Chapter 1
Environmental Stewardship, Water Quality and Nutrient Balance

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Producers need to be aware of the impacts that manure can have on water and air quality. However, management of manure and other byproducts of livestock and poultry production has important impacts on farm profitability, neighbor relations and protecting soil and water quality.

How Can Manure Affect the Environment?

The livestock and poultry industry is facing growing scrutiny of its environmental stewardship. While emotion and limited information on the part of the general public contribute to this concern, problems also result from a few producers who have allowed highly visible impacts to occur on the environment. These situations create a negative and often biased public view about the impact of livestock and poultry on the environment.

If not carefully managed, manure and other byproducts of animal production such as mortality can have a significant negative impact on the environment. Animal production can negatively affect surface water quality (pathogens, phosphorus, nitrogen as ammonia and nitrate, and organic matter); groundwater quality (nitrate); soil quality (soluble salts, copper, arsenic, and zinc); and air quality (odors, dust and particulate matter emissions, pests, and aerial pathogens). In fact, the U.S. Environmental Protection Agency (EPA) has identified agricultural production as the largest single contributor to water quality impairment for rivers and lakes (Table 1). For nutrients in particular, livestock and poultry manures are a major contributor of total nitrogen (N) and phosphorus (P) inputs into U.S. watersheds. In some watersheds, manure nutrient inputs are substantially greater than those associated with more traditional sources of pollution (e.g., municipalities, industry).

Table 1. Five leading sources of water quality impairment.

Rank	Rivers	Lakes	Estuaries
1	Agriculture	Agriculture	Municipal point sources
2	Municipal point sources	Urban runoff and storm sewers	Urban runoff and storm sewers
3	Urban runoff and storm sewers	Hydrologic/habitat modification	Agriculture
4	Resource extraction	Municipal point sources	Industrial point sources
5	Industrial point sources	Onsite wastewater disposal	Resource extraction
Source: EPA 1998.			

Is manure an environmental risk or benefit?

How you manage your manure can determine if it is; is it…

A source of nutrients and disease causing organisms that degrade the quality of our water for drinking and recreational use?	OR	A source of organic matter that improves the quality and productivity of our soil resources?
One of our nation's largest sources of water pollution?	OR	A source of plant nutrients that can replace commercial fertilizers saving time, energy, and money?
A source of gaseous emissions that reduces the quality of life in rural communities and contributes to possible neighbor health concerns?	OR	A means of recycling and adding carbon to the soils that contributes to a reduction in atmospheric carbon and global warming?

Manure can produce both good and bad results. The actual results often depend upon choices that you make in managing this resource.

Principles of Environmental Stewardship

As someone who manages animal manure on a livestock or poultry operation, you make the decisions that determine if manure will be a benefit or risk to the operation. Several fundamental principles of good environmental stewardship must be considered in the production of livestock and poultry.

Awareness of environmental risks

The potential impact of an individual operation on the environment varies with animal concentration, weather, terrain, soils, and a host of other conditions. You must understand these risks and manage your operation's manure to minimize them.

No point source discharge

Livestock and poultry production systems operate on the principle of "no discharge" of manure or wastewater to surface water from point sources such as animal housing, storage facilities, or treatment lagoons. Under EPA rules, the only time a discharge is allowed is in extreme rainfall events such as a 25-year, 24-hour storm (This is a defined amount of rain expected to fall in one day once every 25 years on the average). The no discharge management standard for animal manure is distinctly different from the management of human and industrial waste, which is routinely discharged into surface waters following treatment. Avoiding manure or wastewater spills directly into surface waters is essential to being a good environmental steward. Minimizing runoff from nonpoint sources (NPSs) (e.g., land application) is also central to good environmental stewardship. Making proper decisions related to timing and site selection for land application should minimize the risk of these NPS discharges.

Follow a nutrient management plan (NMP) for land application

A good stewardship program includes a plan for managing manure nutrients in crop production systems. The plan must maintain a balance between nutrient application and crop use as well as minimize the risk of runoff and leaching of nutrients. Proper nutrient management allows you to use the nutrients in manure as a resource for your operation.

Be a good neighbor

The byproducts of animal production create several potential nuisances (including odors, flies, noise, and others) in rural communities. You must be fully aware of these potential issues and the degree of concern they cause neighbors. Where reasonable technologies and management strategies are available to reduce or eliminate these nuisances, such strategies should be implemented. Where such options do not exist, producers may need to consider alternatives such as separation distances and good communication to minimize these nuisances.

Know the rules

Good stewardship requires knowledge of and compliance with current regulations established by federal, state, and local governments. Knowledge of these rules and careful planning of manure management systems to meet these requirements is essential. Good stewardship, however, goes beyond meeting the minimum requirements and includes reducing environmental risks whenever possible. While these environmental stewardship principles appear simple, they require knowledge, hard work, and commitment from everyone involved with the operation.

Understanding Water Quality Issues

While land application of manure provides many benefits, incorrect manure use can have negative impacts on water quality. Good stewards should be aware of the components of manure that are of greatest concern, their specific impact on water quality, and their common pathways to surface and groundwater.

Water Quality Contaminants

Manure contains four primary components that impact water quality: nitrogen (N), phosphorus (P), pathogens (disease-causing organisms), and organic matter. These components, their environmental risk, and typical pathways to water are summarized in Table 2.

Table 2. Summary of manure components that can impact water quality, the associated environmental risk, and most common pathway to water.

Potential Pollutant	Environmental Risk	Most Common Pathway to Water
Nitrate-N	Blue Baby Syndrome Algal blooms	Leaching to groundwater Subsurface flow to waterways
Ammonia-N	Fish kills	Surface water runoff
P	Eutrophication	Erosion and surface water runoff
Pathogens	Human health risk	Surface water runoff
Organic solids	Reduced oxygen level in water body-fish kills	Surface water runoff

Nitrogen

For growth and survival, all living things require N, the fundamental building block of protein. Livestock and poultry use only part of the protein in their feed. The remaining protein is excreted as N in manure. Some of this N is quickly transformed into ammonia-N. When manure is applied to land, the soil's aerobic environment converts common manure-N forms to nitrate-N.

Nitrate contamination of drinking water supplies (primarily a groundwater issue) can present a health hazard. Infants and pregnant women are at greatest risk. The U.S. EPA has set a maximum contaminant level of 10 parts per million (ppm) for nitrate-N in public water supplies, and this is used as a ground-water quality standard in many states.

Ammonia-N in surface water also represents an environmental risk. In most natural surface waters, low levels of ammonia-N (around 2 ppm) can cause fish kills.

Nitrogen is a very mobile element that has many different forms. Most N in manure exists in forms that are easily transported by surface runoff or shallow groundwater flow. The filtering ability of soil restricts movement of most forms to groundwater, but if sufficient oxygen is available, some forms can be transformed into nitrate-N and can leach through soils to groundwater. Some forms can also be transported through the atmosphere by volatilization and deposition processes.

Excessive nitrogen loading to surface waters can cause algal blooms. Algae or phytoplankton are microscopic, single-celled plants. Most species of algae are not harmful and are actually food sources for many forms of life. Too much algae, however, causes water quality problems. Occasionally, conditions allow algae to grow very fast or "bloom." As these blooms die and decompose, oxygen in the water is removed. The low oxygen levels inhibit aquatic life, reduce fishery production, and cause fish kills. Nutrient loading, whether from fertilizers, manure, or other waste is a leading contributor to poor water quality in ponds, rivers, lakes, and coastal waters.

Phosphorus

Phosphorus transported from agricultural land to surface waters can also promote eutrophication (abnormally high growth of algae and aquatic weeds and associated low oxygen levels in surface waters). Other common problems associated with eutrophic water bodies include less desirable recreational use, unsuitable drinking water, and increased difficulty and cost of drinking water treatment. Eutrophic surface waters may also experience massive blooms of cyanobacteria (aka blue-green algae), some of which can kill animals and pose health hazards to humans.

Since P binds readily with soil or organic matter, soil erosion is the main way P moves to surface water. Soil water also contains a small amount of dissolved P that is essential for plant uptake. Phosphorus leaching is rarely an issue unless the soils are sandy and have high water tables. However, as P levels in the soil increase, dissolved P in runoff water will also increase. Since dissolved P is readily available to algae, overloading soils with excessive amounts is a water resource concern.

Pathogens

A pathogen is typically considered any virus, bacterium, or protozoa capable of causing infection or disease in animals or humans. Two pathogens shed in animal manure, *Cryptosporidium parvum* (*C. parvum*) and *Giardia lamblia* (*Giardia*), are of greatest concern to humans. *C. parvum*, commonly referred to as "crypto," and *Giardia* are parasites that cause severe diarrhea, nausea, fever, vomiting, and fatigue in humans. The risk of infection from these organisms is much greater for the very young, the elderly, and those with weak immune systems. These pathogens pose a particular risk since they are resistant to the disinfection processes used in most water treatment plants.

Livestock and poultry shed a number of viruses and bacteria in manure. While some of these can infect humans, it is relatively unlikely that they will unless the manure has direct access to a drinking water supply. Most bacteria can be controlled with common water disinfectants such as chlorine. Where untreated water such as that from wells (no chlorine treatment) is located near animal housing or manure storage, some cases of human illnesses and deaths due to bacteria such as *Escherichia coli* (*E. coli*) have been reported.

Most pathogens, including *C. parvum* and *Giardia*, do not multiply outside a host organism so they have a limited lifetime outside a host. The viability of these organisms can range from a few days to many months, depending on a number of environmental factors such as temperature, pH, sunlight, moisture, and the amount of oxygen available. Land application and composting are two processes that commonly speed up the decay of pathogens, because they are subjected to wider ranges of temperature and pH than they normally encounter.

Pathogens are most likely transported to water supplies through surface runoff and erosion or by direct animal access to surface water. Streams and lakes used for drinking water supply and recreational purposes provide the greatest opportunity for these pathogens to be transported to humans. Animal operations located upstream of drinking water supplies or recreational areas should recognize the potential risks associated with pathogens.

Soils provide a filtering mechanism, especially for larger organisms such as protozoa and bacteria. Although it is unlikely that pathogens will reach a groundwater supply, it can happen. Proper wellhead protection and separation distances are important. There is evidence that viruses and bacteria can travel some distance through sandy soils. Research and experience have shown that water can be contaminated from tile drainage shortly after the land application of manure because drainage tiles can short-circuit natural filtration processes that normally occur in the soil.

Organic matter

Organic matter in manure, silage leachate, and milking center wastewater degrades rapidly and consumes considerable oxygen in the process. If this occurs in an aquatic environment, oxygen can be quickly depleted, resulting in fish kills and other aquatic impacts. Manure, silage leachate, and waste milk are extremely high in organic matter that can break down and use oxygen. These products can be 50 to 250 times more concentrated than raw municipal sewage (primarily because animal production does not add the large volume of fresh water used for the dilution and transport of municipal waste).

Organic matter, like pathogens, P, and ammonia, is transported to water by surface water runoff. Rarely does it leach through soils. Organic matter is unlikely to be transported in sufficient quantities to nearby surface waters unless one of the following situations occurs:

- A direct discharge from an animal barn, manure storage, open lot, or other facility is allowed to enter surface water.

- A catastrophic failure such as an earthen storage break, broken pipeline, or continuous application by an irrigation system on the same location.
- Significant rainfall occurs immediately after the surface application of manure.
- Significant application is made on frozen, snow-covered, sloping, or saturated soils in close proximity to surface water.

Point vs. NPS pollution

Historically, “point sources” of pollution have been regulated at the state and federal level. Point source pollution is a single identifiable source of pollution such as a pipe discharging effluent from an industrial operation, a wastewater treatment plant, or a processing plant. A permit is usually required for this type of discharge because it is easy to find and regulate. “Nonpoint source” pollution is more difficult to trace to a single source because it takes place over a broad area, and the release of pollutants can occur over a variety of areas and at different times. Usually, NPS pollution occurs following rainfall when runoff carries pollutants into surface water; however, contaminated groundwater that recharges rivers and streams also can be classified as NPS pollution. Today, greater emphasis is being placed on regulating NPS pollution as state and federal agencies realize that simply regulating point sources will not result in the clean water that we all want.

Pollution pathways

The potential pollutants typically follow one or more of five possible pathways for reaching water. These pathways include:

1. **Runoff**. Runoff from open lots, land application sites, and manure or feed storage units is a common pathway for contaminant transport. Contaminants in manure can travel with surface water runoff and soil erosion. Problems associated with P, pathogens, ammonia, and organic matter are most commonly associated with runoff or erosion.
2. **Leaching**. Dissolved contaminants such as nitrate nitrogen can leach beyond a crop's root zone when the soil moisture exceeds its water-holding capacity and will eventually reach groundwater. Most contaminants in manure and other byproducts (e.g., organic matter, pathogens, and typically P) are filtered by soil and will NOT leach to groundwater. However, it is possible to overwhelm the soil's ability to restrict contaminant movement. For example, soils can allow ammonia movement of up to a few feet per year below manure storages.
3. **Macropore flow**. Most contaminants in manure can travel through soil to shallow groundwater tables or tile drains by macro-pore flow. Macro-pore flow (root holes, wormholes, and cracks due to soil drying) provides pathways for contaminants to bypass the filtering capability of soils. Sinkholes and karst topography (fractured rock) also provide opportunities for contaminants to directly reach groundwater.
4. **Wells**. Poorly constructed or maintained wells can provide a direct pathway for contaminants to reach groundwater. Abandoned wells, wells with poor well-casing designs, or wells located in close proximity to open lots or manure storage can provide a pathway for manure contaminants to move to groundwater.

5. **Ammonia volatilization and deposition**. Ammonia-N can go from a liquid to a gas in a process called volatilization. Ammonia-N volatizes from manure storage, lagoons, and open lots. Once volatilized, most ammonia is re-deposited with rainfall. It can be transported over long distances. While some areas benefit from this deposition, other areas such as large water bodies are experiencing high enough deposition that it threatens the vitality of local ecosystems. In the United States, coastal areas are often adversely affected by ammonia deposition.

Whole Farm Nutrient Management

Nutrients are transported along multiple pathways and in a variety of forms on an animal operation, but an understanding of the overall farm nutrient balance is necessary in identifying the underlying causes of nutrient-related water quality problems as well as the solutions.

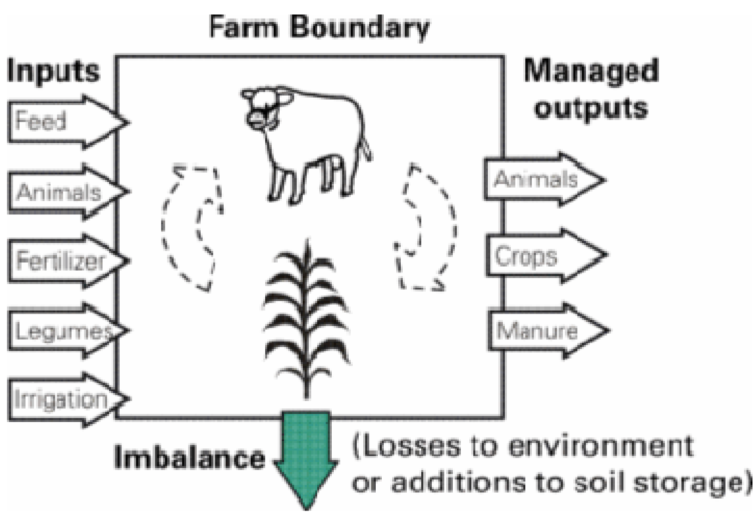

Figure 1. A whole operation nutrient balance considers all nutrient inputs, managed outputs, losses for a livestock or poultry operation.

A picture of the nutrient flow on an operation is presented in **Figure 1**. On an animal operation, nutrients arrive as purchased products (fertilizer, animal feed, and purchased animals), nitrogen fixed by legume crops, and nitrates in rain and irrigation water. Some of these "Inputs" are converted to outputs such as meat, milk, or crops while some escape into the environment. Within the operation's boundaries, there is a "Recycling" of nutrients between the animal and crop components if crops are fertilized with manure and fed to animals.

Nutrients exit an animal operation preferably as "Managed Outputs," including animals and crops sold and possibly other products moved off the operation (e.g., manure sold or given to a neighboring crop producer). Some nutrients exit the operation as losses to the environment (nitrates in groundwater, ammonia volatilized into the atmosphere, and N and P into surface water). Nutrients (especially P) also accumulate in large quantities in the soil. Although not a direct loss to the environment, a growing accumulation of nutrients in the soil adds to the risk of future environmental losses, especially through erosion.

The "Imbalance" is the difference between the Inputs and the Outputs. This Imbalance accounts for both the direct environmental loss and the accumulation of nutrients in the soil. Animal operations with an imbalance pose a greater risk to water quality. In contrast, animal operations that have achieved a balance represent a potentially sustainable production system.

The nutrient balance on an operation can often be expressed as the ratio of nutrient inputs to nutrient outputs. Ideally, your operation should be balanced for both N and P. An imbalance in N does not distinguish between the relatively harmless losses (e.g., denitrification of nitrate to N_2 gas) and the relatively harmful environmental losses (e.g., nitrate loss to water). In contrast, P losses affect water quality through increased soil P levels and greater concentration of P moving with surface runoff water. Ideally, an operation manager would want to manage an operation to maintain a P ratio near 1:1. Input-to-output P ratios on operations across the United States are commonly reported to range from less than 1:1 up to 8:1. Livestock and poultry operations with a large imbalance (1.5:1 and greater) should expect steadily increasing soil P levels that are not environmentally sustainable.

Is My Livestock/Poultry Operation in Balance?

An understanding of nutrient balance and primary source of purchased nutrients is the key to operating an animal operation in an environmentally sustainable manner. A method that most regulatory agencies require is a check of manure nutrient production vs. crop nutrient utilization. This method checks the ability of your land base to utilize the nutrients in manure. An excess of manure nutrients for crop production suggests a whole farm nutrient imbalance. This will be part of your NMP. A Whole Farm Nutrient Balance provides the "bottom line" answer to this issue. It also provides a measurement of progress made toward environmental sustainability following the implementation of changes. The producer must assemble information for animal purchases and sales, feed and grain purchases and sales, fertilizer purchases, manure sales, and possibly other contributors for a one-year period. A spreadsheet to aid the producer in conducting a whole farm nutrient balance is located at http://manure.unl.edu/Koelsch-nbalance.html.