags will be reused between biweekly monitoring events. The Tedlar bags will be taken to an off-site location away from the farms between monitoring events and purged a minimum of two times with zero-grade air. The tubing will not be reused between measurements.

7.3.3 Hydrogen Sulfide Monitoring Quality Control

Quality control of the sampling procedure and portable monitoring equipment will consist of field blanks, field duplicates, analytical duplicates and check samples. Field blanks are used to determine if gases have entered the instrument or the sample collection devices. The field blanks will be prepared by filling a Tedlar bag with zero-grade air that contains no constituents of concern. The zero-grade air may be site air drawn through a filter to remove the constituents of concern or air upwind of the farms. One field blank will be collected daily and analyzed for H_2S. The Jerome meter is known to drift so it will be rezeroed after each monitoring event.

Field duplicates will assess total sampling and analysis precision. An additional sampling pump will be placed directly adjacent to the main sampling pump and two 10-L Tedlar bags will be filled simultaneously. Field duplicate samples will be collected for at least 10% of the samples collected.

Analytical duplicate samples will be used to assess the repeatability of measurements made with the H_2S meter. Duplicate measurements will be made out of the same Tedlar bag from which the first aliquot was drawn. Analytical duplicate measurements will be made at least daily.

Check samples will be analyzed to demonstrate the accuracy and precision of the field measurements. The check sample will be a 250-ppm gas standard supplied by Arizona Instruments. This check sample will be analyzed two times per day during the biweekly monitoring. It is known that temperature, humidity, and continuous use of the Jerome meter (gold film sensor becomes coated) may affect the accuracy of the instrument; therefore, the check samples will be run once in the morning and then once in the afternoon at different temperature and humidity values. The results of the check samples will be used to determine if the field measurements are being made with an acceptable accuracy of $\pm$ 20 percent and a precision of 20 percent as measured by the relative percent difference between replicate measurements. Given that paired measurements are being collected, precision will be more critical than accuracy, assuming environmental factors equally affect all measurements.

7.4 Olfactometry Analysis

Olfactometry samples will be collected and analyzed on a limited basis as part of the odor control evaluation process. Dr. Dwayne Bundy of Iowa State University is coordinating the collection and analysis of olfactometry samples.

7.4.1 Olfactometry Sampling Locations

Olfactometry samples will be collected concurrently with hydrogen sulfide sampling at sources. Olfactometry will not be used at ambient sampling locations.

7.4.2 Olfactometry Sampling and Analysis Procedures

Samples will be collected in 10-L Tedlar bags. A Supelco Model 1062 suitcase-type pump will be used to draw air into the Tedlar bags at a flow rate of 1.0 L/min until the bags are completely full.

Prior to sample collection, the bags will be purged by filling the bag with on-site farm air at a rate of 5-10 L/min and emptying the bag twice. Olfactometry samples will be analyzed at Iowa State University following the laboratory's Standard Operating Procedures.

7.4.3 Olfactometry Quality Control

Sampling QA/QC procedures will include duplicates and blanks. Field duplicates will assess total sampling and analysis precision. This will indicate the precision of the sample splitting techniques. Blanks will be used to monitor for container or shipping induced contamination. Duplicate samples for olfactometry will be collected by placing an additional sampling pump directly adjacent to one of the main sampling pumps. The original olfactometry sample and its duplicate will be sent to the olfactometry laboratory for analysis.

Field blanks for olfactometry will be collected by sampling air away from the farms. To avoid causing a bias in the olfactometry lab, these blanks will be labeled with a sample number that does not indicate that the sample is a blank. Field blanks will be collected at the beginning of each day.

7.5 Liquid Manure Sampling

The composition of liquid manure is not expected to change dramatically within a day. Therefore, only one composite liquid sample will be collected monthly from each lagoon involved in the lagoon treatment technology evaluation. Liquid samples also will be collected once prior to commencement of any air monitoring. The liquid samples taken prior to any air monitoring will be used to assess the chemical similarity among the lagoons to ensure that the lagoon chosen as the control lagoon is not different than those receiving an odor-control technology. Liquid samples will be collected from the recycled water pump station for each lagoon. Effluent from this pumping station will be collected in a 1,000-milliliter (mL) plastic bottle. The bottles will be placed on ice in a cooler and sent to an off-site laboratory for analysis. For odor reduction evaluations, the samples will be analyzed for phenolics, volatile fatty acids, total nitrogen, ammonia, sulfate, sulfides and biochemical oxygen demand. For wastewater treatment evaluations, parameters will be determined on a system-specific basis for each component of a treatment or reuse system (Sections 3.2.3.2 and 5.1.3). Liquid samples will be labeled with a number that distinguishes the sample from others based on location and time of collection. The sample number will consist of an abbreviation for the farm and site number of the lagoon and the collection date. All sampling and analysis of wastewater will be conducted in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20^{th} Edition.

7.6 Weather Monitoring

A continuous recording meteorological monitoring station is installed at the Homan site. The meteorological conditions that will be monitored are wind direction, wind speed, rainfall, humidity, and temperature. The observer collecting the scentometry and other measurements will also have a pocket-sized temperature, humidity, wind speed and wind direction measuring device in order to record accurate measurements of these parameters at the exact monitoring points. Building sampling points (near the fan exhaust) will be monitored for ventilation velocity, temperature, humidity and activity of the mechanical ventilation.

7.7 Documentation

All field activities will be thoroughly documented. Field personnel will maintain notes during the sampling and monitoring events either in bound logbooks or on field sheets. The field logbooks will contain detailed information on the sampling and monitoring activities performed, as well as information on weather conditions, problems, and deviations from the sampling plan. Each page of the logbook will be sequentially numbered and labeled with the project name. Completed pages will be signed and dated by the individual responsible for the entries. Errors will have one line drawn through them and will be initialed and dated.

All field monitoring measurements will be recorded on field sheets maintained in three-ring binders or in a clipboard. The field sheets will contain information on the project name, farm number, odor control technology, time, date and location of sample collection and unusual conditions noted (in a comment section) during measurement. Completed field sheets will be signed and dated by the individual responsible for the entries. Errors will have one line drawn through them and will be initialed and dated.

Original field sheets and chain-of-custody forms will accompany all liquid samples and olfactometry samples that are shipped to the analytical laboratory. Copies of field sheets and chain-of-custody forms for all samples will be maintained in the project file.

7.8 Data Management and Analysis

As part of these evaluations, a data management system will be established that will include computerized data files and hard copy documentation, such as field and laboratory sheets and hardbound logbooks. This data management system will be used to store data obtained from each odor control method test site and control test site.

This section describes the procedures that will be used for recording the data as well as obtaining and entering data into the data management system and for analyzing the data after it has been entered.

7.8.1 Data Reduction, Validation, and Reporting

To maintain good data quality, specific procedures will be followed during data reduction, validation, and reporting. Data reduction will be performed by the field personnel for the on-site monitoring. The on-site monitoring will produce data in field logbooks, hard copy spreadsheet reports, and floppy disks or computer cassettes containing spreadsheet data. This data will be reduced to produce a report detailing the monitoring and analytical results.

The project leader will review calculations and inspect field logbooks and data sheets to verify accuracy, completeness, and adherence to the specific analytical and sampling method protocols. Calibration and QC data will also be reviewed for acceptability. Outlier data are defined as those QC data lying outside a specific QC objective window for precision and accuracy for a given on-site monitoring or analysis method. Should QC data be outside of control limits, the cause of the problem will be examined. If the problem involves an analytical problem, the sample will be reanalyzed. If the problem can be attributed to the sample matrix, the result will be flagged with a data qualifier. This data qualifier will be included and explained in the final analytical report submitted by the laboratory.

Data reports generated from the on-site monitoring and off-site analysis will include the following information:

- Analytical results for each parameter including units of measurement.
- Data and time of sample analysis.
- Summaries of QC data including control limits and identification of QC outliers.
- Qualifications for analytical data effected by outlier QC data, along with definition of the outlier.
- A data assessment that details the analytical procedures, QC procedures employed, QC outliers, qualifications, corrective actions, and assessment of the data.
- Field data sheets.
- Chain-of-custody records.

7.8.2 On-Site Monitoring and Off-Site Sample Analysis Data Management

Samples submitted for chemical or odor analysis will either be analyzed by on-site monitoring or off-site chemical analysis. Chain of custody forms will be used for all samples shipped off site for analysis. All samples will be tracked by field sheets and log books. After samples are analyzed, the data will be reduced, validated, and reported as described above.

Validated sample results will be entered into the data management system. In addition to sample results, QA/QC data will be entered as appropriate. This will allow verification of the quality of data generated. All data transcribed will be double-checked for accuracy.

7.8.3 Observational Data Management

Information about each odor control method will be obtained through direct observation, literature review, and direct measurement during the evaluation. This information will include a general description of the method and how it is used. Notes will be taken on specific aspects of each method and the environmental conditions during its use. These notes will be based on a checklist created for each method before the evaluation activities begin. The checklist will provide information that will be used in the evaluation report. In general, the checklists will contain the following items:

- Description of equipment or materials used.
- Logistical considerations including structural requirements, power requirements.
- Support needed from the vendor, and whether this support was provided by the vendor.
- Estimated implementation cost of the odor control method.
- Operation and maintenance requirements.
- Personnel requirements.
- Training required.
- Description of the expected outcome of application.
- Reliability under the test conditions (specific problems or breakdowns during the evaluation).
- Susceptibility to environmental conditions (ruggedness).
- Ease of operation and maintenance.
- Ease of learning to use the odor control method.
- Degree of production or operation disruption.

Notes taken by each observer will be documented in a hardbound logbook and will be used as a reference when preparing reports evaluating each technology, and when preparing addenda to this Work Plan.

8 Budget

The Team has approved expenditures relating to certain items through April 2001 (Section 1). In addition to these approved expenditures, PSF is proposing additional expenditures for new projects beginning in April 2001. PSF has estimated the expenditures required for these new projects. Because of the innovative nature of these projects, there is some uncertainty in these budget estimates. A detailed description of the budget for the Capital Improvement Program, including actual expenditures to date, is contained in Appendix 7.

9 Summary

The goals for identifying new technology at PSF include source reduction, improved manure treatment, beneficial reuse of waste products (creation of value-added products) and water reuse. To date, the following projects have been approved as part of the Capital Improvement Program at PSF:

- Phytase addition
- Installation of 38 permeable covers
- Whitetail treatment project
- Internal Recirculation System
- Crystal Peak Farms process
- Changing World Technologies process
- Water Reuse Pilot plant
- Consulting and monitoring expenditures

Most activity in the next 12 months will focus on monitoring the systems installed during year one and in designing and permitting systems that may be installed in the next year. The following projects are proposed in this Work Plan:

- Fund university research to remove fiber from raw feedstuffs
- Conduct on-site nutrition research to further lower nitrogen and phosphorus levels
- Test an essential oil air treatment system on several barns
- Investigate the feasibility of oil sprinkling
- Test slat pH adjustment
- Conduct a study on agronomic optimization of existing manure and land resources
- Install permeable lagoon covers on all remaining grow/finish lagoons before November 2001
- Complete aerial photography and contour mapping of all grow/finish sites
- Start-up and monitoring of the full-scale Whitetail wastewater treatment system
- Conduct a biological pilot test of the Whitetail system
- Design the Homan farm with a treatment system similar to Whitetail
- Construct a second generation Internal Recirculation System
- Complete a marketing and a feasibility study on the Crystal Peak Farms process
- Design the South Meadows farm using the Internal Recirculation and Crystal Peak processes
- Complete pilot testing and a feasibility study on the Thermal Depolymerization and Chemical Reforming Process
- Start-up and monitoring of the pilot water reuse project
- Conduct a small-scale pilot test of other innovative water reuse processes

During the next twelve months, PSF should determine the technology to be implemented on a widespread basis. The technology evaluation is proceeding along a parallel path of evaluating both “baseline” and “value added” processes simultaneously. PSF will meet with the Team and update the Work Plan in approximately six months in order to expedite final technology selection.

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