The Economic and Environmental Indicators for Evaluating the National Pilot Project on Livestock and the Environment

Livestock Series Report 1

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Tim Jones, and Ron Jones

Staff Report 93-SR 64
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CARD
Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011

and

TIAER
Texas Institute for Applied Environmental Research
Tarleton State University
Stephenville, Texas 76402

Aziz Bouzaher is associate professor of economics and head of the Resource and Environmental Policy Division, CARD; P.G. Lakshminarayan is a CARD research associate; S.R. Johnson is C.F. Curtiss Distinguished Professor of Agriculture and director of CARD; Tim Jones is a TIAER research associate; and Ron Jones is director of TIAER.

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CONTENTS

FIGURES

TABLES

FOREWORD

This is the first in a series of CARD research papers prepared as part of Livestock and the Environment: A National Pilot Project, a cooperative agreement with the U.S. Environmental Protection Agency. The research is being conducted jointly with the Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville, Texas, and in cooperation with Blackland Research Laboratory, Temple, Texas.

The project was started in September 1992. Its objective is to determine technologies, management methods, policies, and institutional settings that can reduce the negative impacts of livestock production for the environment and at the same time result in a national livestock industry that is economically viable and competitive in increasingly open international markets. Subsequent papers in this series will address the various facets of the project, including economic and environmental modeling, policy evaluations, and institution building.

Research on dairy pollution in Erath County, Texas, serves as the baseline study. These baseline results, along with satellite studies conducted to set parameters for cutting-edge waste management and production technologies nationwide and around the world, will be used to construct cross-species, interregional, and national analytical systems.

This first paper discusses the economic and environmental indicators to be used for assessing the relative effectiveness of various policy options. This series will report on state-of-the-art development of analytical, policy, and institutional systems designed to identify a sustainable livestock production system. The project will address other livestock industry strategies in subsequent years, including the implications of alternative environmental policy scenarios on the economic viability and competitiveness of the livestock sector, on indicators of environmental quality, and on the sustainability of U.S. livestock production systems.

For additional information about the Livestock and the Environment project or about obtaining copies of future reports, please contact my office.

Aziz Bouzaher

Head,
Resource and Environmental
Policy Division, CARD
Iowa State University
568D Heady Hall
Ames, IA 50011

ABSTRACT

The livestock and dairy industries are consolidating and concentrating within confined geographical areas. Accompanying these structural adjustments that are under way in the dairy and livestock industries is the potential for increased point and nonpoint source pollution problems from animal waste disposal. An assessment of optimal policies and best management practices to control pollution from CAFOs requires an integrated evaluation of economic and environmental consequences from alternative policies and practices. To perform this integrated assessment, a set of important economic and environmental indicators that these policies will affect have to be identified. This paper reviews indicators used in other site-specific studies and recommends a feasible set of economic and environmental indicators for the national pilot project.

THE ECONOMIC AND ENVIRONMENTAL INDICATORS FOR EVALUATING THE NATIONAL PILOT PROJECT ON LIVESTOCK AND THE ENVIRONMENT

Issues concerning water quality and ecological balance have made agricultural nonpoint source (NPS) pollution a major environmental issue in the United States. Two primary agricultural enterprises, crops and livestock, are the principal sources of agricultural NPS pollution. It is estimated that 64 percent and 57 percent of NPS pollution of the nation's rivers and lakes is from agriculture, of which livestock waste may account for 20 percent (USDA 1991). Nitrogen (N), phosphorous (P), pathogens, biochemical oxygen demand (BOD), and salts are the principal contaminants from livestock waste that are carried into bodies of water, including groundwater. A dairy cow weighing 1,000 pounds will produce 30,000 pounds of manure containing 150 pounds of N and 61 pounds of P, per year (MWPS 1985).

Odor problems and the greenhouse effect from cow gas containing methane (CH_4) and carbon dioxide (CO_2) are also significant. Annual loss of CO_2 by a dairy cow roughly equals that of an average Dutch passenger car (Taminga 1992). There are many health and environmental concerns related to these contaminants. For instance, infants exposed to water containing nitrate nitrogen (NO_3-N) exceeding the drinking water standards (10 milligrams per liter [mg/L]) are at risk for methemoglobinemia; increased phosphorous loading can cause eutrophication in lakes and streams; increased BOD presents risks to aquatic life; and elevated counts of pathogenic bacteria pose a risk of infection to both livestock and human health. Long (1992) describes the geographic extent and the potential impact of livestock waste problem.

Approximately 50 percent of the annual gross receipts from the U.S. agricultural sector are from livestock enterprises. In recent years there has been trend in dairy and livestock enterprises towards large-scale, concentrated animal feedlot operations (CAFOs). For example, specialized drylot dairies doubled between 1974 and 1987 (U.S. DOC 1989). Between the 1954 and 1987 agricultural censuses, commercial dairies with more than 100 cows increased from 0.2 percent to 10 percent of the total while in the same period dairies with fewer than 50 cows decreased from 99 percent to 66 percent of the total. The consolidation is driven by a number of important economic and institutional factors, especially economies of scale in livestock production and the processing industries. The list of factors also includes the scale advantages of new technologies, vertical integration, location of processing facilities and final demand, state and federal policies on corporate farming and livestock operations, and environmental regulation at the local and federal levels (Matulich 1978; Novakovic, Bills, and Jack 1991; Knutson 1992).

Vertical integration and marketing contracts are more concentrated in the livestock industry, particularly in the dairy industry (Cramer and Jensen 1982). Nearly 66 percent of the U.S. milk supply is regulated by the federal milk marketing order system. Vertical integration is the linking of successive stages in the production, processing, and marketing of a commodity within a single decision entity. Novakovic, Bills, and Jack (1991), who examined the structural adjustments in the dairy industry, conclude that milk production in the 1990s will be concentrated in fewer production regions with fewer but larger dairy farms. Strong vertical integration and major technological breakthroughs in milk processing and storage are the catalysts for structural changes in the dairy sector. The increasing volatility of fluid milk prices since the late 1980s, coupled with a minimalist support policy, has also been the driving force behind consolidation of dairy firms and their concentration within geographic locations having the greatest comparative advantage.

The increased concentration of the various livestock sectors has resulted in increased animal density per unit of land, posing a threat to ground and surface water resources and leading to difficult animal waste handling issues. The CAFOs are major sources of point and NPS pollution because of the large quantity of livestock waste generated by these enterprises. On a Pennsylvania dairy farm, 15 times more nitrogen was added from wastes than from nitrogen fertilizer (Bacon, Lanyon, and Schlauder 1990). In the absence of best management practices (BMPs) for dairy waste handling, there is considerable potential for an alarming increase in point and NPS pollution.

The U.S. Rural Clean Water Program (RCWP) symposium documents the NPS pollution threat from livestock runoff (EPA 1992a). Because of the RCWP research reports and the emerging trends in the livestock industry, a national pilot project (NPP) to address the issue of livestock waste and nonpoint pollution has been initiated in Erath County, Texas. A major task of this project is to develop an extensive baseline of information about the economic and environmental consequences of dairy production and waste management practices confined to a single watershed, the Upper North Bosque watershed in Erath County, and the surrounding Cross Timbers region. Given this baseline, the project will assess the impact of economic and environmental policies in terms of relative changes from the baseline.

During the past 10 years, the dairy industry in the Cross Timbers region has grown dramatically. Erath County, with approximately 69,000 cows, is one of the top 20 milk producing counties in the country (TIAER 1992). It has a clearly distinguishable dichotomous dairy producer structure (traditional and specialized drylot dairy). Between 1954 and 1987, the number of milk cows increased 5 times and the average dairy herd size increased from 7 to 189 cows per farm (see

Figure 1). Masud and Lacewell (1992) provide a detailed, descriptive analysis of economic and resource conditions of the Cross Timbers region, including Erath County.

Accompanying this growth is a heightened environmental concern because of the enormous amount of dairy wastes generated in the region. The area has been designated by USDA as a Hydrologic Unit Area, eligible for special dairy waste management and NPS projects. The ground and surface water resources in this area have been targeted by the Texas Water Commission (TWC) as the number one NPS problem in Texas (TIAER 1992). The environmental regulations prescribed by the TWC include zero discharge from CAFOs; permit requirements for dairies with more than 250 milking cows; requirement of 25-year, 24-hour capacity lagoons to hold dairy wastes; and cropland manure spreading regulations. Air quality permits are also required for Texas dairy farms with 1000 cows or more and heifer farms. Leatham et al. (1992) estimate that a representative 300-cow dairy unit in Erath County will incur an additional cost of $61 per cow when waste management facilities are expanded to comply with water quality regulations.

The economic and environmental implications of such regulations, however, have to be jointly evaluated. Therefore, the conceptual framework for this project uses an integrated, economic and environmental modeling approach, which is essentially a Comprehensive Economic Environmental Policy Evaluation System framework (CEEPES) (Johnson et al. 1990), tailored to the livestock waste management problem. This paper addresses one of the issues involved in the development of the NPP: the specification of economic and environmental indicators for assessing the impact of alternative policies and technologies on the dairy industry, the environment, and the local and regional economy.

The Clean Water Act and the National Pilot Project

In an effort to curb pollution of the U.S. water supply, legislation has been enacted and modified during the past 20 years. The 1972 Federal Water Pollution Control Act (PL 92-500) was established to restore and maintain the physical, chemical, and biological integrity of the surface water of the United States. Strengthened over the years to expand the scope of environmental protection, PL 92-500 was amended in 1987 by the Water Quality Act, emphasizing ambient standards and assessments as strategies to further abate pollution. Section 319 of the act mandates identification of waters that cannot protect balanced aquatic communities without NPS pollution controls (Hughes and Paulsen 1990). Prior to 1987, the focus was on point source contributions. Following the amendment under section 319 of the Clean Water Act (1987) the nonpoint sources, particularly agricultural contributions, received attention. Specifically, Section 319 calls for reports

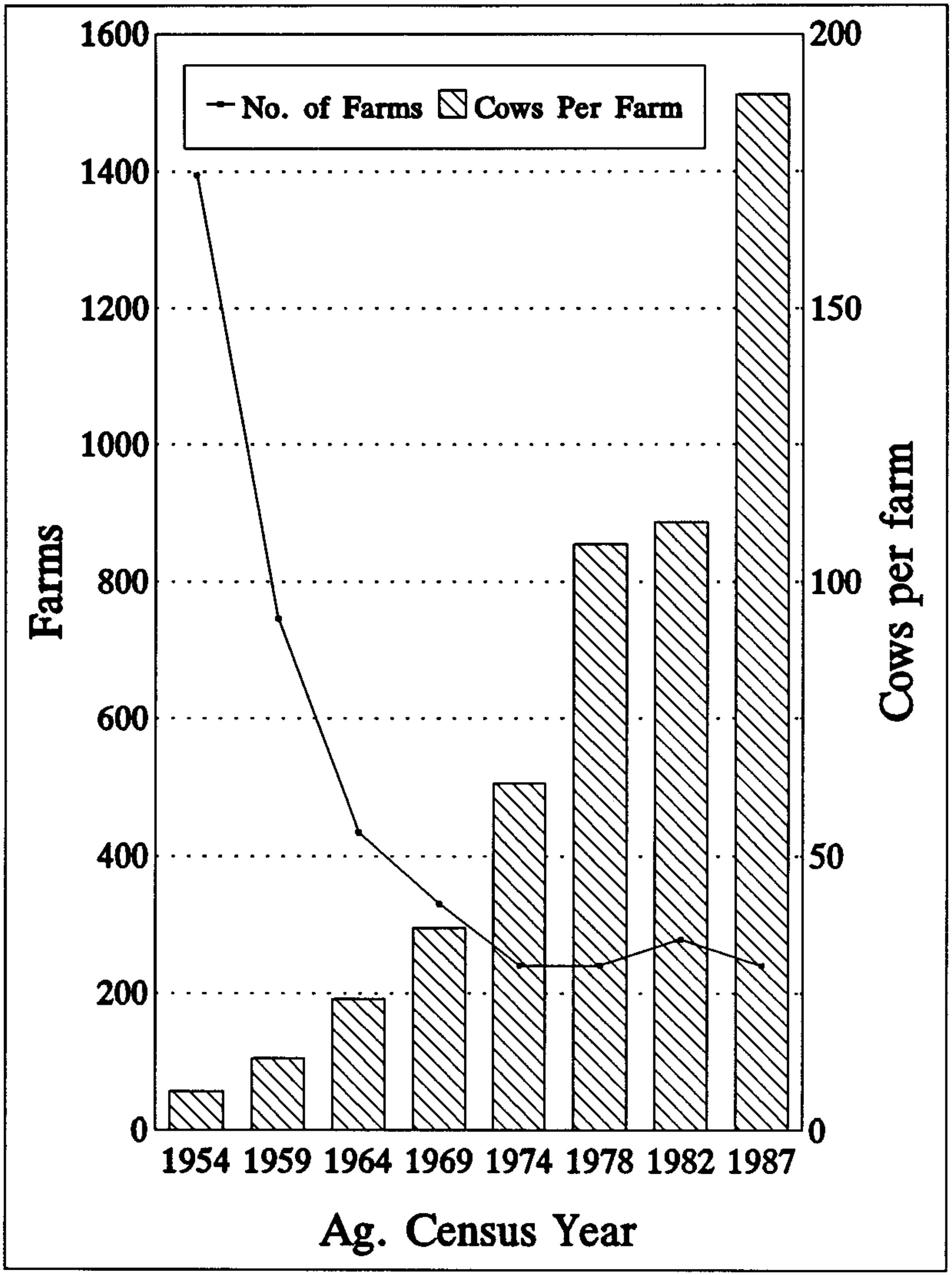

Figure 1. Number and average size of dairy farms in Erath County, Texas

of states' progress in addressing NPS pollution and for recommendations concerning future programs. However, to make such recommendations the EPA requires an overall assessment, including an evaluation of the need for any changes in the current program. It is in this context that the EPA has initiated several pilot projects and programs to evaluate the pervasive NPS problem.

The EPA in its report to Congress (EPA 1992b) assesses in detail sources and pollutants of NPS pollution by water body type (rivers, lakes, wetlands, estuaries, and coastal waters) and compiles a national summary of existing NPS regulations by source. A summary of the EPA's NPS assessments of sources and pollutants impacting rivers, lakes, and estuaries is shown graphically in Figures 2 and 3. Also described in this report are the regional and state programs corresponding to the 10 EPA regions. Texas (in Region VI) is a leading recipient of NPS (319) grant awards, totaling $1.63 million, second only to California (in Region IX). As already noted, the Erath County animal waste management program is the state's top priority. A subprogram of the Clean Water Act, called the National Pollution Discharge Elimination System (NPDES) program (EPA 1992b), specifically covers the management of manure and wastewater runoff accumulated in livestock operations.

The national pilot project envisioned here is broad, addressing the U.S. livestock industry, pollution abatement, and other environmental impacts. The objective is to identify alternative technologies for livestock production and waste handling, management methods, policies and programs, and institutional settings that can reduce the environmental pollution from livestock production, and at the same time protect the economic viability and competitiveness of the domestic livestock industry in an increasingly free global market. The broader goal is to assist the U.S. EPA in its five-point NPS agenda: (1) to raise public awareness of NPS pollution, (2) to provide state and local governments with practical and feasible solutions to NPS problems, (3) to examine the economic forces that contribute to ecological impairment, (4) to assist state and local governments in improving their regulatory capabilities, and (5) to promote research to develop tools and techniques for informed decision making (EPA 1992b). In a nutshell, this five-point agenda requires that EPA provide strong leadership for the U.S. NPS program and help state and local governments overcome barriers to successful implementation of NPS controls.

This project, initially focusing on dairy manure management in Erath County, will later be extended through satellite studies to other livestock species and areas with different resource base settings. This approach provides detailed technical information that can be used to address regional and national issues related to livestock and the environment. The project not only focuses on policy description but also on actual policy implementation and institutional changes required to cope with structural changes in the industry. This project has an interdisciplinary focus integrating agricultural, environmental, geophysical, and sociopolitical sciences. The experience and information gained from

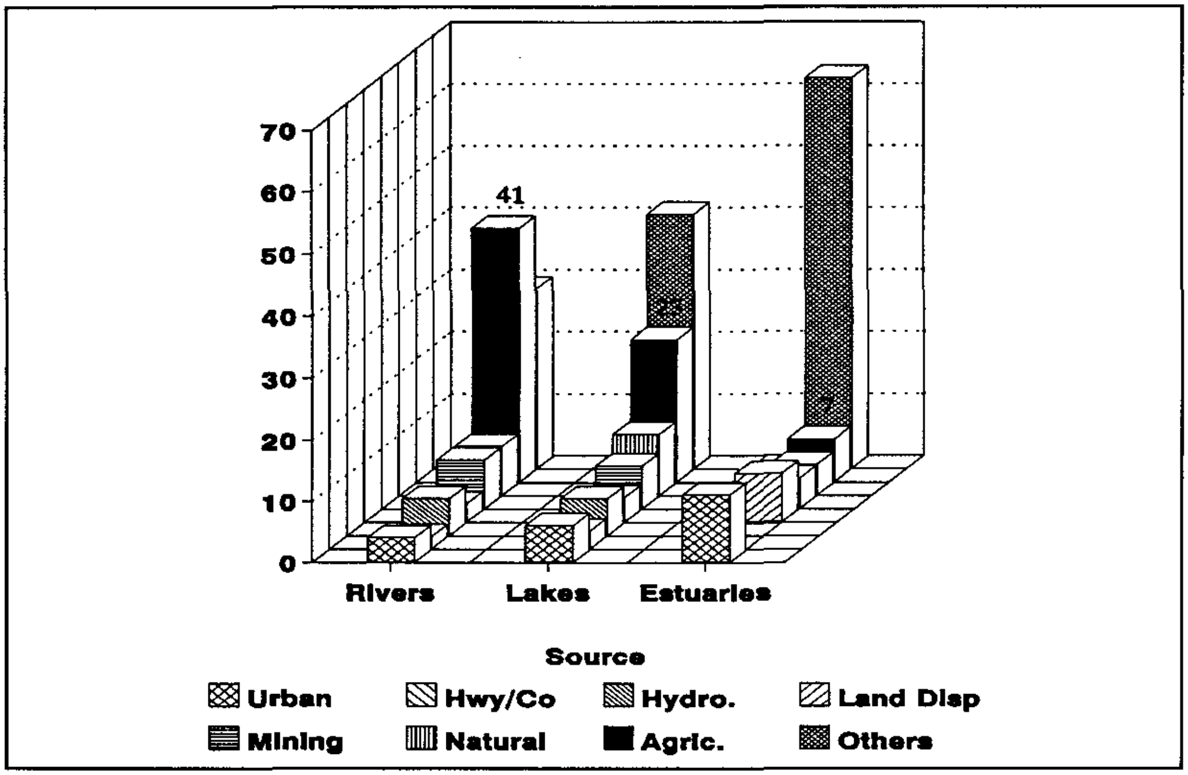

Figure 2. Sources of nonpoint pollution of surface water

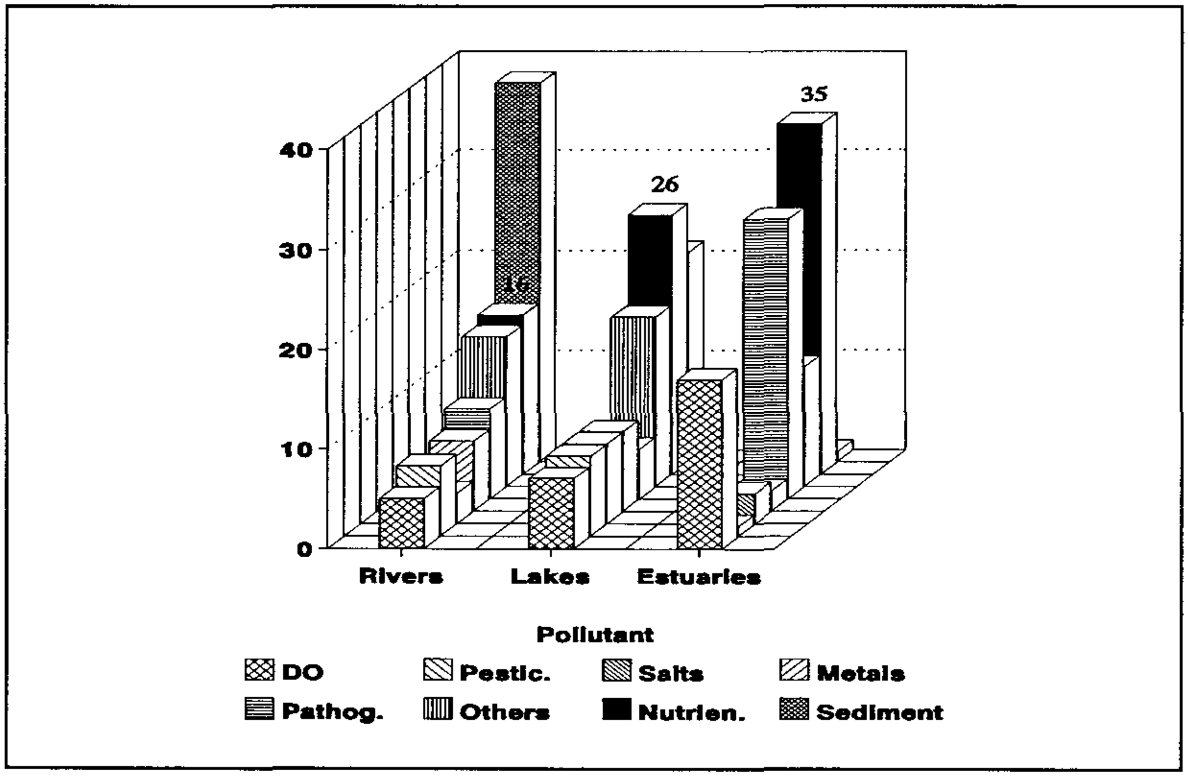

Figure 3. Types of pollutants entering surface water

this multidisciplinary project will be of great value for future projects requiring integration of disciplines and approaches.

Integrated Modeling Framework

There is growing awareness of far-reaching environmental impacts from agricultural and livestock production activities. The greater degree of interdependence between the economic and environmental systems calls for integrated modeling. Because environmental policy analysis includes conflicting goals, competing social interests, and power structures, it requires a multidimensional approach (Nijkamp 1980). Clearly, an integrated modeling framework is necessary for such a broad view of environmental policy analysis. Pioneering work in the regional and sectoral integrated modeling can be credited to Nijkamp et al. (1986). Brower (1987) provides a state-of-the-art survey of integrated environmental models (IEMs). Lately, there have been a spurt of integrated models for economic and environmental policy assessment both at the farm level (Cole and English 1990; Taylor 1990; Wossnik et al. 1992) and at the watershed level (Milon 1987; Bouzaher et al. 1990; Lakshminarayan et al. 1991). At the regional level, studies by Bouzaher and Shogren (1992) and Setia and Piper (1992) represent the most comprehensive current modeling systems.

NPS pollution problems are typically multidimensional because the pertinent phenomena emerge from different disciplines such as economics, ecology, physical and natural sciences, and sociopolitical sciences. Therefore, a comprehensive treatment of this problem requires an integrated modeling framework that embraces all the disciplines. The comprehensive approach also is key to understanding not only the interactions between the agricultural and environmental factors in determining the nature and intensity of pollution, but also the policy implications for economic efficiency and environmental quality. The policy implications are in turn vital when designing regulations and institutions for environmental protection.

In order to analyze dairy production, waste management, environmental quality, and local economy interactions simultaneously, an integrated system is needed. The integrated system for the NPP consists of an economic module, an ecological module, and a sociopolitical module. The conceptual framework represented as Figure 4 draws mainly from the CEEPES modeling structure. CEEPES is structured to evaluate agricultural chemical policies based on chemical concentrations in ground and surface waters and their economic impacts from a regional linear programming model. This conceptual framework demonstrates the economic relevance of dairy enterprises and local infrastructure built to support the dairy industry, as well as the ecological consequences of CAFOs and waste handling. It also depicts simultaneous interactions with the sociopolitical system and the

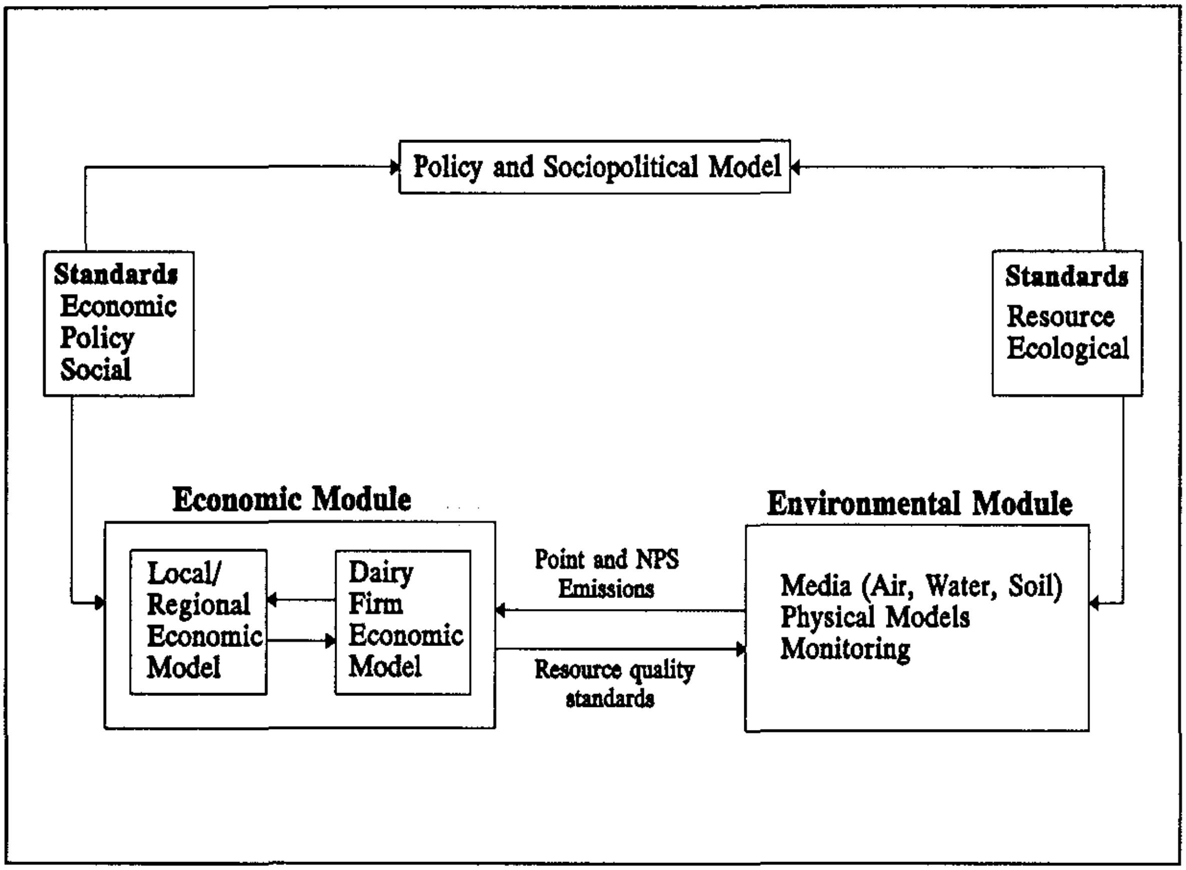

Figure 4. Conceptual framework describing economic, environmental, and policy linkages for evaluating NPS emissions from the livestock systems

implications of alternative social standards and policy regulations on the economic and ecological systems.

The Economic Module

The economic module has two major subsystems, one representing the dairy economy and the other representing the local economy, with a link to the regional and national economies. These two systems are highly interdependent in Erath County because of the importance of the dairy industry to the local economy. A representative of the American Farm Bureau Federation summarized the impact of small dairy farms leaving the local economy by saying that:

> A regulation-induced reduction in farm numbers will surely translate into reduced opportunity off the farm in rural areas and communities. Larger farm units are not as likely to do business locally. These units will be large enough to buy directly from input suppliers, bypassing the services of local farm input suppliers.

The local economic system is modeled by an input-output model (Leontief 1951). Input-output models summarize economic transactions that take place within a local economy and evaluate how impacts originating in one sector (such as the dairy sector) are transmitted throughout the economy. The economic impacts will be contrasted with the environmental impacts on the area resources.

The dairy economic module consists of an analytical decision system defined at the dairy farm level (microlevel) with three representative models for large, medium, and small dairies. Modeling the dairy economic system by herd size is important because of the scale economies in both milk production and waste handling systems (Matulich 1978; Heimlich 1982). The objective is to simulate the dairy economic decision making process and the behavior of dairy farmers and evaluate the economic and ecological impacts under various policy alternatives.

The success of any NPS pollution project depends largely on the ability to correlate and measure pollutant loading under alternative dairy production and waste management practices and crop production systems. The dairy economic system has three major components: (1) milk production and feed response, (2) dairy waste management including manure handling and marketing and nutrient balance, and (3) crop and forage production.

The Environmental Module

This module describes the impact of dairy runoff and nutrient emissions in various media. It is linked with the dairy economic system through emission loading data and feedback of emission standards. It is also linked to the policy and sociopolitical modules and provides them with information on environmental (multimedia) quality. The ecological system will be made operational by a set of mathematical models simulating the environmental fate and transport processes, metamodels, and monitoring network. The use of metamodeling to provide an interface between the economic and environmental systems is an innovative concept (Bouzaher et al. 1992; Bouzaher et al. 1993). Even the most detailed animal waste modeling effort to date, in the Vechta district of Lower Saxony in northern Germany (Witte and Kramer 1989), had to limit its focus on its ecological system to a single driving force: the excessive amount of manure to be disposed. Manure per se is not the problem; it is the nutrients and the bacteria reaching the ground and surface waters that are of concern. The framework suggested here — which integrates multimedia physical process models, including atmospheric models, and sampling data collected from a spatially designed network of monitoring stations — is useful in targeting hot-spots and identifying economically feasible and environmentally sound BMPs.

The Policy and Sociopolitical Module

The sociopolitical module describes the behavior of people living in the region, their health, and their concern about deteriorating environmental quality, as well as the dairy group interests and concerns. The policy module primarily focuses on public and producer concerns derived as input from the social module in prescribing the necessary environmental standards and regulations that balance the interests of conflicting groups.

The implementation of this integrated modeling system depends on the availability of data, including economic, technological, social, hydrogeological, and physical data; operational tools and methods; and the effective coordination of agencies. Coordination is the cornerstone of this project. Therefore "there is a need that all subprojects use the same systems concept" so that relevant methods and tools are available to achieve efficient interface of various modules (MAB 1983). That is, the choice of tools and methods in each discipline must be consistent with the ultimate objective of integrating the modules to evaluate the environmental impacts of dairy economic decisions.

Decision Making Techniques

Cross-disciplinary integrated modeling has been a widely accepted conceptual framework for comprehensive economic and environmental analysis (Capalbo and Antle 1989). We develop a simple economic formulation for the environmental planning problem. Let $g(Q)$ denote the net social returns to producing output (milk) Q. A stylized form is assumed for $g(Q)$ with $g_Q > 0$ and $g_{QQ} < 0$. That is, the net returns are decreasing at large output levels. The net social benefits are calculated after accounting for all production costs, including the cost of pollution abatement (environmental compliance costs) such as investments in dairy waste storage and handling systems. Associated with output production is a vector of pollutants, $\underset{\sim}{z}$, that may be damaging to welfare, either directly (nutrient contamination of drinking water) or indirectly (fish kills due to elevated BOD). Such a social damage function is denoted as $d(\underset{\sim}{z})$, where d is assumed to be a positive function. Let $c(\underset{\sim}{z})$ be the function denoting the clean-up expenditure with $c_z > 0$ and $c_{zz} < 0$. The environmental planners' welfare criterion is to maximize the net social benefits, net of pollution damage and clean-up costs (Dasgupta 1982). The formulation is:

$$\begin{aligned} &\underset{Q}{Max}[g(Q)-d(\underset{\sim}{Z}) - c(\underset{\sim}{Z})] \\ &s.t.\ \underset{\sim}{Z} = h(Q,\underset{\sim}{\omega})\ and\ Q \geq 0, \end{aligned} \qquad (1)$$

where h represents the physical process explaining the amount (concentration) of pollutant Z_i and $\underset{\sim}{\omega}$ is a vector of soil properties, hydrogeological conditions, weather, chemical characteristics, management practices, and policy parameters. These are represented by a set of statistically validated metamodels (response functions). Metamodels are reduced-form expressions for the detailed physical process models. They are nothing but statistical regression functions fitted to a subset of physical process model outputs (Bouzaher et al. 1992). The key environmental indicators identified in this paper will determine the elements of this subset. This simple formulation captures the essential features of the dairy waste pollution problem. This formulation, however, can be readily extended into spatial and temporal dimensions and the related social discounting framework. A *dose-response* type of damage function is conceptualized. Examples of dose-response relationships include the health effects of pollution and the effects of pollution on aquatic species (OECD 1989). It is hard to measure such damage functions, so the problem in (1) is generally posed differently. That is, the planner maximizes net benefits, net of clean-up expenditure only, subject to the constraint that pollutant concentrations $\underset{\sim}{z}$ are within the environmental safety thresholds $\underset{\sim}{z}^{T}$ (for example, maximum contaminant level [MCL] of nitrate N in drinking water).

$$\begin{aligned}
&\underset{Q}{Max}[g(Q) - c(\underset{\sim}{Z})] \\
&s.t.\ \underset{\sim}{Z} = h(Q,\ \underset{\sim}{w}), \qquad (2)\\
&\underset{\sim}{Z} \le \underset{\sim}{Z}^{T} \quad (\le \textit{ applies to all elements in the vector}),\\
&Q \ge 0.
\end{aligned}$$

The analytical decision making techniques for the environmental policy problem posed in (1) and/or (2) include cost-benefit analysis, cost-effectiveness analysis, risk-benefit analysis, multiple criteria analysis, decision analysis, and environmental impact assessment (OECD 1989). The cost-effectiveness and risk-benefit analyses are only variants of the cost-benefit analysis.

Environmental Impact Assessment

The analytical framework for decision making suggested here is the environmental impact assessment (EIA). The EIA is the preferred approach because of convergence and other numerical problems associated with identifying *the* optimal solution for integrated systems with inherent trade-offs and a high degree of sensitivity to spatial and temporal dimensions (Hafkamp and Nijkamp 1982). In precise terms, EIA involves establishing a baseline profile of the planning area; making projections with and without the environmental policy; identifying, describing, and evaluating all significant effects; getting feedback at every stage for making midterm project modifications; and making recommendations (Randall 1982). The assessment process is comprehensive, avoids value judgment, and emphasizes the environmental consequences of a policy with decisions being made on the basis of elements in the impact vector. Finally, this approach can be easily extended into a multicriteria analysis, where objectives other than economic efficiency are explicitly considered, which is the most appropriate framework for water quality problems (Cohon 1978).

Cost-Benefit Analysis

Cost-benefit analysis (CBA), as the name suggests, emphasizes benefit measurement by placing, as far as is possible, a monetary value on environmental improvements, or conversely, monetary valuation of damage accrued to the society from environmental deterioration. The CBA assumes the existence of a social welfare function and aims at maximizing this function. The basic assumption of a social welfare function, which is the existence of preferences and fulfilling those preferences, involves value judgments. For most environmental problems, particularly water quality and air pollution problems, measuring benefits and damages in purely monetary terms is not possible because of the absence of market and price signals. Recent progress in nonmarket valuation research has produced several methods, such as contingent valuation, hedonic pricing, and travel cost method to overcome this problem (Brookshire et al. 1982). These methods are applicable only when the people are aware of the cause and effect linkage (dose-response relationship) of environmental damages so they can articulate their preferences, which is not the case for most environmental problems (OECD 1989). Therefore, indirect procedures through physical damage function estimation are employed.

In addition to these problems, CBA is plagued by value judgment in situations where it is not possible to measure benefits in monetary terms. Questions such as how to value loss of life or limb are judgment loaded. Furthermore, benefit estimation is uncertain, ignores distributional issues, and tends to concentrate on economic efficiency impacts only. There also are conceptual limitations in applying CBA for environmental pollution problems (Pearce 1976), not withstanding the practical problems of limited information, nonconvexities, and complexities in empirically estimating shadow prices for environmental goods (Dasgupta 1982). Finally, the core of the integrated modeling framework is the linkages among various processes. It is impractical for CBA to trace and capture all these linkages.

A Review of Economic and Environmental Indicators

Identification of relevant economic and environmental indicators is crucial to the environmental impact assessment framework. In other words, the socioeconomic environmental impacts of an environmental policy regulating economic actions cannot be based on a single criterion. Unlike CBA, with a narrow focus on a single indicator, the EIA considers a very broad set of indicators. The elements of this set are broadly grouped into economic and environmental indicators.

The Economic Indicators

The economic indicators are grouped into three categories: direct, indirect, and induced (Leat and Chalmers 1991). The direct indicators are income, sales, employment (both absolute levels and share relative to regional total), number of firms, and average size of the dairy farm. The compliance costs and benefits of environmental regulations and standards are also measures of direct economic impact.

The indirect (knock-on) effect of dairy sector output (direct output effect) among supplying sectors is measured by the indirect indicators, such as input and infrastructure industry impacts, impacts on crop and other livestock sectors, and other nonfarm industries in the area. The changes in other economic activity induced by the changes in household consumption of goods and services arising from changes in wages or salaries is referred to as the *induced effect*. The indicators of induced effect include consumption, per capita income, prices, transportation, utilities, health care, real estate, banking, and manufacturing. In general, the impact multipliers can be used to quantify the indirect and induced effects. In addition to economic indicators, social indicators also are of crucial importance. In-migration and out-migration of people, dairy firms, nondairy firms, and relocation of firms are some of the social indicators (Randall 1981). Figure 5 is a summary of the key indicators.

The Environmental Indicators

The magnitude of point and nonpoint source impacts on ground and surface water resources, as well as the human health and ecological concerns from pollution, are very clear. It is for these reasons that efforts are under way to not only preserve unimpaired water, but to reclaim the quality of impaired water. Progress toward adequate monitoring to mitigate or prevent adverse ecological effects, however, has been slow (NRC 1977; EPA 1984, 1987). Inadequacies described by these agencies include: (1) no long-term assessment of environmental change; (2) a focus on pollution sources rather than a discovery and prediction of environmental problems; (3) inability to associate problems with causes; and (4) unknown nonpoint source impacts and controls. In response to these criticisms, the EPA began to re-evaluate their monitoring programs and decided that they needed a national monitoring framework with well-defined objectives and guidance.

In an effort to better assess the condition of the nation's ecological resources, the Office of Research and Development of the EPA has initiated the Environmental Monitoring and Assessment Program (EMAP). Under this program, EPA will implement a monitoring network to estimate the

Sociopolitical Indicators

- In-migration
- Out-migration
- Dairy firm location
- Income distribution
- Local and regional government revenue, including sales tax, property tax, personal business income tax, environmental charges collected, and environmental subsidies paid

Economic Indicators

Direct

- Income from dairy and its share to total regional income
- Milk and milk product sale and its share to total sales
- Employment in dairy industry and its share to total employment
- Number of dairies
- Average size of dairies
- Diary size distribution
- Average and distribution of "farm" size (number of acres)

Indirect

- Impact on dairy input supply industries
- Impact on dairy processing industries
- Impact on other dairy infrastructure
- Changes in crop production patterns
- Changes in other livestock enterprises
- Changes in forestry and rangeland distribution
- Impacts on nonfarm industries

Induced

- Changes in consumption
- Changes in per capita income
- Price level changes
- Other sectoral impacts such as service, health, transportation, utilities, banking, real estate, deteriorating condition of roads and bridges, increases in participation in public assistance programs, overcrowded and under-funded schools, and increased crime rate

Figure 5. Sociopolitical and economic indicators

current status, extent, changes, and trends in indicators of ecological condition; monitor indicators of pollutant exposure and habitat condition and seek associations among indicators that provide plausible explanations for adverse conditions; and provide periodic reports on status and trends to the EPA Administrator and to the public. In 1988, the USDA Soil Conservation Service developed the *Water Quality Indicators Guide: Surface Water* (Terrell and Perfetti 1989). This document helped field personnel recognize nonpoint source problems and their potential causes and identify corrective measures. Although the book is designed as a field user's guide, it does include a description of the indicators approach to environmental assessment.

Currently, the EPA is developing a system of environmental indicators to predict the community health of various ecosystems. The environmental indicators such as habitat alteration, eutrophication (nutrient enrichment), and contamination (point and nonpoint, toxic and nontoxic) are recognized by the agency. Habitat alteration may be one of the most serious hazards to inland waters (EPA 1990). Loss of habitat may range from channel modification by dams or channelization to increased sedimentation through the loss of natural vegetation from agriculture or municipal development.

Eutrophication, the excessive enrichment of lakes and streams with nutrients, has for a long time been considered a major threat to surface waters worldwide (Terrell and Perfetti 1989; Hughes et al. 1990). Eutrophication has been a significant problem for some time and is the most cited problem that occurs in U.S. lakes (EPA 1988). It is associated with blooms of nuisance algae, reduced water clarity, and fish kills from reduced dissolved oxygen. Excessive nutrient (nitrogen and phosphorous) loading from nonpoint and point sources have repeatedly been linked to increases in phytoplankton (Dillon and Rigler 1974) and reduced water clarity. Smith (1979) reported that control of phytoplankton populations varied with respect to nitrogen and phosphorous loading, indicating both nutrients should be measured. Lake trophic status indices have been developed using a combination of measures of chlorophyll-a, total nitrogen or total phosphorous, and Secchi disk transparency (Brezonik 1984).

Acidification of surface waters resulting from chemical contamination is another indicator that could be measured by low pH, acid-neutralizing capacity (ANC), dissolved inorganic carbon (DIC), and dissolved organic carbon (DOC). Human activities that affect acidification as well as pH and ANC of surface waters have been evaluated by the National Academy of Sciences (1981) and the National Research Council of Canada (1981). Additional chemical stressors include high levels of chlorine, total suspended solids (TSS), and total dissolved solids. These stressors are usually not associated with toxic contaminants (Hughes et al. 1990), but are most often associated with runoff from agricultural practices.

A category of indicators that should be considered but that is not a high priority is water column bacteria. Water column bacteria can be used to determine the extent of contamination by pathogenic organisms. These pathogens can be categorized as introduced or indigenous organisms that "bloom" as a result of increased nutrient loading (Hughes et al. 1990). Most commonly investigated among introduced pathogens are the fecal coliforms, *Escherichia coli* and *enterococci*. Sources of these indicators are not restricted to inadequately treated sewage but can also result from runoff from pastures, feedlots, dairies, and urban areas (EPA 1990). Monitoring of indigenous potential pathogens is not routine, but is being proposed by EMAP strategists. Organisms proposed for monitoring include *Aeromonas hydrophile* and *A. salmonicida*. Both of these pathogens are associated with fish kills and human infections. EPA also concluded that biological criteria and physical habitat monitoring were needed to assess the impacts of nonpoint source pollution and controls. In order to provide adequate assessment and management decisions, EPA is designing a national monitoring framework with appropriate biological indicators for inland surface waters.

Finally, the EPA used three general criteria to select the research indicators for inland surface waters:

1. The indicators should be socially relevant. There must be clear connections with environmental values, and they must be responsive to the individual or cumulative effects of a broad array of potential stressors. An ideal indicator is applicable in a broad range of surface water types across the nation. Finally, it should provide early warning of detrimental ecological change or indicate the early stages of recovery.

2. The indicators must be sensitive to varying levels of stressors, but not to the degree that they produce false alarms or excessive noise. In fact, they should be insensitive to acceptable, natural variations or at least useful for distinguishing unacceptable and acceptable situations. Another useful feature is sensitivity to important episodes that do not coincide with the sampling period.

3. Useful indicators are cost effective, providing considerable information in a limited amount of sampling time. They should be implemented by persons with basic ecological training, providing reproducible results with low sampling variability. Also, they should have been used successfully in long-term monitoring programs by several different investigators or agencies (Hughes and Paulsen 1990).

Water Quality Indicators from Earlier NPS Pollution Studies. Clearly, identifying a set of key environmental indicators to assess NPS pollution is not a trivial matter. There are instances where the indicators have been changed midway through the project because the original indicator was not relevant for the study area. In the Garvin Brook watershed project in Minnesota, the target indicator was changed from nitrate nitrogen in surface water to nitrate nitrogen in groundwater (Wall et al. 1992). Therefore, lessons from past NPS pollution studies, in particular the RCWP projects, are a valuable source of information in selecting the key indicators. It is important to understand the factors investigated and the findings from other site-specific studies on nonpoint source pollution control as it relates to livestock waste. A major focus should be the environmental indicators addressed by these studies (Table 1).

The Lower Kissimmee River basin study in Florida emphasized reducing P-loading into Lake Okeechobee. The researchers have tied the spread of blue-green algae across more than 120 square miles of the lake surface to the increase in the concentration of phosphorous, which was in turn attributed to the concentrated dairy and beef feedlot operations in that area (Boggess et al. 1992). A coastal plains study in the Central Delmarva Peninsula in Maryland found groundwater at sites with livestock operations had the highest median values of nitrate nitrogen compared with sites near other sources (USGS 1984).

The Chino basin, covering 245 square miles in the Santa Ana region of Southern California, has the largest concentration of dairy feedlot operations in the United States. This area is now dealing with the threat of elevated levels of nitrate nitrogen and total dissolved salts (TDS) in groundwater. It is estimated that 60 percent of the TDS load in groundwater comes from dairy waste discharges and from the time dairy operations began in the area, up to 1986, the nitrate nitrogen concentration in groundwater increased from 6 ppm (mg/L) to 16 ppm (Anton et al. 1988). High nitrate and chloride levels in the Boone St. Joe aquifer in Arkansas were tied to animal waste according to studies indicating a positive correlation between nutrients and chlorides (Steele et al. 1987).

The Texas Water Commission's water quality program aims at reducing groundwater and North Bosque River pollution from nutrient loading from animal wastes (TWC 1989). The Chesapeake Bay NPS pollution control program focused on bay-wide nutrient loading from all sources, including animal wastes, and had an objective of reducing them by 40 percent by the year 2000. It is estimated that the animal wastes make up to 26.6 percent of the phosphorus and 10.5 percent nitrogen loads that come from all agricultural NPSs combined (EPA 1992b).

Lake Merhl in Frederick County, Maryland, had an elevated bacterial count from a single, nearby dairy feedlot operation (Payer 1992). By studying the Little Black River basin in Missouri and Arkansas, USGS researchers have identified livestock waste as the principal source of elevated bacterial population in the basin (Berkas et al. 1987). Lake Pontchartrain, Louisiana, is another water body that is infested with increased bacterial colonies partly attributed to cow excrement washed into the lake (*U.S. Water News* 1992). Nutrients and bacteria in surface water were the target indicators in the St. Albans bay program. A study by Meals (1992) found that bacterial count in streams increased with higher animal density but declined with an increasing percentage of animals under best manure management practices, while there were lower bacteria counts with greater use of manure from storage.

Table 1. Summary of ground and surface water indicators used in earlier NPS pollution studies of animal waste runoff

Study/Program	Groundwater	Surface Water
Lake Okeechobee, Florida		Total N, Total P[a], Dissolved P
Chino Basin, S. California	Nitrate N, Salts	
Chesapeake Bay		Total N, Total P
Coastal Plains, Maryland	Nitrate N	
Conestoga River, Lancaster County, SE Pennsylvania	Nitrate N	Nitrate+Nitrite N, Amm. N, Org. N, Total P, TSS, Bacteria
Tillamook Bay, Oregon		Bacteria
Lake Merhl, Maryland		Bacteria
Little Black River, Missouri		Bacteria
Lake Pontchartrain< Louisiana		Bacteria
Boone St. Joe Aquifer, Arkansas	N, Diss P, Sodium, Chloride	
St. Albans Bay, Vermont		Total N, Amm. N, Total P, TSS, BOD, Bacteria, Chlorophyl a
North Bosque River, Texas	Nutrients	Nutrients
Garvin Brook, Minnesota	Nitrate N	
Lake Champlain, NW Vermont		Total P[a], TSS, Total N, Bacteria
Rock Creek, Idaho		TSS, Total N, Ortho P, Bacteria
Big Pipe Creek, Maryland		Nitrate+Nitrite N[a], Total N, Amm. N, Kjeldhal N, Org. Carbon, Ortho P, Total P[a], TSS, Bacteria
Snake Creek, Utah		Bacteria[a], Total P[a], Ortho P, TSS, Nitrate+Nitrite N, Amm. N, Kjeldahl N, BOD

SOURCE: EPA 1992a.

[a] denotes principal indicator.

Notes: TSS Total Suspended Solids, Bacteria include Coliform and Streptococcus; Amm. N = Ammonium Nitrogen, BOD = Biological Oxygen Demand.

Odor and Air Quality. Principles of odor generation, release, and detection from livestock enterprises are the subject of ongoing research. Many aspects of these processes are not fully understood at this time. Odor control decisions therefore represent judgments based on partial knowledge. Although various instruments can be used to measure the intensity of odor producing gases as perceived by humans, no instrument can yet reflect the qualitative appraisal of odorant mixtures necessary to establish its degree of unpleasantness (ASAE 1991). Furthermore, odor intensity fluctuates with climatic conditions making it difficult to make precise measurements. Odors associated with livestock operations are most frequently attributable to the type of manure management system being used. Feed storage, processing and distribution of feed, milk, and other livestock products are also some potential sources of odor. Emission of malodorous gases and vapors is related to the volatility of the compound in question, the chemical composition of the medium in which it is produced, temperature, and air movement (ASAE 1991). Effective long-run solutions to odor problems are achieved by selecting a combination of physical manure management practices, chemical control, and slurry treatment process controls such as aeration, dehydration, and disinfection.

Indicators and a Feasibility Study

This review suggests that the choice of economic and environmental indicators should be specific to the environmental planning problem. The indicators should be general and relatively flexible so that they can be readily extrapolated to other regions and other livestock and related enterprises. The site- and region-specific socioeconomic and environmental attributes should play a major role in selecting these indicators. The identifying of key environmental indicators for the Erath County dairy waste management pilot project, is very important because they have the potential to be extended into other livestock wastes and regions. The lessons learned from past studies are of great value in selecting the indicators of importance.

The socioeconomic indicators that are chosen should reflect the impact on the producers, the consumers, the local economy, the environment (benefits to the society from environmental clean-up), and the government or regulatory agency. Keeping this in mind and also the feasibility of measuring them within the context of economic models used in the study, these indicators are proposed: net returns to dairy farming, employment, producer and consumer surplus, private costs of compliance including the opportunity cost, and policy implementation costs, such as technical information dissemination costs, and cost-sharing expenses.

Benefits from environmental improvements include increased recreational benefits, and willingness to pay for clean air. It should, however, be recognized that monetary measurement of the environmental benefits requires nonmarket valuation, which is beyond the scope of this project. However, an attempt is made to identify the environmental improvements in qualitative terms. The private and government costs of complying with the policy regulations and standards under alternative technologies is a useful economic indicator because it determines the economic viability of dairy farms and also indicates least cost policy options.

Although environmental indicators have been used for many years, there is apparently much research to be done to develop strategies for use in a wider array of environmental systems. Using a single indicator cannot produce sufficient information with which assessments can be made. Although these indicators are recognized separately, it is apparent that each is related to the other and cannot be addressed independently. Environmental indicators must account for differences in soil, hydrological, and other spatial attributes and they should be specific to the medium (water, air, and soil). Note that the higher the correlation between the management factors and the physical and spatial attributes the greater the ability to extrapolate the results to other settings. Biological information, in addition to the chemical and physical information, must be integrated with all phases of environmental quality assessment (Overton 1991). Besides these technical concerns of direct relevance to the objectives of the project there is another concern, minimizing total analytical cost, implying that we need to be as parsimonious as possible in our choice and at the same time preserve the quality of information generated. Clearly, there is a trade-off between these two concerns.

Water quality is a multidimensional concept with more than one indicator. That is, the function describing water quality is a vector-valued function with such attributes as nutrients, chemicals, sediment, and microorganisms. The elements of this vector vary according to the type of water body. Also factors such as hydrology, topography, weather, soil characteristics, and management practices influence the level of these indicators in a particular medium (Saliba 1985). One approach to developing these indicators is to establish baseline monitoring information based on spatial characteristics of the region. Given the spatial and temporal heterogeneity of NPS pollution, establishing a well-knit monitoring network for collecting and measuring periodic samples is costly and impractical. Therefore, in regional NPS pollution projects, monitoring needs to be complemented with environmental fate and transport process models. This introduces the major limitation on choice of indicators because there is no single, or group, of process models that can measure all indicators including physical, chemical, and biological. Note that indicators measured by monitoring can be assessed only for the baseline and not for any of the policy simulation exercises. Even with monitoring there are certain indicators that cannot be measured. Appendix A elaborates some of these concerns by type of water body.

Odorous gases emitted during collection, transport, storage, treatment, and land application of animal manures are principally products of anaerobic microbial metabolism (ASAE 1991). There are more than 45 harmless gases released from animal waste by anaerobic decomposition (bacterial breakdown of compounds in the absence of oxygen), which are causes of odor pollution. A list of compounds released from the anaerobic decomposition of livestock manure that have been identified in the nearby atmosphere is shown in Figure 6. Because there are so many indicators and since there is a lack of instrumentation to quantify these indicators, the emphasis should be on alternative BMPs that can reduce odor emissions with the fewest impacts on water quality and can still be compatible with the total production system. Odor intensity from "scentometer" readings, which are sniff-tests based on the number of dilutions relative to threshold, will be used as a judgment criterion for quantifying odor nuisance.

Alcohols

Acids
- Butyric
- Acetic
- Propionic
- Isobutyric
- Isovaleric

Carbonyls

Sulfur Compounds
- Hydrogen sulfide
- Dimethyl sulfide
- Diethyl sulfide
- Methylmercaptan
- Disulfides

Amines
- Methylamine
- Ethylamine
- Trimethylamine

Esters

Fixed Gases
- Carbon dioxide (odorless)
- Methane (odorless)
- Ammonia

Nitrogen Heterocycles
- Indole
- Skatole

Figure 6. Compounds released from the anaerobic decomposition of livestock manure
SOURCE: ASAE Standards 1991.

Solving the problems of contamination from dairy runoff includes an examination of the indicators that quantify physiochemical and biological constituents introduced by dairy wastes, and the indicators that measure the impact on the ecological health of the water body. Intensive dairy operations load the system with organics, inorganic nutrients, and enteric bacteria. To measure the impact on ecological health, there are parameters for which there is a water quality standard and parameters characterizing the biological system. For Texas, as well as for other states, the most important water quality standard is dissolved oxygen (DO). Dairy wastes could have an impact on the DO status either by direct depletion through oxygen demanding organics or indirect consumption through inorganic nutrient reactions. While BOD is a good measure for chemical and biological contaminants, the direct load of inorganic nutrients serves as a useful indicator of impact on ecological health.

Summary and Recommendations

Even with these limitations, a number of specific indicators can be identified for ground and surface waters. For groundwater, we recommend nitrite plus nitrate nitrogen, ammonium nitrogen, Kjeldahl nitrogen, phosphate, chloride, and sodium. For surface water, we specify TSS and variably suspended solids, total nitrogen, ammonium nitrogen, nitrate nitrogen, total phosphorous, soluble phosphorous, chloride, pH, BOD, and coliform bacterial count. While the primary focus of this project is surface water quality, it also examines potential groundwater contamination but is restricted to the vadose zone by physical model limitations. For groundwater impact assessments, apart from measuring actual nutrient loads, the path by which the nutrients reach the groundwater system, the transport rates, and potential recharge areas need to be explored. However, because of funding limitations these groundwater assessment activities, including measurement of nutrient loads in groundwater below the vadose zone, will not be performed.

APPENDIX A. SURFACE WATER QUALITY INDICATORS BY WATER COURSE

(by George Ward, CRWR, University of Texas at Austin)

The selection of parameters and the time intensity of sampling will vary with the water course being sampled. For this reason, we need to consider several generic categories. *Occasional* her means at a less frequent interval than normally necessary to completely resolve a storm hydrograph, and may be composited samples. *Intense* means a sufficiently frequent sampling rate to resolve the hydrograph. For a 12-hour event, this might be hourly, for example. (There are major problems with implementing flow-weighted sampling that may require time-interval sampling and manual compositing.) *In situ* means manual sampling on an opportunistic or scheduled basis using electrometric probes or portable kits. (This focuses on the surface water component. Groundwater presents its own sampling problems and key parameters. Also, biological sampling is not addressed.)

Table A.1. Physical, chemical, and bacteriological parameters by water course type and sampling source

Water Course Type/Sampling Source	Physical			Chemical			Bacteriological		
	Occasional	Intense	In situ	Occasional	Intense	In situ	Occasional	Intense	In situ
Field scale sampling[d]	-	Stage[a], TSS, conductivity	-	amm-N nitrate-N BOD phosphate-P	-	-	coliforms	-	-
Intermittent stream[e]	-	Stage[a], TSS conductivity	DO temperature conductivity	Amm-N nitrate-N BOD phosphate-P	-	-	coliforms[b]	-	-
Permanent stream: flood stage[c,f]	-	Stage[a], TSS conductivity	DO temperature conductivity	amm-N nitrate-N BOD phosphate-P	-	-	-	-	-
Permanent stream: low flow stage[c,g]	Stage[a], TSS, pH, conductivity	-	DO, pH, temperature conductivity	amm-N nitrate-N BOD phosphate-P	-	-	-	-	-
Small flood-control reservoir[c,h]	State, TSS, pH, conductivity turbidity	-	DO, pH, temperature conductivity transparency	amm-N nitrate-N phosphate-P	-	-	-	-	-

[a] From which the flow is determined.

[b] At selected stations only.

[c] Bacteriological sampling is not suggested here because it will not be capable of direct relation to loadings, nor is it amenable to modeling. Organic-N may be desirable if there is an indication of inorganic-N loading not accounted for by runoff or wasteloads (in which case, mineralization of organic-N may be a possible explanation).

[d] This applies to the direct runoff from dairy-scale operations, sampled in the principal drainageways from the area. This is also probably the scale at which we will most directly asses the effects of control strategies. Flow will be event-dominated, and therefore sampled primarily by automative devices.

[e] Many of the natural drainageways only carry flow during or following storm events. Their response may be somewhat longer than the field-scale operations, due to the larger watersheds, but they are still transient, storm-dominated systems, and therefore will require basically the same strategy of sampling as category (1).

[f] This system, typified by main-stem reaches of the Bosque, has essentially perennial flow (barring long-term droughts). It is, however, important to distinguish the high-stage regime from the low-stage regime, since the response to wasteloads and the character of the stream are very different. For the flood stage regime, the sampling intensity is keyed to the hydrograph and will vary according to the stage time-history.

[g] This is the flow regime traditionally monitored for water-quality management, since the minimum dilution at low-stage (particularly in combination with summer conditions) results in stressed water quality, generally conceived to be the "worst-case." The low variability in hydrology also allows application of "steady-stage" water quality models. One of these, QUAL-TX (a first cousin to EPA's limits in Texas water management. Little direct loading from dairies are expected in this flow-regime, but the concern is more on the residual impacts from dairy wasteloads introduced during higher-flow events. This regime therefore has the greatest need for evaluation of kinetic transformations and impacts of dairy wastes. It also has the greatest need to separate the impacts of other waste sources (many of which, like municipal effluent, are active under low-flow conditions), so must be supplemented by waste-stream data from other types of loading. The "intense" scale is irrelevant at this stage. If hyperstimulation (eutrophication) is indicated, parameters characterizing alkalinity and leavening may be desirable.

[h] This refers, of course, to the PL-566 reservoirs that dot the Erath County landscape. Not only is there a concern *per se* about impacts of dairy and other agriculture operations on the quality of these lakes, these lakes also act as collection basins for the evanescent runoff from intermittent streams (category 2 above, holding and integrating the loadings from storm events on these small watersheds. Sampling these lakes therefore offers a valuable counterpoint to the dynamic sampling necessary on the streams themselves, and may yield information on the relative importance of different constituents on water quality impacts. If hyperstimulation (eutrophication) is indicated, parameters characterizing alkalinity and leavening may be desirable.

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