National Program 206: Manure and Byproduct Utilization
Action Plan

Part I. Introduction

Vision

Turning refuse into resource.

Mission

The mission of the Manure and Byproduct Utilization National Program is to develop cost-effective management practices, control technologies and decision tools that will allow producers to capture the value of manure and other byproducts without degrading environmental quality or threatening human and animal health.

Background

The total amount of manure, biosolids (treated sewage sludge), and industrial and municipal wastes generated annually in the U.S. exceeds 1 billion tons. The majority of all animal manure and biosolids and significant amounts of other byproducts are spread, sprayed, or otherwise applied to agricultural land; because of the benefits they can provide. These benefits include providing nutrients for crop production and organic matter to improve soil properties. Improperly managed manure and other byproducts, however, can pose a threat to soil, water, and air quality, and to human and animal health.

Animal production in the U.S. is valued at over $100 billion annually. New technological innovations and the economic advantage of size have driven a structural shift from small to large operations where animals are grown in houses, feedlots, and other confinement facilities. These production facilities are referred to as animal feeding operations (AFOs). Large AFOs are called concentrated animal feeding operations (CAFOs). The largest 2% of all livestock farms now produce over 40% of all animals.

The development of AFOs and CAFOs has separated animal production from crop production. Consequently, less land is often available for on-farm recycling of manure- derived nutrients to crops; although nationwide there is more than enough agricultural land available to readily utilize all the nutrients in manure. Transportation costs inhibit distribution of manure at sites distant from where it is generated. Most manure, therefore, is usually land-applied within about 10 miles of beef cattle feedlots, dairy barns, poultry houses, or swine facilities. The amount of manure generated in the U.S. is estimated to exceed 335 million tons of dry matter per year. The volume of animal waste produced at CAFOs or AFOs often exceeds local demand for use as fertilizer. Because of this imbalance and other concerns (e.g., water quality, air quality, pathogens), CAFOs are subject to regulation. These developments have increased the challenge of using manure on agricultural lands while protecting the environment. In addition, there is a

great demand for scientific information about effective management of manure to guide policy and regulatory decisions.

Each year millions of tons of industrial and municipal byproducts are produced. They are often considered to have little value; and are often disposed in landfills or incinerated at considerable expense. However, many of these byproducts are potentially useful on agricultural land or in horticulture, either, individually or through blending, mixing, or treatment with other byproducts. Byproducts have many characteristics that may make them useful for direct land application, soil reclamation and remediation, as components of manufactured soils and composts, or as feedstuffs. Research and development is needed, however, to determine the composition and bioactivity of these products and to determine potential hazards and appropriate uses. At this time, state regulatory agencies lack analytical tools to make reasonable policy decisions regarding the beneficial use of these byproducts in agriculture or horticulture. Protocols and methodology standards are needed to enable regulatory authorities to examine and approve byproducts for agricultural use. Treatment technologies and management practices to make these products usable will reduce potential environmental hazards, reduce disposal costs, and increase cost-effectiveness of agriculture.

Goal

The goal of the Manure and Byproduct Utilization National Program is to effectively and safely manage and use manure and other byproducts while protecting the environment and human and animal health. This goal will be achieved by characterizing potential hazards, developing treatment practices and systems to alleviate problems, and providing information and decision support tools for technology transfer that can be used by other scientists, extension, action agencies, producers, regulators and policy makers. Sustainable agriculture depends on effective management of manure and byproducts.

The Manure and Byproduct Utilization National Program is part of Goal 5, Protect and Enhance the Nation's Natural Resource Base and Environment, of the ARS Strategic Plan (http://www.ars.usda.gov/aboutus/docs.htm?docid=1766) and the USDA - Research, Education and Economics (REE) strategic plan (http://www.csrees.usda.gov/ree/strategic_plan.htm). It also contributes to Goal 1 (Enhance Economic Opportunities for Agricultural Producers) and Goal 3 (Enhance Protection and Safety of the Nation's Agriculture and Food Supply) of these strategic plans.

Approach

The approach being used in this National Program is to address all phases of manure management (animal feeding, handling, storage, treatment, and land application). Research will be conducted to determine transport and fate of potential contaminants (nutrients, air pollutants and odorants, pathogens, pharmaceutically active and other organic chemicals, and trace elements) as well as beneficial substances (nutrients, organic matter, liming agents) in all environmental matrices (soil, water, and air) for both manure and byproducts. Other topics to be

studied are crop production issues, best management and conservation practices, and alternative uses. The overall goal is to provide solutions to problems in the utilization of manure and byproducts.

The Manure and Byproduct Utilization National Program is organized into four components:

- Atmospheric Emissions
- Nutrient Management
- Pathogens and Pharmaceutically Active Chemicals
- Byproducts

Problem areas within each component address specific concerns. These components and problem areas were chosen after receiving input at a planning workshop (described below) designed to learn the problems and needs of our customers, stakeholders, and partners and from other interactions with interested parties.

Cooperative research among ARS units will occur to develop the products and achieve the outcomes identified in this action plan. Cooperators from academia and other agencies will assist in the actual research and in outreach and technology transfer. Product users such as extension, EPA, and NRCS will work with us to provide the information in the most useable formats for their organization so that the expected outcomes are quickly achieved.

Planning Process and Plan Development

The second Manure and Byproduct Utilization National Program workshop was held in April 2004. Approximately 150 participants including producers, commodity group representatives, public interest group representatives, scientists from universities, and scientists and administrators from ARS and other Federal and State agencies attended this workshop. Input from other activities such as USDA and interagency programs, committees, meetings attended by our scientists and national program leaders, and most important the assessment of this national program's impact over the previous 4 years also was used to formulate the components and problem areas in this action plan. The workshop and other activities are used to make this national program as relevant as possible to the concerns of our constituents.

ARS scientists used the program logic model to identify the outcomes, the outputs or products to be produced to achieve the outcomes, and the resources or inputs available to develop these products for each of the problem areas in this action plan. ARS scientists at each of the laboratories participating in this and other relevant national programs (e.g., Water Quality and Management, Soil Resource Management, Air Quality, Animal Production, Food Safety, and Integrated Agricultural Systems) will use this action plan to develop project plans that describe the research they will conduct. The project plans provide detailed information on objectives, anticipated products or information to be generated, the approach that will be used, roles and responsibilities of ARS scientists and their cooperators, and timelines and milestones to measure progress of the research. All project plans are reviewed for scientific quality by an independent panel of experts in the field. ARS scientists use input from the review panel to revise and improve their planned research.

Research Components

Atmospheric Emissions Component

Introduction

Understanding emissions of gases and particulates from livestock operations and the fate (i.e., any change in the substance's composition) and transport of emissions across the landscape surrounding production, manure storage, and manure application sites is critical to identifying and implementing management practices that will reduce these emissions. Concerns and questions raised by livestock producers and air quality regulators center around four major themes: (1) process-based models that incorporate biological, chemical, and physical factors to describe the emission of gases, particulates, and pathogens; (2) development of scientifically sound emission factors for air quality constituents; (3) development and assessment of technologies that will reduce emissions from agricultural operations; and (4) fate and transport of atmospheric constituents to receptors through which human health assessments could be conducted. These areas continue work started in this program during the previous 5-year cycle and although substantial progress has been made, the questions that surround these themes remain major items of concern. The implementation of air quality regulations in livestock-producing states increases the need for answers to these questions and tools that help livestock producers better manage facilities to solve air quality problems. Answers in these areas and their application to livestock operations will yield positive impacts for livestock producers and reduce tension among rural residents. The research program described in this component will build upon progress to date and apply results to management systems within the next 5-year cycle. Air quality constituents are comprised of ammonia (NH_3), hydrogen sulfide (H_2S), volatile organic compounds (VOCs), odor, methane (CH_4), nitrous oxide (N_2O), particulates (2.5 and 10 μm and total suspended particulates), and airborne pathogens. The variation among these constituents in the overall scope of emission, nutrient, and pathogen control associated with animal production increases the complexity in addressing these problem areas. The research is conducted across multiple ARS locations.

Problem Area 1. Understanding the Biological, Chemical, and Physical Mechanisms Affecting Emissions

Problem Statement

Rationale. A combination of biological, chemical, and physical processes controls the emission of gases, odors, and particulates during animal production, manure storage, and manure application. Biological and microbial processes in particular act at all levels from the animal digestive tract through the field application of manures to form a variety of volatile compounds, gases, and other products including odors. Additionally, chemical and physical factors influence not only biological activities but also directly affect emission rates. Information on how these factors interact to affect emissions and other relevant processes (pathogens and nutrients) is lacking. Elucidating microbial processes and their interaction with the chemical and physical environment at all stages of manure generation, handling, storage, and utilization will lead to an

improved understanding of mechanisms controlling emissions. This research will enable the development of efficient management practices and control technologies for emission reduction and will speed the development of emission prediction models.

Research needs. There is a need to provide information to extension educators, private sector consultants, and emission scientists about the biological, chemical, and physical mechanisms affecting emissions associated with animal production agriculture. The overall objective of this problem area is to identify key emission control points spanning the range of animal production from diet, through manure storage, and eventually to manure application in order to better manage and predict emissions. Research within this objective needs to be focused on the interrelating roles of microorganisms and the physical and chemical environment controlling emissions. Furthermore, the effect on nutrient and pathogen issues of manipulations at key points to control emissions must also be determined.

Emissions Problem Area 1. Understanding the Biological, Chemical, and Physical Mechanisms Affecting Emissions

Inputs/Resources	Output/Products	Outcomes
Location Contribution: Ames, IA Beltsville, MD Bowling Green, KY Bushland, TX Clay Center, NE Florence, SC Kimberly, ID Mississippi State, MS Peoria, IL Watkinsville, GA **Cooperators:** Cooperators will be partners in the conduct of research to develop the array of products and will include groups from the National Center for Manure Management, National Pork Board and state groups, Univ. of Illinois, Univ. of Nebraska, National Cattlemen and state groups, Cornell Univ., Univ. of Vermont, Texas Agricultural Experiment Station, West Texas A&M Univ., Kansas State Univ., Colorado State Univ., Western Kentucky Univ., nutrition consultants, and Cooperative Extension.	**Short-term** Scientific information regarding the microbial populations involved in emissions. Information on the effect of animal diet and nutrition on emissions. **Long-term** Decision support module for ammonia emissions from land applications of manure. Decision support module for cattle feedlot surface management to influence emissions. **Product Users** Extension and private sector consultants will be able to provide the products (information and decision support modules) to producers to better manage production and minimize emissions. Regulators will have additional scientific information. Scientists developing process-based models will utilize the information to develop emission models.	**Short-term** A catalog of qualitative fact sheets and flow charts, in plain language, describing emission process and control points that can be used to evaluate potential strategies to reduce emissions and to more narrowly focus future emissions-related research. **Long-term** A quantitative description of the key biological, chemical, and physical processes influencing emissions that can be applied to animal production to reduce emissions.

Problem Area 2. Emission Factors from Livestock Facilities

Problem Statement

Rationale. Regulators, conservation specialists, scientists and producers require tools to assess the potential of animal agriculture operations to affect air quality and impact the environment. One approach is to develop emission factors. An emission factor is a number that expresses the expected release of a particular chemical or pollutant per measure of animal production (e.g., per animal) over a certain time period. Emission factors for ammonia allow decision makers to compare contributions of ammonia from transportation or industrial sources with those from CAFO. Large differences among CAFOs across animal species, production practices, geographic regions, and climates make generating accurate and transferable emission factors extremely challenging. Development of emission factors for ammonia, hydrogen sulfide, methane, nitrous oxide, volatile organic compounds that comprise odors, and PM10 and PM2.5 particulates would enhance our ability to evaluate differences among production systems and their impact on the environment. Accurate and reproducible sampling and measurement technologies for these pollutants are lacking and need to be developed. Currently applied emission factors often are based on information limited by a lack of directly relevant research, and are non-representative of many U.S. production practices and facilities. Whether derived from empirical studies, or based on mechanistic, process-based models, emission factors will continue to play a critical role in understanding CAFOs as sources of gases and particulates. Comprehensive, relevant, science-based emission factors are needed to provide the best information to develop national emission inventories and to evaluate the contribution of CAFOs to air quality.

Research needs. The development of accurate emission factors will require surveys and synthesis of current knowledge and information regarding emission factors; evaluation of measurement tools, technologies, and sampling methods used to quantify concentrations and emissions; evaluation of field-based, scale-appropriate measurement of concentrations; and estimation of fluxes across animal species, geographic regions, seasons, climates, and management practices.

Emissions Problem Area 2. Emission Factors from Livestock Facilities

Inputs/Resources	Output/Products	Outcomes
Location Contribution : Ames, IA Beltsville, MD Bushland, TX Fayetteville, AR Kimberly, ID Madison, WI Starkville, MS Watkinsville, GA **Cooperators:** Cooperators in this research program will be partners in addressing the variety of emissions from different animal production systems and include Mississippi State Univ., Univ. of Idaho, Texas A&M Univ., West Texas A&M Univ., Texas Tech Univ., New Mexico State Univ., Univ. of Kentucky, Purdue Univ., National Center for Manure Management, Southern Utah Univ., Space Dynamics Laboratory (Logan, UT), Univ. of Alberta, Agriculture and Agri-Food Canada, Univ. of Ghent, Danish Institute of Agricultural Science, and Canadian Meteorological Centre.	**Short-term** Fact sheets and guidelines on emission factors based on definable animal or input units that adequately represent regional climate, management input, and other factors. **Long-term** New technologies to quantify emission factors based on improved technologies for concentration and flux measurement. Comprehensive, relevant, science-based emission factors that represent a mass balance of the nutrient input. Interaction among ARS scientists working on the underlying mechanisms of gas, particulate, and pathogen emissions and those addressing emission factors to develop process-based models of emissions. **Product Users** NRCS and other conservation agencies, organizations and practitioners. EPA and state environment regulatory agencies, National Center for Manure Management, animal industry commodity groups, producers, Land Grant Universities, researchers, and environmental groups.	**Short-term** Synthesis of current emission factors that can be applied to CAFO and animal production systems to assess the potential impacts of animal operations on air quality **Long-term** Measurement technologies and methods and guidelines for their application that are used in the development of improved emission factors. Mathematical models to practically and accurately estimate emission factors that can be used by air quality regulators and policy makers to assess potential changes in animal management.

Problem Area 3. Control Technologies and Strategies for Emissions

Problem Statement

Rationale. Producers are under growing pressure to reduce emissions such as ammonia, hydrogen sulfide, VOCs, odors, particulate matter, and greenhouse gases. Ammonia emissions result in nutrient depositions onto the landscape resulting in potential ecological impacts, while methane and nitrous oxide contribute to global climate change. Odor, VOCs, and particulate

matter have created stress and complaints from neighbors and neighboring communities. Innovative management strategies and treatment technologies will improve air quality, the environment for animals, farm workers and surrounding communities, and will promote relationships among regulators and producers. Innovative, cost-effective and reliable emission control strategies and treatment technologies are needed to reduce emissions from animal production facilities, manure storage, and manure field application sites.

Research needs. Effective and reliable control strategies and technologies can be developed through the application of scientific knowledge to various components of animal production and manure storage and handling processes. Research projects should aim to quantify the role of modified animal diets; the microbial interactions that result in the production of odor, VOCs, greenhouse gases and ammonia; chemical amendments and inhibition of microbial interactions; and systems of treatment technologies including improved manure handling and storage, all of which will yield potential solutions to these problems. System analysis approaches through mechanistic process models incorporating cross-media and interactions with nutrients are needed to effectively reduce overall emissions from agricultural operations.

Emissions Problem Area 3. Control Technologies and Strategies Research

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Ames, IA Beltsville, MD Bowling Green, KY Bushland, TX Clay Center, NE Fayetteville, AR Florence, SC Lincoln, NE Madison, WI Mississippi State, MS Peoria, IL Watkinsville, GA **Cooperators:** Cooperators in these studies will assist in developing guidelines for application of control technologies and economic analysis and include a variety of federal, state, and livestock commodity organizations such as: NRCS, State and Federal Regulators, CSREES, Consulting Engineering Industry, National Center for Manure Management, Commodity Groups, and Land Grant Universities.	**Short-term** Database of information on gas formation and emissions based upon the current body of knowledge that can be used to identify potential control points for emissions. BMP for manure storage and cleaning pen surfaces to reduce dust. **Long-term** Control practices and strategies with associated decision support tools to reduce emissions of ammonia, greenhouse gases, VOCs, and odor that balance emission control, economic, and labor considerations. **Product Users** Extension and private sector consultants will be able to provide the practices and strategies to producers to better manage production and minimize emissions. Regulators will have additional scientific information. Scientists developing decision	**Short-term** Recommendations for improved control strategies and management practices that can be applied in livestock operations by producers. **Long-term** Innovative and cost-effective management practices and treatment technologies that can be identified by NRCS, EPA and others as acceptable air quality control practices for cost-share support and useable by livestock producers.

Inputs/Resources	Outputs/Products	Outcomes
	support tools.	

Problem Area 4. Atmospheric Fate and Transport to Receptors

Problem Statement

Rationale. Transport of atmospheric constituents derived from livestock operations and the fate of these constituents in the atmospheric environment is critical to the development of air quality standards and the assessment of potential human and animal health effects downwind of livestock operations. Transport of gases, particulates, and pathogens in the atmosphere requires an understanding of air movement patterns across complex terrain. The fate of these various compounds and particles in the atmosphere is relatively unknown, and a knowledge base to quantify the loading rate (e.g., amount of odorant, concentration or viability of pathogens, etc.) at the downwind receptor sites is critical to evaluating the impact of livestock operations on the environment. Bioaerosols refer to aerosols consisting of biologically active chemicals (endotoxins) and pathogens (bacteria, fungi, mycotoxins, viruses and protozoans) that may have an effect on the environment, animals, and humans.

Odors are the number one nuisance complaint from the public downwind of CAFOs; endotoxins are extremely biologically active lipopolysaccharide molecules formed from the cell membranes of all gram-negative bacteria, many of which have their origin in the manure. Aerosolized endotoxins, when respired, have the ability to induce a fever and increase the peripheral white blood cells in animals and humans. Microbial pathogens by themselves or attached to aerosolized particles can be transported downwind to animals and humans and may induce infectious disease of the epidermis and respiratory system, or they may cause allergies. Aerosolized particles also affect the air environment (haze). Organic toxic dust syndrome is now frequently diagnosed in humans and EPA has set limits on the concentration of aerosol particles with a diameter of 10 μm, however, smaller particles with diameters less than 2.5 μm are more pathogenic and contribute to health problems in humans. Our knowledge base to make these evaluations is limited and insufficient to achieve the goal of providing reliable information on concentrations at the receptor sites. To increase the knowledge base requires a combination of improved dispersion models for the various atmospheric constituents and improved atmospheric chemistry and biological models that can be integrated to improve our understanding of the fate and transport of these compounds.

Research needs. Much of the data needed to determine the atmospheric fate and transport of gases, odorants, particulates and bioaerosols will come from research in components 1 and 2 on processes and emissions factors, respectively. Additional information on fate and transport is needed once these substances are in the atmosphere. Transport models for gases, particulates, and pathogens emitted from livestock facilities to receptor sites are needed to assess the impact of livestock operations on the environment. Current atmospheric transport models are limited by a lack of understanding of the turbulent regime adjacent to the facility or manure storage site and the movement of air across complex terrain present in agricultural areas. Constituents in the atmosphere travel differently because of size and interactions with air and there is a need to

quantify how these components change with distance traveled in the atmosphere to provide more realistic estimates of the concentration at the receptor site. Research is needed to develop improved atmospheric transport models capable of estimating the movement of gases, particulates, and pathogens from livestock facilities to downwind receptor sites, quantify the micrometeorological conditions adjacent to livestock buildings, manure storage, and manure application sites for inclusion into transport models, and develop enhanced estimates of gases, particulates, and pathogens at receptor sites for linkage with human and animal health assessments.

Emissions Problem Area 4. Atmospheric Fate and Transport to Receptors

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Ames, IA Beltsville, MD Bowling Green, KY Bushland, TX Lincoln, NE Peoria, IL Watkinsville, GA **Cooperators:** Cooperators on this Focus area will be participating in the design and implementation of many of the project objectives and jointly preparing research reports on the findings from these experiments. Cooperating agencies include NOAA, DOD, Los Alamos National Laboratory, Space Dynamics Laboratory, and Utah State Univ. To assess the health effects will require cooperation with scientists and staff from EPA, the Centers for Disease Control and public health departments.	**Short-term** Transport potential of different gases, particulates, or pathogens through the atmosphere to receptor sites. Standards and protocols for aerosol collection and analysis. **Long-term** Transport models for gases, particulates, and pathogens capable of accurately predicting transport across complex terrain. Assessment and prediction of the concentration of gases, particulates, and pathogens at receptor sites that can be linked with human and animal health assessments. **Product Users** Producers will be able to use decision support tools derived from models to assess management options for their facilities; scientists will have access to improved transport models; public health groups will have access to information on the concentration of various gases, particulates, and pathogens.	**Short–term** Assessment tools for the determination of gas, particulate, or pathogen concentration at receptor sites around livestock facilities that can be used in cooperative studies to evaluate health effects of livestock operations. Baseline data for different CAFO types, in different geographical areas to help target effective use of resources in evaluating and reducing potential health effects. Guidelines for protecting health of CAFO workers based on scientific observations. **Long-term** Decision support tools for guiding management decisions about placement and modifications of production facilities that can be used by livestock producers to evaluate management strategies.

Nutrient Management Component

Introduction

Manure and biosolids contain nutrients [e.g., nitrogen (N), phosphorus (P), potassium (K)] essential for plant growth and development. Other byproducts also may contain beneficial nutrients. Moreover, the worldwide readily available amount of some of these nutrients, such as P, is finite, so that recycling is highly desirable. In addition manure, biosolids and other byproducts high in organic matter, when applied to soil, can enhance carbon sequestration and soil tilth. Increasing soil organic matter, for example, usually increases water holding capacity and root growth as well as improving other soil properties. Land application is, therefore, the preferred method of utilizing animal manure, biosolids, and many other byproducts.

Manure and byproducts must be carefully managed, however, if they are to be used beneficially in agriculture. The nutrients in manures and byproducts are usually less concentrated and released more slowly than those in most commercial fertilizers, so a greater quantity must be applied to supply the same amount of nutrients. This slow release property of organic amendments can be a positive attribute if the material is appropriately managed. Nutrients also can be lost from manure before it is land applied. Nitrogen is especially susceptible to loss through ammonia volatilization, denitrification, leaching, and runoff. Furthermore, the ratio of nutrients in manure and byproducts often do not match the needs of plants. In particular, the relative content of N to P in manure differs from that in crops. Manure application rates based on meeting crop N needs generally result in over-application of P. Manure application based on meeting crop P needs significantly reduces manure application rate, requires more land, results in higher manure transportation costs, and requires application of commercial N fertilizer to meet plant needs. Similar issues are often present with other byproducts.

Over-application or mismanagement of manure can degrade water quality with excess N and/or P. For example, N, from manure and other sources, transported by the Mississippi and other rivers has been associated with the ever-increasing hypoxic zone (hypoxia condition) in the Gulf of Mexico. Manure-derived trace elements (e.g., copper, selenium) and salts also have been recognized as environmental contaminants. Nutrients (e.g., N as ammonia) can also be lost to the atmosphere from animal production areas, during handling and storage, and during land application. If manure and byproducts are over-applied to land, excess nutrients, trace elements, and salts can degrade soils. These problems have become more pronounced recently because of the greater concentration of animal production. Less land is now available near many AFOs for on-farm recycling of manure-derived nutrients to crops. Suitable land needs to be accessible and near the site of manure or byproduct generation to cost-effectively avoid environmental, soil, and water contamination.

Strategies to address the issues identified above revolve around managing the manure or byproduct to minimize the amount of nutrients that cannot be beneficially used in agriculture. Methods to do this are the basis for the four problem areas identified for this component. They are: (1) animal feeding and management; (2) innovative technologies for collection, storage, and treatment of manure; (3) management tools for indexing and evaluating nutrient fate and transport, and (4) farming systems and practices for efficient and balanced nutrient management.

Problem Area 1. Animal Feeding and Management

Problem Statement

Rationale. Modifying the nutrient content of animal diets can alter nutrient losses to both the animal and the environment. Major factors controlling the quantity of nutrients in animal manures are diet composition, quantity of diet consumed, nutrient retention in the animal or animal products, and, in some cases, the route of excretion by the animal. Because of increased regulations concerning manure application to crops and pastures, nutrient composition of manures and phytoavailability of those nutrients are increasingly important. Thus, animal production efficiency needs to be balanced with environmental impacts. Revising the nutrient content of diets can have dual benefits. Production efficiency can be increased and losses to the environment can be decreased.

Research needs. Modifications are needed in animal feeding and management to increase the proportion of dietary nutrients retained in the animal or animal products and decrease the proportion of dietary nutrients excreted and lost to the environment. Information is needed concerning the impact of diet manipulation and animal management on animal production, health and reproduction, manure composition, the availability of manure nutrients to plants, and potential nutrient losses to the environment.

Nutrient Management Problem Area 1. Animal Feeding and Management

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: **Product 1 Participants** Bushland, TX Ames, IA Beltsville, MD Clay Center, NE **Product 2 Participants** Ames, IA Bushland, TX Clay Center, NE Madison, WI Mississippi State, MS **Product 3 Participants** Bushland, TX Fayetteville, AR Kimberly, ID Madison, WI	1. Simple, reliable methods to determine bioavailability of feed nutrients and information on the bioavailability of nutrients in feeds for use in feed formulations. 2. Feed processing and ration formulation recommendations that balance animal production and environmental outcomes. 3. Methodologies that help identify the impacts of feeding regimes on manure nutrient composition, phytoavailability, and subsequent reactivity in the environment.	Feeding and animal management strategies that improve nutrient capture in animals and their products, thereby reducing manure nutrient loads and the potential for nutrient losses to the environment. Improved feeding and management recommendations.

Inputs/Resources	Outputs/Products	Outcomes
Product 4 Participants **Bushland, TX** **Ames, IA** **Clay Center, NE** **Madison, WI** **Cooperators:** Land Grant Universities (Texas Agric. Exp. Sta., New Mexico State, Kansas State, Mississippi State, etc.); non-land grant universities (Texas Tech, West Texas A&M); producers and producer groups; feed industry; consultants; animal nutritionists; NRCS; and equipment manufacturers.	4. Data sets that help predict the effects of feeding strategies on animal production, farm profitability, and environmental outcomes. **Product Users** Consultants, nutritionists, and extension specialists through new knowledge to formulate diets that balance animal production and environmental concerns. Livestock and poultry producers through use of improved diets and animal management that decrease feeding and manure management costs and negative impacts on the environment. Scientists via new knowledge that can be used to conduct parallel research studies that provide additional information.	

Problem Area 2. Innovative Technology for Collection, Storage, and Treatment

Problem Statement

Rationale. Significant losses of nutrients can occur during manure collection and storage. Additional losses can occur during land application. Best management practices (BMPs) are needed to efficiently utilize manure nutrients and protect water quality. Treatment can be enhanced with the use of biological, chemical, and physical treatment methodologies, especially in combination as part of holistic systems.

Research needs. Innovative treatment technologies need to be developed and integrated into systems to prevent off-farm release of nutrients. Technologies are needed to control feedlot runoff, reuse water, and integrate these practices into holistic management systems. A combination of new biological, physical, and chemical treatment technologies are needed to efficiently separate manure liquids and solids, to capture and concentrate manure nutrients, and to treat lagoon sludge. New manure application techniques to reduce nutrient losses to the atmosphere, surface water, and groundwater need to be tested and developed. The efficacy of current BMPs and treatment systems need to be quantified and new ones developed. These technologies and systems will decrease the potential for problems at farms and AFOs and improve the possibility for transport of manure to where it can be used safely and beneficially, thus protecting the environment and human and animal health.

Nutrient Management Problem Area 2. Innovative Technology for Collection, Storage, and Treatment

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: **Product 1 Participants** Clay Center, NE Bushland, TX Florence, SC **Product 2 Participants** Florence, SC Beltsville, MD Fayetteville, AR **Product 3 Participants** Florence, SC **Product 4 Participants** Florence, SC **Odor Linkages:** Beltsville, MD Peoria, IL **Pathogen Linkages:** Beltsville, MD Bowling Green, KY Bushland, TX Kimberly, ID Lincoln, NE Riverside, CA Watkinsville, GA **Cooperators** NRCS, state and federal regulators, CSREES, university scientists, National Manure Center, EPA, consulting engineering industry (national and international), Livestock integrators, commodity associations, agri-business, foundations, scientific and technical organizations (national and international).	1. Alternative technology to control runoff and improve water reuse in feedlots and at other AFOs. 2. Superior technologies to capture, transform, concentrate, and reuse nutrients in animal manures. 3. Refined constructed and natural treatment technologies to effectively manage nutrients. 4. New technologies to recycle or recover nutrients from lagoon sludge. **Product Users** Livestock producers, NRCS, EPA, state and federal regulators, general public, consulting engineering industry, other researchers. Information will be provided to users through scientific publications, patents and licenses, ASAE Standards, NRCS practices, and ARS websites.	**Short-term** Reduction of runoff and improved water reuse for feedlots. Improved biological, physical, chemical, and mechanical treatment technology. Improved reduction of odor, pathogens, and PACs, linked to nutrient treatment technology. Improved constructed and natural treatment technologies. Improved treatment for lagoon sludge. **Long-term** Development of holistic treatment systems to prevent off-farm release of nutrients.

Problem Area 3. Management Tools for Indexing and Evaluating Nutrient Fate and Transport

Problem Statement

Rationale. Animal manures and other byproducts contain nutrients, such as N and P, which can be valuable plant nutrient sources. However, nutrient concentrations and forms must be known to properly and efficiently utilize the nutrients present in animal manures. For example, since N is susceptible to loss through ammonia volatilization, denitrification, leaching, and runoff, knowing the amount present in the material applied and its forms and availability would improve appropriate application. The P Index is the primary tool used by field staff, watershed planners, and land managers to assess various landforms and management practices for potential risk of P movement to water bodies. Wide adoption of the P Index to assess risk of P loss to surface waters is testament to the need for such tools. Nevertheless, the P Index needs to be validated in many areas in which it is being used, and a similar index for N transport also is needed. There is a continuing need for improved understanding of P accumulation capacity, transport, and impact of BMPs at farm to watershed scales. Process-based numerical models are efficient tools for integrating site-specific data with current knowledge of the physical, chemical, and biological processes governing nutrient dynamics. Model results allow quantitative assessment of the environmental impacts of wastewater pollutants and improved understanding of watershed-scale pollutant transport.

Research needs. New tools are needed to evaluate manure nutrient availability. Research is needed to develop "Quick Tests", which are appropriate for on-farm use, particularly for plant-available N and bioactive P. Research is needed to improve the P Index input parameters and validate the P Index at the watershed scale. A Nitrogen Transport Index is needed to determine the potential impacts of manure application on N transport to air, rivers, and lakes. The impact of soil properties, climatic variables, and manure composition on manure N availability must be quantified so that manure N availability to crops can be accurately predicted. Expanded knowledge is needed that quantifies the linkages among C, N, and P cycling processes and incorporates this information into process-based models. Decision support tools are needed that incorporate all this information.

Nutrient Management Problem Area 3: Management Tools for Indexing and Evaluating Nutrient Fate and Transport

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: **Product 1 Participants** Beltsville, MD Bowling Green, KY Fayetteville, AR Miss. State, MS Lincoln, NE Univ. Park, PA West Lafayette, IN	1. Refined P Index	1. Enhanced utility and application of the P Index for identifying areas with varying risks of P contamination.

Inputs/Resources	Outputs/Products	Outcomes
Product 2 Participants Beltsville, MD Bowling Green, KY Lincoln, NE Miss. State, MS	2. N Transport Index	2. Ability to discern areas with differing vulnerabilities for N loss/transport.
Product 3 Participants: Beltsville, MD Orono, ME Kimberly, ID Clay Center, NE Madison, WI	3. Quick Tests for Determining Manure Nutrients	3. Improved utilization of manure derived nutrients in crop production.
Product 4 Participants Beltsville, MD Bushland, TX Ft. Collins, CO Orono, ME Univ. Park, PA	4. Refined Process Based Model for Organic Nutrient Management at Multiple Scales.	4. Increased accuracy in evaluating whole farm management impacts on nutrient availability and accumulation.
Product 5 Participants Ames, IA Auburn, AL Beltsville, MD Bowling Green, KY Clay Center, NE Lincoln, NE Madison, WI Orono, ME Pendleton, OR Tifton, GA	5. Decision Support System for Predicting N Availability from Manure **Product Users** Producers, NRCS, Cooperative Extension Agents and Specialists, regulators, community planners, consultants.	5. Optimized N use efficiency by crops in manure-amended soils.

Problem Area 4. Farming Systems and Practices for Efficient and Balanced Manure Nutrient Management

Problem Statement

Rationale. Land application of manure as a soil amendment and nutrient source is generally the most viable method of recycling animal wastes. Land application, however, does carry a risk of excess nutrients in soil, especially within short distances of AFOs. Excess levels of soil P, N, and trace elements are known to contribute to pollution of surface and ground waters. Application method can dramatically affect nutrient availability and environmental impact of manure addition to soil. For example, more than 80% of poultry litter is surface-applied to pasture lands without incorporation. This results in loss of N through ammonia volatilization, carbon (C) as carbon dioxide, and P and other nutrients through surface soil erosion and runoff. Subsurface band application of litter may reduce nutrient losses to the atmosphere, surface water, and ground water, while also reducing odors. Subsurface application would, however, need to be performed in a manner that would not cause erosion or other environmental problems. Adoption of this and

other BMPs will be maximized if their attributes are evaluated and benefits are demonstrated at whole farm and watershed scales. There are also situations in which land application is not viable. Producers often lack cost-effective and reliable alternatives to land application of untreated manures.

Research needs. Customers need BMPs, e.g., tillage and cropping systems, application timing, and application equipment for efficient use of manure nutrients. These BMPs and their associated nutrient management plans must be economically viable, environmentally sound, and evaluated at field, farm, and watershed scales. New application methods and associated equipment need to be developed. Alternative systems of manure utilization are needed where land application is not a viable practice. To be adopted, these practices (both land and non-land based) should be effective, efficient, and fit into crop production systems used by the producer.

Nutrient Management Problem Area 4: Farming Systems and Practices for Efficient and Balanced Manure Nutrient Management

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: **Product 1 Participants** Auburn, AL Bowling Green, KY Lincoln, NE Madison, WI Miss. State, MS Orono, ME **Product 2 Participants** Auburn, AL Bowling Green, KY Miss. State, MS **Product 3 Participants** Ames, IA Bushland, TX Bowling Green, KY Coshocton, OH Lincoln, NE Miss. State, MS Temple, TX Tifton, GA Univ. Park, PA West Lafayette, IN Also includes scientists working on the Pathogen focus areas "Survival and Transport" and "Modeling Fate and Transport of Manure-borne Pathogens from	1a. Effective and environmentally sound nutrient management plans for nutrient-balanced livestock and crop production systems. 1b. BMPs for manure nutrients that are specific to livestock and crop producers' goals and reflect the sensitivity of the watershed to nutrient loading. 2. Improved manure application equipment that increases nutrient use efficiency. 3. Alternative management systems for nutrient use and pathogen transport reduction at farm/watershed scales. **Product Users** Cattle, dairy, poultry, and swine producers; regulators; action agencies; and scientists	1a. **Short-term** Adoption of BMPs for manure nutrients that are specific to livestock and crop producers' goals and reflect the sensitivity of the watershed to nutrient loading. 1b. **Long-term** Adoption by producers of crop, livestock, pasture, and range products to minimize the loss or accumulation of manure nutrients at field, farm, and watershed scales. 2. **Long-term** Greater crop uptake of manure nutrients and decreased loss of nutrients through runoff, leaching, and volatilization. 3a. **Short term** Improved collaborations that increase impact of farm/watershed scale research so that manure management research is synchronized with whole farm and watershed scale nutrient management. 3b. **Long term** Adoption of regulations and recommendations for farming

Inputs/Resources	Outputs/Products	Outcomes
Pedon to Watershed Scale." **Cooperators** Livestock producers; animal production integrators; NRCS; EPA; state regulatory agencies; Land Grant Universities (MS State Univ.; Western KY Univ.; Univ. NE-Lincoln; AL A&M; Auburn Univ.)		based on scientifically defensible results and conclusions.

Pathogens and Pharmaceutically Active Compounds (PACs) Component

Introduction

Pathogens and pharmaceutically active compounds in manure, biosolids, and other byproducts can be transmitted to other animals and humans through food supplies, water, and possibly air. Animals on the farm or at AFOs can also be re-infected not only via water and air but also from other vectors such as birds, rodents, and insects that can directly infect the animal or contaminate animal feeds or water. The potential for serious health effects both on and off the farm and the lack of knowledge about pathogen survival in manure, collection, storage, treatment, and application systems as well as in soil, water, and air after manure and other byproducts have been land-applied or otherwise disposed clearly point to the need for research on these issues.

Certain foodborne and waterborne microorganisms are of particular public health concern. The following pathogens have been targeted for immediate attention by the Federal Food Safety Initiative Consortium: *Salmonella* species, *Campylobacter jejuni/coli*, *Escherichia coli* O157:H7 and other related strains; the parasite *Cryptosporidium parvum*; and enteroviruses. In addition, the recurring incidence of foodborne illness outbreaks caused by *Listeria monocytogenes* and the potential for more extensive involvement of *Mycobacterium paratuberculosis* and *Yersinia enterocolitica* indicate the need for additional research on the involvement of these microorganisms in the farm-to-table pathway of disease agent spread. The most significant of the manure-borne zoonotic pathogens are the protozoan parasites *Cryptosporidium parvum* and *Giardia duodenalis*, and the bacterial pathogens *Salmonella*, *Campylobacter*, *Escherichia coli*, and *Listeria monocytogenes*. These organisms will be the focus of most of the research in this component of the Manure and Byproduct Utilization National Program.

Large amounts of PACs such as hormones and antibiotics also may be present in animal wastes (wastewater and manure) and disseminated in the environment. Pathogenic microorganisms in livestock and poultry can become resistant to antimicrobial agents, and the practices that have been traditionally relied on to eliminate or prevent their growth are not always effective. Researchers have identified pharmaceuticals and antibiotic-resistant bacteria in lakes, streams, and aquifers near animal production operations. In addition, manure-borne antibiotics and antibiotic-resistant bacteria may influence indigenous bacterial populations in soil and water. Selective pressure and transmission of genetic information conferring antibiotic resistance may

result in a reservoir of antibiotic-resistant bacteria in environments associated with animal agriculture. Knowledge of the processes that control the transport and persistence of pharmaceuticals and survival of antibiotic- resistant microorganisms in livestock manure and wastewater is therefore needed to accurately assess risks and vulnerabilities, and to develop control mechanisms.

ARS' research in the pathogen component will focus on the following problem areas:

1. Pathogen Detection Methods Assessment and Development.
2. Fate and Transport in the Environment, which has five sub-problem areas:
    a. determination of inactivation rates and transport characteristics of pathogens in wastes, soil, water, and air.
    b. identification of suitable pathogen indicators
    c. biological source tracking
    d. bioaerosols
    e. model development
3. PACs
4. Holistic Treatment Technologies for Nutrients, Pathogens, and PACs.

The logical structure of the program is to determine better what organisms and PACs are present, determine how they are disseminated and survive in both the on-site and off-site environment, quantify this behavior (e.g., with models), and develop treatment methods for pathogen and PAC control that are compatible with nutrient and other management objectives. ARS will not conduct risk assessments *per se* on pathogens, antibiotic resistance, and PACs because conducting risk assessments is outside of our mission. ARS will, however, provide its highly relevant data and considerable expertise to those who do have this risk assessment responsibility, such as the Center for Disease Control (CDC) and the Environmental Protection Agency (EPA). This program will, however, lead to a lessoning of the risks posed by pathogens and PACs.

Problem Area 1. Methods Assessment and Development

Problem Statement

Rationale. All pathogen research is predicated on the existence of appropriate methods. However, there are currently no standard methods for the detection of pathogens in the environment with the exception of USEPA Method 1623 for water-borne *Cryptosporidium*. The absence of standard methods is in large measure due to the extraordinary diversity of pathogens, matrices and detection technologies. Environmental matrices of concern include air, soil, water, manure, biosolids and other organic byproducts. The fundamental detection technologies are microscopic, culture-based, genetic (PCR), and immunological (antibody-based). The choice of method(s) will be dictated by the pathogen, matrix, and research goals. This is currently a very active area of research across all sectors (private, government, academic) interested in pathogens. Consequently, there is a need to assess the methods that are being developed as well as develop new methods when the current methods are found to be inadequate. It also means that it is highly unlikely that standard methods will be adopted in the near future.

Research needs. There is a need for scientists to rigorously evaluate current and new methods and then communicate their observations and findings to other scientists conducting related research to minimize duplication of effort. Specifically, it would be useful to evaluate methods with respect to (1) selectivity, (2), sensitivity, (3) quantitativeness, (4) analysis time, and (5) cost. These methods need to be tested in all relevant matrices – soil, manure and biosolids, wastewater, air and water. New methods need to be developed when current methods are lacking.

Pathogens Problem Area 1. Methods Assessment and Development

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Ames, IA Beltsville, MD Bowling Green, KY Bushland, TX Kimberly, ID Miss. State, MS Riverside, CA Watkinsville, GA **Cooperators** Academia, private sector, government agencies	**Short-term** A compendium of current methods. **Long-term** A set of validated methods for specific pathogens and matrices. **Product Users** Research Scientists conducting fate and transport, or watershed monitoring studies; Government agencies (EPA, CDC, APHIS); commercial labs.	**Short–term** Communication among scientists at different locations regarding sample preparation and pathogen detection. **Long-term** More precise and accurate determination of pathogens in wastes and in the environment from a set of validated methods for specific pathogens and matrices.

All the ARS units conducting pathogen research necessarily utilize one or more detection methods depending on the mix of pathogens, matrices, and research goals. Consequently, all units will contribute, either by actively developing or optimizing new methods, or by validating previously existing methods.

Problem Area 2. Fate and Transport of Pathogens

Problem Statement

Rationale. The presence of pathogens in manure and other byproducts requires knowledge of their fate and transport to protect human and animal health.

Research needs. Information is needed on pathogen inactivation and die-off as well as their potential for regrowth as functions of environmental conditions (e.g., temperature, moisture, etc.) during all stages of waste management. These stages include deposition, collection, storage, handling, treatment, utilization and application. This information should be linked to pathogen movement in air and water. The determination of their transport characteristics needs to address variables such as soil type and vegetative cover. In addition, a better understanding of the connection between the pathogens and indicator organisms is needed, if, for example, regulated total maximum daily loads (TMDLs) for indicator organisms are to be meaningful measurements of surface water impairment.

Because fate and transport of pathogens from animal agriculture is a complex and multifaceted area of research, five sub-problem areas and groups will be established to concentrate on a particular aspect of pathogen fate and transport:

a. Determination of inactivation rates and transport characteristics of pathogens in wastes, soil, water and air.
b. Identification of suitable pathogen indicators – there is still a need to use indicators despite recent advances in directly detecting pathogens.
c. Source tracking - a critical examination of methods developed to identify sources of fecal contamination of surface water.
d. Bioaerosols - the fate of pathogens in the air and the atmospheric transport of pathogens across the landscape.
e. Model development - development of predictive mathematical models based on data from fate and transport studies.

Expanded information on each of these topics is provided below.

Problem Area 2a. Inactivation Rates and Transport Characteristics of Pathogens from Animal Agriculture

Problem Statement

Rationale. Limiting exposure to pathogens is a major concern of public health officials throughout the world. An expanded understanding of the fate and transport of pathogens through a watershed or agricultural landscape is required. For example, there is a need for better knowledge of the inactivation rates for pathogens in relationship to environmental conditions (e.g., temperature, moisture, etc.) and the determination of their transport characteristics across variable soils and vegetative covers. Data that fill these gaps will improve decision support tools, development of on-the-farm BMPs and the predictability of models.

Research needs. An improved and more extensive data set on the survival of particular pathogens is needed. Pathogens such *E. coli* 0157:H7, *Salmonella* spp., the protozoan parasite *Cryptosporidium parvu* and viruses will have different die-off rates under the same environmental conditions. These die-off rates need to be determined and compared with those of the indicator organisms that are used to monitor the presence of pathogens from animal agriculture. Rates of die-off for pathogens need to be carried out under controlled laboratory conditions as well as under variable field conditions in both soil and water. In addition to these survival studies, transport studies need to be designed. Small-scale plot studies that involve rain simulation in conjunction with small watershed scale studies need to be undertaken in which both particular pathogens and indicator organisms are measured. The objectives of this research will be to:

1. Develop a data set of die-off rates for particular pathogens and indicator organisms for controlled environmental conditions as well as field conditions in different seasons.
2. Determine the transport characteristics of the pathogens and indicator organisms at plot and watershed scales.

3. Develop survival and transport datasets that can be readily used by modelers and decision makers who make recommendations for BMPs.

Pathogens Problem Area 2a. Inactivation Rates and Transport Characteristics of Pathogens from Animal Agriculture

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Albany, CA Beltsville, MD Bowling Green, KY Bushland, TX Kimberly, ID Miss. State, MS Riverside, CA Watkinsville, GA **Cooperators** Universities and other agencies. Cooperators will assist in conducting the research and technology transfer.	**Short-term** Data sets on inactivation rates for *Salmonella*, *E. coli* 0157:H7, *Campylobacter*, *Cryptosporidium parvum,* and fecal indicator bacteria. Data sets on transport parameters on *Salmonella*, *E. coli* 0157:H7, *Campylobacter* and *C. parvum* relative to fecal indicator bacteria. Data on the ability of various pathogens to contaminate or infect various crops. **Long-term** Knowledge of pathogen persistence, inactivation rates, and transport parameters that will be useful to producers, managers of watersheds, regulators, decision makers, and developers of predictive models. **Product Users** Municipal watershed managers, regulators, scientists, modelers, EPA, NRCS, state Departments of Environmental Protection, extension agencies, industry, NGOs and producers.	Improved treatment technologies, BMPs, and regulations that protect public health from pathogens in manure and other wastes A scientific basis for establishing total maximum daily loads (TMDLs) for indicator organisms

Problem Area 2b. Pathogen Indicators for Fate and Transport Research

Problem Statement

Rationale. Historically indicator organisms have been used instead of actual pathogens to estimate the fate and movement of pathogens in the environment because of the difficulties and costs associated with detecting true pathogens. Also, currently used indicators such as fecal coliforms and *E. coli* leave much to be desired because their survivability and transport differ from many other pathogens. The situation is further complicated by the fact that manure is not

the only on-farm source of pathogens and parasites. Other farm sources include: dust, aerosols, irrigation and runoff water, insects, wildlife, farm workers, plant residues, and the soil. For example, *Bacillus cereus*, *Clostridium* spp, and *Listeria monocytogenes*, can be readily found in many soils in association with plant material, vegetables, and decaying leaves and other plant parts. In addition, coliforms such as *Enterobacter* spp. and *Klebsiella* spp. are common inhabitants of soil and plant material, even in the absence of fecal material. This limits the use of traditional fecal coliform methods as indicators of fecal contamination. Certainly, the recent development of improved methods, e.g., those based on DNA and RNA using PCR and other procedures, have greatly improved our capacity and capability to directly detect pathogens in manure, soil, water, and air. Despite these recent advances there remains a need to use indicators. Pathogen outbreaks and occurrences are sporadic and episodic. Not all labs have the capacity and capability of measuring actual pathogens. Many of the new methods do not work well with "dirty" samples, organic (e.g., humic substances) and inorganic compounds and elements found in manure, soil, sediment and water interfere with pathogen detection. Pathogen fate and transport models will use indicator organisms until more pathogen-specific data become available. Regulatory and action agencies likely will continue to use indicators in developing policies (e.g., TMDLs) in the foreseeable future. Therefore, indicator organisms will continue to have an important role in pathogen fate and transport research.

Research needs. There is a need for more indicators and more appropriate indicators. More indicators are needed because of the variety of pathogens present in manure and some other byproducts. Bacteria, protozoans, fungi, and viruses are all present. In addition, within each genus there are differences in their properties, such as the capability to form spores resistant to environmental factors leading to their death. These indicators for each class of organism also then need to more appropriately mimic the properties and behavior, such as attachment, survival and regrowth in soil, water and air, of actual pathogens. Research on this topic has three primary objectives:

1. Identification of improved indicators.
2. Testing of their traits and behavior (survivability, transport, etc.) relative to current indicators and pathogens.
3. Development of a robust data set of indicators and their properties for use in models and to inform policies.

Pathogens Problem Area 2b. Pathogen Indicators for Fate and Transport Research

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Albany, CA Ames, IA Beltsville, MD Bowling Green, KY Bowling Green, KY Bushland, TX Clay Center, NE Columbia, MO Fayetteville, AR	Database of indicators and their properties (e.g., which indicators work well for which pathogens and their strengths and weaknesses). Database from fate and transport studies that have used a common set of indicators at laboratory to watershed scales.	**Long-term** Improved BMPs and models and more informed policies because of a more reliable and robust set of indicators for determination of pathogen fate and transport.

Inputs/Resources	Outputs/Products	Outcomes
Kimberly, ID Lincoln, NE Miss. State, MS Riverside, CA Watkinsville, GA All pathogen researchers working on fate and transport will contribute. **Cooperators:** EPA, university and industry scientists will assist in doing the research and in outreach and technology transfer.	**Products Users** Regulators, action agencies (e.g., NRCS), scientists.	

All ARS researchers conducting fate and transport studies will use the same indicators to help develop this robust dataset. Many ARS scientists also will be cooperating with scientists at other agencies and universities. We will cooperate with end-users, such as extension, state agency offices, NRCS, USEPA, industry, etc. to put the information into formats that are most readily useable for their organizations so that the expected outcomes are quickly achieved.

Problem Area 2c. Biological Source Tracking

Problem Statement

Rationale. Biological source tracking has been proposed as a method to ascertain the origin of microbial contamination in the environment. Ideally, source tracking would not only enable the species of the indicator or pathogen to be determined (e.g., human, bird, cattle, swine), but also pinpoint the specific flock, herd, community, etc. that caused the contamination. However, use of this method to definitively establish sources of microbial contamination depends on the requirement that four key assumptions be met. For any pathogen in question, the following points need to be answered: (1) host specificity, (2) geographic stability of clonal composition, (3) temporal stability of clonal composition, and (4) clones isolated from the environment must correspond to those of the fecal source (secondary vs. primary host). At this time, it has not been demonstrated (using scientifically based methods) that it is possible to meet all four of these conditions with respect to any microorganism. A key concern is the apparent lack of a pathogen/indicator organism with appropriate host specificity. A strict interpretation of host specificity would be "the microorganism in question is capable of replication only in a single host," thus the presence of this microorganism also implies the presence of that host. A more relaxed definition of host specificity could include the presence of a dominant species of microorganism or, say, a DNA fingerprint pattern that appears to be associated primarily with a specific host organism.

Research needs. All four key assumptions must be validated on the basis of sound science for biological source tracking to be accepted as a valid environmental method. Each animal species

(swine, beef, dairy, etc), with their attendant pathogen(s), operating under different production and environmental conditions need to be investigated to address the above four assumptions. Scientific methodology such as the following are just some of the identifiable research areas (1) valid sampling methods regarding production system/geographical location, (2) statistical validation of sampling methodologies, (3) validation of detection methods, (4) robust DNA fingerprinting techniques to establish clonal relationships, (5) knowledge of environmental stability of pathogens, and (6) knowledge of pathogen transmission pathways. Results for these efforts will thus define future high priority research topics. Alternatively, the lack of adequate technologies may indicate either the futility of this endeavor or cost-ineffectiveness of conducting biological source tracking at this time.

Pathogens Focus Area 2c. Biological Source Tracking

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Ames, IA Bushland, TX Riverside, CA Watkinsville, GA **Cooperators** Cooperators will assist in the conducting of research, outreach efforts and technology transfer. As necessary, other locations and or other agencies (e.g., EPA, CDC) will be added to achieve desired goals.	**Short-term** Database/whitepaper of microbial source tracking "case studies," including microorganisms/ecosystem(s) involved, and a critical assessment of studies with respect to the four key assumptions. Testing innovative technologies such as DNA micro-array based approaches and other technologies with the potential to reduce cost and improve efficiencies. Following organisms from excretion through environmental sample. **Long term** A model system in which all four assumptions are met with respect to a specific candidate source tracking organism, thus resulting in a defined system(s) where microbiological source tracking may be applied to identify sources of environmental contamination. This model may vary for a given organism and may reflect different animal production systems and/or different ecosystems. **Product Users** Regulators and scientists.	**Long-term** Valid biological source tracking methodologies that can be used to measure environmental contamination within defined temporal and spatial parameters for the pathogen and source host in question.

Problem Area 2d. Bioaerosols
Problem Statement

Rationale. Bioaerosols are airborne particles, ranging in size from 0.5 to 100 μm in diameter that contain microorganisms (viruses, bacteria, protozoa, and fungi) or their byproducts (i.e., microbial toxins). Zoonotic pathogens (pathogens capable of causing disease in humans and animals) and microbial toxins may become aerosolized by manure management practices such as land application of animal biosolids, livestock wastewater spray irrigation, livestock wastewater injection, or animal pen scraping. Additional sources of bioaerosols include exhausted air from livestock confinement buildings, high winds that carry bioaerosols from open livestock wastewater systems, and dust that is blown from outdoor livestock pens. Animals or humans may come in contact with these contaminants by accidental ingestion or inhalation downwind of these practices or because these airborne contaminants reach water sources, food crops, or inanimate objects in contact with humans or animals. Although a few bioaerosol studies have been carried out downwind of land-application of municipal biosolids and partially treated municipal wastewater, very little information has been collected regarding manure-borne contaminant carriage in bioaerosols generated by livestock management practices.

Research needs. Since no standard protocols exist, methods suitable for the collection and detection of bioaerosol contaminants are needed. Establishment of methods to collect bioaerosols generated by livestock production practices will include (1) evaluation of bioaerosol collection equipment to efficiently recover bioaerosol contaminants from different livestock production practices; (2) evaluation of the manner in which to collect (location of bioaerosol collection equipment, air collection rate, etc.) bioaerosol contaminants to achieve a representative sample under different environmental conditions; and (3) definition of the physical and chemical parameters (weather conditions, wastewater and biosolids characteristics, etc.) that should be evaluated simultaneously to develop an understanding of fate and transport of manure-borne biological contaminants in air. Following methods assessment, baseline information needs to be collected to enhance our understanding of the (1) types and concentrations of biological contaminants in bioaerosols generated by various livestock production practices; (2) fate (survival or persistence) of biological contaminants in bioaerosols generated by different management practices and under various weather conditions; and (3) distance that contaminants travel from the bioaerosol source. These data can then be used to modify currently available, or establish new, bioaerosol transport models.

Pathogens Problem Area 2d. Bioaerosols

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Bushland, TX Lincoln, NE Ames IA Beltsville, MD Miss. State, MS	Bioaerosol sampling and detection protocols. Database of baseline information relating to bioaerosol contaminant fate and transport by various livestock management practices.	More informed policies and models, risk assessments, and better BMPs and treatment technologies.

Cooperators Univ. of Nebraska, Univ. of Arizona, Texas Tech Univ., other university scientists, EPA, livestock producers, consultants.	Development or modification of management practices to reduce bioaerosols. **Product Users** Producers, veterinarians, regulators, action agencies (e.g., NRCS), environmental scientists, risk assessors, health agencies.	

Identification of effective bioaerosol collection protocols and microbial contaminant detection methods will be important products of this work. This work also will provide baseline data concerning manure-borne contaminants in bioaerosols generated by different livestock production environments. This information will be used to identify current or develop new strategies for reducing bioaerosol generation by various livestock production practices and to develop bioaerosol transport models. Bioaerosol transport models will enhance our understanding of the fate of biological contaminants and the ability of these contaminants to reach water or food supplies under given environmental and livestock management conditions. Baseline information gained by the above research needs will provide critical information to those conducting risk assessments for evaluating human and animal health risks of bioaerosols generated by various livestock production practices. The development of tools and treatment strategies for bioaerosols will be advanced in collaboration with the NP 206 Atmospheric Emissions Component.

Problem Area 2e. Modeling Fate and Transport of Manure-borne Pathogens from "Pedon" to Watershed Scale

Problem Statement

Rationale. Models are needed for the development of decision support aids for producers, action agencies and regulators. There have been advances in adopting general contaminant transport models to simulate pathogen fate and transport in soils and landscapes. Nevertheless, existing models leave much to be desired, as many of the essential fate and transport processes are not understood or modeled well. This includes a wide initial distribution of pathogens in manure, release of manure-borne pathogens, interactions of pathogens and manure particulates, partitioning of pathogens between different media, and inactivation due to environmental factors and biotic effects. The fate and transport of pathogens need to be observed and managed at different scales, including soil horizon scale, pedon scale, hillslope scale, and watershed scale. At horizon and pedon scales, modeling serves as a research tool to test hypotheses about mechanisms and factors that influence pathogen fate and transport. At hillslope and watershed scales, modeling serves as a knowledge packaging and delivery tool to address issues of public interest. To that end, models of manure-borne pathogen survival and release in field conditions have not been developed. No reliable model has been proposed to explain wide variations in efficiency of vegetation filter strips and riparian zones in retention of manure-borne pathogens. Watershed-scale pathogen fate and transport modeling is hampered by the absence of

relationships between transport parameters and available data on soil, topography, and vegetation. Uncertainty in pathogen fate and transport model estimates has not been researched, although it is critical for pathogen exposure risk assessment, for risk-informed decision-making, and for evaluating management and treatment practices. Therefore, development, testing, parameter estimation, and evaluation of models will continue to have an important role in pathogen fate and transport research.

Research needs. There is a need for reliable models at different scales. Proper models and parameters have to be found to simulate behavior of pathogens such as attachment; survival; and regrowth in soil, water, and air. At the pedon scale, models are needed to evaluate the potential for pathogen transport through soil to groundwater. Models of pathogen transport and partitioning between runoff and infiltration need to be developed at the hillslope scale to assess the potential for pathogen contamination of surface water sources and the mitigation efficiency of various management practices. Watershed-scale modeling needs to more precisely identify and establish relationships between parameters of models and environmental factors affecting pathogen transport. Model flexibility needs to be achieved to incorporate specific fate and transport characteristics of the various pathogen genera. Research on this topic has three primary objectives at each of the three scales:

1. Identification of dominant processes and the development of appropriate models.
2. Development of appropriate data sets to refine and test the models.
3. Development of user-friendly tools for the efficient use of models in decision support and regulation development.

All ARS researchers conducting pathogen fate and transport studies will contribute their data and expertise to achieve objectives 1 and 2. Many ARS scientists also will be cooperating with scientists at other agencies and universities. Objective 3 requires close cooperation with users and a partnership with software developers.

Pathogens Problem Area 2e. Modeling Fate and Transport of Manure-borne Pathogens from "Pedon" to Watershed Scale

Input/Resources	Outputs/Products	Outcomes
Location Contribution: Beltsville, MD Riverside, CA West Lafayette, IN Essentially all pathogen researchers working on fate and transport will contribute data. **Cooperators** Univ. of CA, Riverside; Virginia Tech; federal and states' NRCS and EPA offices; as well as other state's Cooperative Extension and environmental organizations	**Short-term** A set of pathogen transport submodels to use at different scales with water and solute transport and erosion models for determination of pathogen fate and transport. **Long-term** Decision-support tools at pedon, hillslope, and watershed scales that will inform policies and assist in the development of better BMPs. **Product Users** Regulators concerned with	**Short-term** Integration of the available research and monitoring data in models and parameter databases for pedon, hillslope, and watershed scales. **Long-term** Use of improved BMPs and treatment technologies for pathogen control based on more robust and tested models.

Cooperators will assist both in doing the research and in assisting in outreach and technology transfer.	TMDL, BMPs, risk assessment, and other pathogen-related issues. Action agencies (e.g., NRCS) focused on implementation of pathogen-oriented BMPs and their cost-benefit evaluation. Scientists involved in contaminant transport studies, and planning and conducting experiments on pathogen fate and transport. Models will be developed in consultation with users.	

To maximize the usability of proposed models, potential model users will be involved at all stages of the model development process, including model design, model evaluation, and model integration.

Problem Area 3. Pharmaceutically Active Compounds (PACs)

Problem Statement

Rationale. Animal drugs and feed additives are routinely used in AFOs to improve health and production. Large volumes of hormones, antibiotics, and antibiotic resistant bacteria may be present in animal wastes (wastewater and manure). Naturally excreted hormones and many of these drugs can interfere with the endocrine systems of humans and wildlife. Drugs may mimic natural hormones or lead to the development of antibiotic-resistant bacteria. The potential health effects of endocrine disrupting chemicals on human and aquatic ecosystems are not clearly understood since these chemicals appear to occur in the environment and function at very low doses. The environmental fate and transport of pharmaceutically active chemicals is virtually unknown. Pathogenic bacterial populations, which have acquired antibiotic resistance genes, are a major human and animal health problem since conventional antibiotic treatment of some of these infections is no longer effective. Furthermore, the use of antibiotics can stimulate the generation of antibiotic-resistant bacteria that, in turn, can transfer antibiotic resistance to other bacteria. Knowledge of the processes that control the transport and persistence of pharmaceuticals and survival of antibiotic- resistant microorganisms in livestock manure and wastewater is therefore needed to accurately assess the risk and vulnerability of water resources to contamination. To date, limited studies have been conducted on the environmental persistence, sorption, and transport of pharmaceutical compounds and degradation byproducts, and potential interactions with manure suspensions have not yet been quantified. In addition, manure-borne antibiotics and antibiotic-resistant bacteria may influence indigenous bacterial populations in soil and water. Selective pressure and transmission of genetic information conferring antibiotic resistance may result in a reservoir of antibiotic-resistant bacteria in environments associated with animal agriculture.

Research needs. To accurately determine the exposure risks associated with hormones, antibiotics, degradation byproducts, and antibiotic-resistant bacteria derived from animal wastes, the following research needs to be conducted: (1) evaluation of current or development of new methods for the detection of manure and biosolid borne hormones, antibiotics, degradation byproducts and antibiotic resistant bacteria from environmental samples; (2) determination of the presence, persistence, and transport of these agents in manure, soil, water, and air; (3) determination of the presence, development, survival, and transport of antibiotic-resistant bacterial populations in manure, soil and water, and air; (4) development of tools (e.g., computer models) to predict the fate of hormones, antibiotics, and antibiotic-resistant bacterial populations under different management practices and environmental conditions. Concurrent research is needed to develop treatment strategies and BMPs for manure and wastewater to minimize the occurrence and environmental dissemination of PACs and antibiotic-resistant bacteria.

Pathogens Problem Area 3. PACs

Input/Resources	Outputs/Products	Outcomes
Location Contribution: Athens, GA Bushland., TX Lincoln, NE Miss. State. MS Riverside, CA **Cooperators** Univ. of NY-Buffalo, Univ. of Nebraska, Iowa State Univ., other university and government (e.g., CDC, EPA) scientists.	Detection methods Baseline information concerning the fate and dissemination of hormones, antibiotics, degradates, and antibiotic- resistant bacteria in manure and manure impacted environments. **Product Users** Regulators, action agencies (e.g., NRCS), environmental scientists, human health agencies, veterinarians, risk assessors, consultants.	Methods to control hormones, antibiotics, degradates, and antibiotic bacterial resistance in the environment based on improved information.

This work also will stimulate the development of treatment and management practices that reduce these contaminants in livestock productions systems. In the long-term, this work will result in protocols and guidelines for protection of the environment and human health. Data collected during these studies are needed for those conducting risk assessments (e.g., EPA, CDC) concerning the human and animal health risks related to antibiotics and endocrine disrupting chemicals associated with livestock manure management practices. The development of tools and treatment strategies for PACs and antibiotic-resistant bacteria will be advanced in collaboration with other NP 206 Components, such as Atmospheric Emissions.

Problem Area 4. Holistic Treatment Technologies for Nutrients, Pathogens and PACs

Problem Statement

Rationale. Traditional and alternative livestock manure, runoff, wastewater control, and treatment systems are primarily designed for the control of nutrients. However, other fecal-

derived contaminants such as pathogens, hormones, and PACs also can be present in these waste streams. The fate of these manure-borne contaminants in treatment systems is largely unknown. Gaining knowledge of the fate of pathogens and PACs during collection, storage and treatment will lead to the development of management practices that optimize manure-borne contaminant control.

Research needs. Reduction of manure-borne contaminants needs to be investigated in both currently used and newly developed treatment systems. This research begins with a determination of the influence of various diets and management systems on pathogen and PAC levels and transmissibility. The survival and persistence of pathogens contained in various types of animal waste products (manure, poultry litter, dairy and swine effluents, etc.) as they pass through collection, storage, treatment and application systems must be determined. This will require knowledge of how different ecosystem variables (geographical, climatic, etc.) affect survival and persistence of various pathogen/waste combinations.

Pathogens Problem Area 4. Holistic Treatment Technologies for Nutrients, Pathogens and PACs

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Ames, IA Beltsville, MD Bushland, TX Clay Center, NE Lincoln, NE Miss. State, MS Riverside, CA This research will be coordinated with the research in Problem Area 1 (Diet Manipulation) and Problem Area 2 (Innovative Technology for Collection, Storage, and Treatment) in the Nutrient Component and Problem Area 3 (Byproduct Utilization Technologies) of the Byproduct Component. **Cooperators:** Producers, industry, environmental engineers/consultants, NRCS, university scientists and extension agents.	A database detailing survival and persistence of pathogens in different treatment systems including the effects of how climate and other variables effects survival and persistence. Identification of critical pathogen and PAC control points of these treatment systems. Models and decision support tools that incorporate critical pathogen and PAC control points. Treatment system design modifications based on the database information. **Product Users** Producers, industry, environmental engineers/consultants, Land Grant Universities, NRCS, Cooperative Extension, USEPA.	Treatment systems that that are effective for pathogens and PACs as well as nutrients.

A publicly available relational database similar to that of ComBase, which estimates the behavior of different pathogenic bacteria in various food environmental conditions, will be established.

Predictive models that can be queried will be made available on the web to influence control point decisions made by producers and/or other agencies regarding management systems for manure by-products.

Byproducts Component

Introduction

Each year millions of tons of agricultural, industrial, and municipal byproducts are generated that have been considered to have little value, are classified as wastes, and often disposed in landfills. Alternative uses for these byproducts are needed to promote sustainable agriculture, as well as to reduce landfill requirements, greenhouse gas emissions, and disposal/remediation costs. This research component examines these byproducts to determine their potential value to agriculture and horticulture either individually or through blending, mixing, or treatment. Many of these byproducts have characteristics that make them prospectively useful for direct land application, soil reclamation and remediation, production of manufactured soils and composts, or feedstuffs for value-added products. Research and development is needed to determine the composition and potential bioactivity of these products. At this time, state regulatory agencies lack analytical tools to make reasonable policy decisions regarding the beneficial use of these byproducts. The USDA-ARS will develop protocols and methodology standards that regulatory authorities can adopt to examine and approve byproducts for agricultural use. Treatment technologies and management practices to make these products usable will reduce potential environmental hazards, reduce disposal cost, and increase cost-effectiveness of agriculture.

Problem Area 1: Phytoavailability and Bioavailability of Nutrients, Trace Elements and Xenobiotics in Byproducts Considered for Beneficial Use

Problem Statement

Rationale. Many agricultural, municipal, or industrial byproducts are being used beneficially in agriculture and horticulture. Other byproducts also may be found to be beneficial and safe. Questions about potential benefits and risks from trace elements or xenobiotics in byproducts and manure can limit approval at the state level for their use. These byproducts could improve soil, reduce costs, and provide environmental benefits. Public interest in recycling rather than landfilling byproducts is high. Thus information must be obtained to develop and demonstrate byproduct uses, and to provide regulatory and advisory agencies with information that will allow use of byproducts. Safe and effective use of byproducts often improves soil fertility and soil physical properties; it may affect availability of contaminants and nutrients, and reduce costs to growers and byproduct generators. Further, adding some byproducts to manure and composts may limit leaching of phosphate, reduce phyto- and bio-availability of trace elements, and aid in remediation of degraded soils. Stabilization techniques and mixing and/or drying may be necessary to make byproducts more uniform or more reactive to allow more effective use. Additionally, the bio-ethanol industry has grown rapidly in the U.S. Many byproducts of the bio-ethanol industry may be useful as livestock feed ingredients. However, these byproducts often contain high concentrations of nutrients such as P and S, which can potentially result in

high nutrient concentrations in generated manures with increased need for nutrient management of these byproducts.

Research needs. Research is needed to characterize the risk and benefits to soil fertility, soil biology, plant production, food safety and the environment when byproducts are used on land. Nutrients, trace elements, or xenobiotics, in manure or byproducts may be a concern to generators, users, and regulators until the fate and potential of these constituents to cause adverse effects can be clarified. Alternatively, byproducts can act as biocontrol agents or liming agents or overcome important physical constraints in manufactured soils and media. Overall objectives include (1) laboratory evaluation, field tests and demonstrations to obtain information for support of state permits for wider beneficial use of many byproducts; (2) characterization of nutrient, trace element or xenobiotic bioavailability to plants, to grazing animals that would ingest byproducts or amended soils, and to animals that would ingest the crops produced on amended soils; (3) in the case of feeding byproducts from the ethanol industry, better characterization of the feeding value, identification of effective ways to utilize these byproducts as livestock feeds without causing environmental concerns, identification of better methods to assess the bioavailability of nutrients to livestock, and identification of methods to improve the consistency and feeding-value of these byproducts.

Byproducts Problem Area 1: Phytoavailability and Bioavailability of Nutrients, Trace Elements, and Xenobiotics in Byproducts Considered for Beneficial Use

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Beltsville, MD Bushland, TX Florence, SC **Cooperators** State university researchers; USEPA; USDA-NRCS; US Composting Council; Foundry Industry Recycling Starts Today (FIRST); Great Lakes Byproduct Management Assn. (GLBMA); In-situ Inactivation and Natural Ecosystem Restoration Technology Action Team; Water Environmental Research Assn.; National Corn Growers; National Grain Sorghum Producers; Bio-ethanol industry; Zero-Waste Alliance	Analysis of nutrients, trace elements and xenobiotics in byproducts being considered for beneficial use. Characterization of potential transfers to plants and livestock, and bioavailability of nutrients, trace elements and xenobiotics in byproducts. Identification of management practices needed to allow beneficial use of byproducts while protecting the environment. Assessment of byproducts as feed ingredients. **Product Users** USEPA (Office of Water, Office of Solid Waste Recycling & Composting), NRCS, Cooperative Extension at state universities, FIRST, GLBMA, US Composting Council/Industry,	Data sheets of nutrients, trace elements, etc., in byproducts will be made available to researchers and regulators to aid in decisions regarding byproduct utilization. Research findings will provide evidence needed for regulatory agencies to achieve balanced assessment of benefits and risks of byproducts if used in agriculture or horticulture.

Inputs/Resources	Outputs/Products	Outcomes
	US Corn Growers Assn., National Poultry Assn., many byproduct generators, State Departments of Environment recycling units (industrial byproducts, compost, biosolids, manure, etc.), small- and large-scale livestock producers.	

Problem Area 2. Protocols and Methodology Standards for Examination and Approval of Byproducts for Beneficial Uses in Agriculture and Horticulture

Problem Statement

Rationale. Each year in the U.S., millions of tons of agricultural, industrial and municipal byproducts are generated. Alternative uses for these byproducts are needed to promote sustainable agriculture as well as to reduce landfill space requirements, greenhouse gas emissions, and disposal/remediation costs. Many of these byproducts have characteristics that make them prospectively useful as soil amendments whether for direct land application, soil reclamation and remediation, or as components of manufactured soils and composts. At this time, state regulatory agencies lack analytical tools to make reasonable policy decisions regarding the beneficial use of these byproducts in agriculture or horticulture. The ARS will conduct valuable research to provide critical information about byproducts to state regulatory agencies. More specifically, ARS will develop protocols and methodology standards that regulatory authorities can adopt to examine and approve byproducts for agricultural use.

Research needs. Many regulators are reluctant to approve byproducts for land application, soil manufacturing and other agricultural and horticultural uses because of a lack of knowledge of interactions with soil, nutrient bioavailability, groundwater impacts, and impacts on other soil-related functions and processes. The development of a process to examine and approve byproducts based on sound science will simultaneously ensure environmental protection, improve soil quality and function, and derive economic benefits to both byproduct generators and the agricultural community. Accurate and cost-effective methods of byproduct evaluation must be established. The specific research goals are to (1) identify agricultural, municipal, and industrial byproducts amenable to beneficial use in agriculture and horticulture; (2) develop a generic framework by which byproducts of different origin and constituents can be evaluated; (3) identify analytical methods that can accurately identify and quantify byproduct constituents using proper QA/QC; (4) develop a Decision Tree to help stakeholders determine which evaluation methodologies are appropriate for matching byproducts with intended uses--then develop a "branching" evaluation protocol that proposes analyses that could ultimately be carried out in independent laboratories and universities; (5) characterize a number of different byproducts using the generic framework to demonstrate to stakeholders that the proposed framework yields comparable and reproducible data; and (6) develop model sampling protocols for byproducts, taking into account differences in uniformity of generation.

Byproducts Problem Area 2. Protocols and Methodology Standards for Examination and Approval of Byproducts for Beneficial Uses in Agriculture and Horticulture

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Beltsville, MD Florence, SC **Cooperators** Foundry Industry Recycling Starts Today (FIRST), USEPA, state regulatory agencies, universities, farming community, ASTM, National Council on Air and Stream Improvement, GLBMA, American Coal Ash Assn.	Generic test models or analyses. Decision trees for state, city, or local agencies. Guidelines on beneficial uses. **Product Users** State regulators and local permitting agencies.	**Short-term** Sampling, analysis, and assessment protocols for byproducts. **Long-term** A model process by which different types of byproducts can be evaluated for use in agriculture and horticulture. Development of generic evaluation methods for potential land applications.

Problem Area 3. Byproduct Utilization Technologies

Problem Statement

Rationale. Agricultural, municipal, and industrial processes result in a wide array of byproducts. Many of these byproducts, if properly processed and used, may have specific benefits to water quality, soil quality, plant health, plant productivity, and to reduce undesirable air emissions. In order to achieve these benefits, the byproducts need to be utilized in an environmentally sound manner that reduces the cost of disposal or converts them into marketable assets. Although the agricultural potential of a number of byproducts has already been assessed, there are many materials and applications for which little scientific information exists or potential benefits have yet to be identified.

Research needs. Technologically sound methods are needed for utilizing byproducts that will be characterized as beneficial. This includes blending, composting, and amending byproducts as well as developing land application and management techniques that will improve soil quality, water quality, and plant growth. Specific sub-areas of research include development of application technologies, measurement of fate and transport of byproduct components, measurement of treatment efficacy and controlling processes, identification of beneficial properties, and cost-benefit evaluations. The overall objective is to utilize agricultural, municipal, and industrial byproducts in a cost-effective and environmentally sound manner.

Byproducts Problem Area 3. Byproduct Utilization Technologies

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Auburn, AL Beltsville, MD Brooksville, FL Florence, SC Madison, WI Miss. State, MS Oxford, MS Tifton, GA West Lafayette, IN **Cooperators** National Council for Air and Stream Improvement Inc. (NCASI), Livestock Integrators Commodity Assn., agribusiness, university scientists, state soil and water conservation commissions, conservation tillage alliances, state and local regulators.	New and improved systems to capture, concentrate, and reuse nutrients from manures and other organic byproducts. Guidelines for using byproducts to stabilize or sequester nutrients in manures and soils. Treatment methods for byproducts that yield biomass that can be used as a horticultural amendment. Procedures to use manure, compost, and byproducts to remediate and improve soils and to formulate manufactured soils. Knowledge of the effects of manure and byproducts on the ecology of fungi in soil and their use as biocontrol materials that promote plant health and product quality. **Product Users** Regulators (U.S. and state EPAs), action agencies (Army Corps of Engineers, NRCS, SWCD), byproduct generators, and producers (farmers and land managers)	**Long-term** Procedures will be used to evaluate, process, and apply byproducts for use as biocontrol agents. **Short-term** Byproducts will be used for soil remediation of contaminated areas. Byproducts will be used for soil improvement of degraded soils. Byproducts will be used as components of manufactured soils.

Problem Area 4. Energy from Byproducts

Problem Statement

Rationale. New technologies are needed or need to be optimized to convert abundant, renewable agricultural residues and byproducts into energy. Manure, crop residues, food processing wastes, and other agricultural byproducts have the potential to be converted to various forms of energy if cost-effective conversion strategies can be developed. Potential conversion technologies include anaerobic digestion to produce methane, gasification, direct burning, and fermentation to fuel alcohol. The production of the liquid fuel ethanol is particularly attractive as it can be transported offsite for sale and use. Many agricultural byproducts have carbohydrate contents that make them promising sources of fermentable sugars for ethanol fermentation.

However, in most cases, serious technical constraints to their exploitation exist and specific conversion strategies need to be developed for individual feedstocks.

Research needs. The overall research objectives are (1) to identify agricultural byproducts suitable for conversion to energy; and (2) to develop specific, cost-effective environmentally acceptable technologies to make the energy conversion and to use residues formed during energy production. A number of research activities need to be performed to accomplish these goals. The composition of byproduct feedstocks needs to be determined so that there suitability for conversion to energy via biological (e.g., fermentation, anaerobic digestion) and/or physical-chemical methods (e.g., gasification, direct burning) can be assessed, and the nature of residues formed during processing are identified. Specific conversion technologies need to be developed that are customized to individual feedstocks; additional co-products will need to be identified and developed; and economic evaluations of the overall processes conducted to determine the potential for commercial development.

Byproducts Problem Area 4. Energy from Byproducts

Inputs/Resources	Outputs/Products	Outcomes
Location Contribution: Albany, CA Bushland, TX Peoria, IL Wyndmoor, PA **Cooperators** Commodity organizations (e.g., National Corn Growers; National Grain Sorghum Producers Assn.) grain processing companies (e.g., Corn Refiners Assn. and its members); fuel ethanol producers and support industries (e.g., Genencor; Aventine, Abengoa); National Corn-to-Ethanol Research Center; university partners.	Specific cost-effective conversion strategies for by-products depending on source, location, and composition. Identification of additional by-products, which may have applications as animal feeds and/or soil amendments. **Product Users** Operators of animal feeding operations; industries producing biomass byproducts including grain processors, paper pulp processors, cotton gins, nut processors, and others; growers of residue-generating crops.	New renewable sources of energy that enhance the value of agricultural residues and byproducts, improve quality of the environment, and reduce dependence on foreign energy sources.

The research is largely being conducted under National Program 307, Bioenergy and Energy Alternatives. The research program focuses on developing alternate energy sources and increasing the use of agricultural crops as feedstocks for biofuels. ARS researchers in NP-307 would be expected to contribute technologies for the conversion of byproducts to energy as an element of their existing research projects.