V. What Environmental and Human Health Impacts Are Potentially Caused by CAFOs?

The 1998 *National Water Quality Inventory,* prepared under Section 305(b) of the Clean Water Act, presents information on impaired water bodies based on reports from the States. This recent report indicates that the agricultural sector (which includes concentrated and confined animal feeding operations, along with aquaculture, crop production, pasture grazing, and range grazing) is the leading contributor to identified water quality impairments in the nation's rivers and lakes, and the fifth leading contributor in the nation's estuaries. The leading pollutants or stressors of rivers and streams include (in order of rank) siltation, pathogens (bacteria), nutrients, and oxygen depleting substances. For lakes, ponds, and reservoirs, the leading pollutants or stressors include nutrients (ranked first), siltation (ranked third), oxygen depleting substances (ranked fourth), and suspended solids (ranked fifth). For estuaries, the leading pollutants or stressors include pathogens (bacteria) as the leading cause, oxygen depleting substances (ranked second), and nutrients (ranked fourth).

The sections which follow present the pollutants associated with livestock and poultry operators, of which CAFOs are a subset, the pathways by which the pollutants reach surface water, and their impacts on the environment and human health. Detailed information can be found in the *Environmental Assessment of the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and Effluent Guidelines for Concentrated Animal Feeding Operations*. The Environmental Assessment and the supporting references mentioned here are included in Section 8.1 of the Record for this proposal.

A. Which Pollutants Do CAFOs Have the Potential to Discharge and Why Are They of Concern?

The primary pollutants associated with animal waste are nutrients (particularly nitrogen and phosphorus), organic matter, solids, pathogens, and odorous/volatile compounds. Animal waste is also a source of salts and trace elements, and to a lesser extent, antibiotics, pesticides, and hormones. Each of these types of pollutants is discussed in the sections which follow. The actual composition of manure depends on the animal species, size, maturity, and health, as well as on the composition (e.g., protein content) of animal feed.

1. Nutrients (Nitrogen, Phosphorus, and Potassium)

The 1998 *National Water Quality Inventory* indicates that nutrients are the leading stressor in impaired lakes, ponds, and reservoirs. They are the third most frequent stressor in impaired rivers and streams, and the fourth greatest stressor in impaired estuaries. The three primary nutrients in manure are nitrogen, phosphorus, and potassium. (Potassium also contributes to salinity.)

Nitrogen in fresh manure exists in both organic forms (including urea) and inorganic forms (including ammonium, ammonia, nitrate, and nitrite). In fresh manure, 60 to 90 percent of total nitrogen is present in organic forms. Organic nitrogen is transformed via microbial processes to inorganic forms, which are bioavailable and therefore have fertilizer value. As an example of the quantities of nutrients discharged from AFOs, EPA estimates that hog operations in eastern North Carolina generated 135 million pounds of nitrogen per year as of 1995.

Phosphorus exists in solid and dissolved phases, in both organic and inorganic forms. Over 70 percent of the phosphorus in animal manure is in the organic form. As the waste ages, phosphorus mineralizes to inorganic phosphate compounds which are available to plants. Organic phosphorus compounds are generally water soluble and may leach through soil to groundwater and run off into surface waters. Inorganic phosphorus tends to adhere to soils and is less likely to leach into groundwater. Animal wastes typically have lower nitrogen:phosphorus ratios than crop requirements. The application of manure at a nitrogen-based agronomic rate can, therefore, result in application of phosphorus at several times the agronomic rate. Soil test data in the United States confirm that many soils in areas dominated by animal-based agriculture have elevated levels of phosphorus.

Potassium contributes to the salinity of animal manure which may in turn contribute salinity to surface water polluted by manure. Actual or anticipated levels of potassium in surface water and groundwater are unlikely to pose hazards to human health or aquatic life. However, applications of high salinity manure are likely to decrease the fertility of the soil.

In 1998, USDA studied the amount of manure nitrogen and phosphorus production for confined animals relative to crop uptake potential. USDA evaluated the quantity of nutrients available from recoverable livestock manure relative to crop growth requirements, by county, based on data from the 1997 Census of Agriculture. The analyses were intended to determine the amount of manure that can be recovered and used. The analyses did not consider manure from grazing animals in pasture, excluded manure lost to the environment, and also excluded manure lost in dry storage and treatment. It is not currently possible to completely recover all manure.

Losses to the environment can occur through runoff, erosion, leaching to groundwater, and volatilization (especially for nitrogen in the form of ammonia). These losses can be significant. Considering typical management systems, the 1998 USDA study reported that average manure nitrogen losses range from 31 to 50 percent for poultry, 60 to 70 percent for cattle (including the beef and dairy categories), and 75 percent for swine. The typical phosphorus loss is 15 percent.

The USDA study also looked at the potential for available manure nitrogen and phosphorus generated in a county to meet or exceed plant uptake and removal in each of the 3,141 mainland counties. Based on this analysis of 1992 conditions, available manure nitrogen exceeds crop system needs in 266 counties, and available manure phosphorus exceeds crop system needs in 485 counties. The relative excess of phosphorus compared to nitrogen is not surprising, since manure is typically nitrogen-deficient relative to crop needs. Therefore, when manure is applied to meet a crop's nitrogen requirement, phosphorus is typically over-applied.

USDA's analyses do not evaluate environmental transport of applied manure nutrients. Therefore, an excess of nutrients in a particular county does not necessarily indicate that a water quality problem exists. Likewise, a lack of excess nutrients does not imply the absence of water quality problems. Nevertheless, the analyses provide a general indicator of excess nutrients on a broad basis.

2. Organic Matter

Livestock manures contain many carbon-based, biodegradable compounds. Once these compounds reach surface water, they are decomposed by aquatic bacteria and other microorganisms. During this process dissolved oxygen is consumed, which in turn reduces the amount of oxygen available for aquatic animals. The 1998 *National Water Quality Inventory* indicates that oxygen-depleting substances are the second leading stressor in estuaries. They are the fourth greatest stressor both in impaired rivers and streams, and in impaired lakes, ponds, and reservoirs. Biochemical oxygen demand (BOD) is an indirect measure of the concentration of biodegradable substances present in an aqueous solution.

3. Solids

The 1998 *National Water Quality Inventory* indicates that suspended solids are the fifth leading stressor in lakes, ponds, and reservoirs. Solids are measured as total suspended solids, or TSS. (Solids can also be measured as total dissolved solids, or TDS.) Solids from animal manure include the manure itself and any other elements that have been mixed with it. These elements can include spilled feed, bedding and litter materials, hair, feathers, and corpses. In general, the impacts of solids include increasing the turbidity of surface waters, physically hindering the functioning of aquatic plants and animals, and providing a protected environment for pathogens.

4. Pathogens

Pathogens are disease-causing organisms including bacteria, viruses, protozoa, fungi, and algae. The 1998 *National Water Quality Inventory* indicates that pathogens (specifically bacteria) are the leading stressor in impaired estuaries and the second most prevalent stressor in impaired rivers and streams. Livestock manure contains countless microorganisms, including bacteria, viruses, protozoa, and parasites. Multiple species of pathogens may be transmitted directly from a host animal's manure to surface water, and pathogens already in surface water may increase in number due to loadings of animal manure nutrients and organic matter. In 1998, the Centers for Disease Control and Prevention reported on an Iowa investigation of chemical and microbial contamination near large scale swine operations. The investigation demonstrated the presence of pathogens not only in manure lagoons used to store swine waste before it is land applied, but also in drainage ditches, agricultural drainage wells, tile line inlets and outlets, and an adjacent river.

Over 150 pathogens found in livestock manure are associated with risks to humans. The protozoa *Cryptosporidium parvum* and *Giardia species* are frequently found in animal manure and relatively low doses can cause infection in humans. Bacteria such as *Escherichia coli* O157:H7 and *Salmonella species* are also often found in livestock manure and have also been associated with waterborne disease. A recent study by USDA revealed that about half the cattle at the nation's feedlots carry *E. coli*. The bacteria *Listeria monocytogenes* is ubiquitous in nature, and is commonly found in the intestines of wild and domestic animals without causing illness. *L. monocytogenes* is commonly associated with foodborne disease. The pathogens *C. parvum*, *Giardia*, *E. coli* O157:H7, and *L. monocytogenes* are able to survive and remain infectious in the environment for long periods of time.

Although the pathogen *Pfiesteria piscicida* is not found in manure, researchers have documented stimulation of *Pfiesteria* growth by swine effluent discharges, and have strong field evidence that the same is true for poultry waste. Research has also shown that this organism's growth can be highly stimulated by both inorganic and organic nitrogen and phosphorus enrichments. Discussions of *Pfiesteria* impacts on the environment and on human health are presented later in this section.

5. Salts

The salinity of animal manure is directly related to the presence of dissolved mineral salts. In particular, significant concentrations of soluble salts containing sodium and potassium remain from undigested feed that passes unabsorbed through animals. Other major cations contributing to manure salinity are calcium and magnesium; the major anions are chloride, sulfate, bicarbonate, carbonate, and nitrate. Salinity tends to increase as the volume of manure decreases during decomposition and evaporation. Salt buildup deteriorates soil structure, reduces permeability, contaminates groundwater, and reduces crop yields.

In fresh waters, increasing salinity can disrupt the balance of the ecosystem, making it difficult for resident species to remain. In laboratory settings, drinking water high in salt content has inhibited growth and slowed molting of mallard ducklings. Salts also contribute to degradation of drinking water supplies.

6. Trace Elements

The *1998 National Water Quality Inventory* indicates that metals are the fifth leading stressor in impaired rivers, the second leading stressor in impaired lakes, and the third leading stressor in impaired estuaries. Trace elements in manure that are of environmental concern include arsenic, copper, selenium, zinc, cadmium, molybdenum, nickel, lead, iron, manganese, aluminum, and boron. Of these, arsenic, copper, selenium, and zinc are often added to animal feed as growth stimulants or biocides. Trace elements may also end up in manure through use of pesticides, which are applied to livestock to suppress houseflies and other pests. Trace elements have been found in manure lagoons used to store swine waste before it is land applied, and in drainage ditches, agricultural drainage wells, and tile line inlets and outlets. They have also been found in rivers adjacent to hog and cattle operations.

Several of the trace elements in manure are regulated in treated municipal sewage sludge (but not manure) by the *Standards for the Use or Disposal of Sewage Sludge*, promulgated under the Clean Water Act and published in 40 C.F.R. Part 503. These include arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Total concentrations of trace elements in animal manures have been reported as comparable to those in some municipal sludges, with typical values well below the maximum concentrations allowed by Part 503 for land-applied sewage sludge. Based on this information, trace elements in agronomically applied manures should pose little risk to human health and the environment. However, repeated application of manures above agronomic rates could result in exceedances of the cumulative metal loading rates established in Part 503, thereby potentially impacting human health and the environment. There is some evidence that this is happening. For example, in 1995, zinc and copper were found building to potentially harmful levels on the fields of a hog farm in North Carolina.

7. Odorous/Volatile Compounds

Sources of odor and volatile compounds include animal confinement buildings, manure piles, waste lagoons, and land application sites. As animal wastes are degraded by microorganisms, a variety of gases are produced. The four main gases generated are carbon dioxide, methane, hydrogen sulfide, and ammonia. Over 150 other odorous compounds have also been identified with animal manure. Aerobic conditions yield mainly carbon dioxide, while anaerobic conditions generate both methane (60 percent to 70 percent) and carbon dioxide (30 percent). Anaerobic conditions, which dominate in typical, unaerated animal waste lagoons, are also associated with the generation of hydrogen sulfide and about 40 other odorous compounds, including volatile fatty acids, phenols, mercaptans, aromatics, sulfides, and various esters, carbonyls, and amines. Once airborne, these volatile pollutants have the potential to be deposited onto nearby streams, rivers, and lakes.

Up to 50 percent or more of the nitrogen in fresh manure may be in ammonia form or converted to ammonia relatively quickly once manure is excreted. Ammonia is volatile and ammonia losses from animal feeding operations can be considerable. A study of atmospheric nitrogen published in 1998 reported that, in North Carolina, animal agriculture is responsible for over 90 percent of all ammonia emissions. Ammonia from manure comprises more than 40 percent of the total estimated nitrogen emissions from all sources.

8. Antibiotics

Antibiotics are used in animal feeding operations and can be expected to appear in animal wastes. The practice of feeding antibiotics to poultry, swine, and cattle evolved from the 1949 discovery that very low levels usually improved growth. Antibiotics are used both to treat illness and as feed additives to promote growth or to improve feed conversion efficiency. In 1991, an estimated 19 million pounds of antibiotics were used for disease prevention and growth promotion in animals. Between 60 and 80 percent of all livestock and poultry receive antibiotics during their productive lifespan. The primary mechanisms of elimination are in urine and bile. Essentially all of an antibiotic administered is eventually excreted, whether unchanged or in metabolite form. Little information is available regarding the concentrations of antibiotics in animal wastes, or on their fate and transport in the environment.

Of greater concern than the presence of antibiotics in animal manure is the development of antibiotic resistant pathogens. Use of antibiotics in raising animals, especially broad spectrum antibiotics, is increasing. As a result, more strains of antibiotic resistant pathogens are emerging, along with strains that are growing more resistant. Normally, about 2 percent of a bacterial population are resistant to a given antibiotic; however, up to 10 percent of bacterial populations from animals regularly exposed to antibiotics have been found to be resistant. In a study of poultry litter suitable for land application, about 80 to 100 percent of bacterial populations isolated from the litter were found to be resistant to multiple antibiotics. Antibiotic-resistant forms of *Salmonella, Campylobacter, E. coli,* and *Listeria* are known or suspected to exist. An antibiotic-resistant strain of the bacteria *Clostridium perfringens* was detected in the groundwater below plots of land treated with pig manure, while it was nearly absent beneath unmanured plots.

9. Pesticides and Hormones

Pesticides and hormones are compounds which are used in animal feeding operations and can be expected to appear in animal wastes. Both of these types of pollutants have been linked with endocrine disruption.

Pesticides are applied to livestock to suppress houseflies and other pests. There has been very little research on losses of pesticides in runoff from manured lands. A 1994 study showed that losses of cyromazine (used to control flies in poultry litter) in runoff increased with the rate of poultry manure applied and the intensity of rainfall.

Specific hormones are used to increase productivity in the beef and dairy industries. Several studies have shown hormones are present in animal manures. Poultry manure has been shown to contain both estrogen and testosterone. Runoff from fields with land-applied manure has been reported to contain estrogens, estradiol, progesterone, and testosterone, as well as their synthetic counterparts. In 1995, an irrigation pond and three streams in the Conestoga River watershed near the Chesapeake

Bay had both estrogen and testosterone present. All of these sites were affected by fields receiving poultry litter.

B. How Do These Pollutants Reach Surface Waters?

Pollutants found in animal manures can reach surface water by several mechanisms. These can be categorized as either surface discharges or other discharges. Surface discharges can occur as the result of runoff, erosion, spills, and dry-weather discharges. In surface discharges, the pollutant travels overland or through drain tiles with surface inlets to a nearby stream, river, or lake. Direct contact between confined animals and surface waters is another means of surface discharge. For other types of discharges, the pollutant travels via another environmental medium (groundwater or air) to surface water.

1. Surface Discharges

a. Runoff

Water that falls on man-made surfaces or soil and fails to be absorbed will flow across the surface and is called runoff. Surface discharges of manure pollutants can originate from feedlots and from overland runoff at land application sites. Runoff is especially likely at open-air feedlots if rainfall occurs soon after application, or if manure is over-applied, or misapplied. For example, experiments by Edwards and Daniels in the early 1990s show that, for all animal wastes, the application rate had a significant effect on the runoff concentration. In addition, manure applied to water-saturated or frozen soils is more likely to run off the soil surface. Other factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity or permeability, and close proximity to surface waters. Runoff of pollutants dissolved into rainwater is a significant transport mechanism for water soluble pollutants, which includes nitrate, nitrite, and organic forms of phosphorus.

Runoff of manure pollutants has been identified by states, citizen's groups, and the media as a factor in a number of documented impacts from AFOs, including hog, cattle, and chicken operations. For example, in 1994, multiple runoff problems were cited for a hog operation in Minnesota, and in 1996 runoff from manure spread on land was identified at hog and chicken operations in Ohio. In 1997, runoff problems were identified for several cattle operations in numerous counties in Minnesota. More discussion of runoff and its impacts on the environment and human health is provided later in this section.

b. Erosion

In addition to runoff, surface discharges can occur by erosion, in which the soil surface is worn away by the action of water or wind. Erosion is a significant transport mechanism for land-applied pollutants that are strongly sorbed to soils, of which phosphorus is one example. A 1999 report by the

Agricultural Research Service (ARS) noted that phosphorus bound to eroded sediment particles makes up 60 to 90 percent of phosphorus transported in surface runoff from cultivated land. For this reason, most agricultural phosphorus control measures have focused on soil erosion control to limit transport of particulate phosphorus. However, soils do not have infinite adsorption capacity for phosphate or any other adsorbing pollutant, and dissolved pollutants including phosphates can still enter waterways via runoff and leachate even if soil erosion is controlled.

In 1998, the USDA Natural Resources Conservation Service (NRCS) reviewed the manure production of a watershed in South Carolina. Agricultural activities in the project area are a major influence on the streams and ponds in the watershed, and contribute to nutrient-related water quality problems in the headwaters of Lake Murray. NRCS found that bacteria, nutrients, and sediment from soil erosion are the primary contaminants affecting these resources. The NRCS has calculated that soil erosion, occurring on over 13,000 acres of cropland in the watershed, ranges from 9.6 to 41.5 tons per acre per year.

c. Spills and Dry-Weather Discharges

Surface discharges can occur through spills or other discharges from lagoons. Some causes of spills include malfunctions such as pump failures, manure irrigation gun malfunctions, and pipes or retaining walls breaking. Manure entering tile drains has a direct route to surface water. (Tile drains are a network of pipes buried in fields below the root zone of plants to remove subsurface drainage water from the root zone to a stream, drainage ditch, or evaporation pond. EPA does not regulate most tile fields.) In 1997, the Ohio Department of Natural Resources documented chicken manure traveling through tile drains into a nearby stream. In addition, spills can occur as a result of lagoon overflows and washouts from floodwaters when lagoons are sited on floodplains. There are also indications that discharges from siphoning lagoons occur deliberately as a means to reduce the volume in overfull lagoons. Acute discharges of this kind frequently result in dramatic fish kills. In 1997, an independent review of Indiana Department of Environmental Management records indicated that the most common causes of waste releases in that state were intentional discharge and lack of operator knowledge, rather than spills due to severe rainfall conditions.

Numerous such dry-weather discharges have been identified. For example, in 1995, two separate discharges of 25 million gallons of manure from hog farms in North Carolina were documented, and both resulted in fish kills. Subsequent discharges of hundreds of thousands of gallons of manure were documented from hog operations in Iowa (1996), Illinois (1997), and Minnesota (1997). Fish kills were also reported as a result of two of these discharges. Discharges of over 8 million gallons of manure from a poultry operation in North Carolina in 1995 likewise resulted in a fish kill. Between 1994 and 1996, half a dozen discharges from poultry operations in Ohio resulted when manure entered field tiles. In 1998, 125,000 gallons of manure were discharged from a dairy feedlot in Minnesota.

d. Direct Contact between Confined Animals and Surface Water

Finally, surface discharges can occur as a result of direct contact between confined animals and the rivers or ponds that are located within their reach. Historically, farms were located near waterways for both water access for animals and discharge of wastes. This practice is now restricted for CAFOs; however, despite this restriction, enforcement actions are the primary means for reducing direct access.

In the more traditional farm production regions of the Midwest and Northeast, dairy barns and feedlots are often in close proximity to streams or other water sources. This close proximity to streams was necessary in order to provide drinking water for the dairy cows, direct access to cool the animals in hot weather, and to cool the milk prior to the wide-spread use of refrigeration. For CAFO-size facilities this practice is now replaced with more efficient means of providing drinking water for the dairy herd. In addition, the use of freestall barns and modern milking centers minimizes the exposure of dairy cows to the environment. For example, in New York direct access is more of a problem for the smaller traditional dairy farms that use older methods of housing animals.

In the arid west, feedlots are typically located near waterbodies to allow for cheap and easy stock watering. Many existing lots were configured to allow the animals direct access to the water. Certain animals, particularly cattle, will wade into the water, linger to drink, and will often urinate and defecate there as well. This direct deposition of manure and urine contributes greatly to water quality problems. Environmental problems associated with allowing farm animals access to waters that are adjacent to the production area are well documented in the literature. EPA Region X staff have documented dramatically elevated levels of *Escherichia coli* in rivers downstream of AFOs (including CAFOs) with direct access to surface water. Recent enforcement actions against direct access facilities have resulted in the assessment of tens of thousands of dollars in civil penalties.

2. Other Discharges to Surface Waters

a. Leaching to Groundwater

Leaching of land-applied pollutants such as nitrate dissolved into rainwater is a significant transport mechanism for water soluble pollutants. In addition, leaking lagoons are a source of manure pollutants to ground water. Although manure solids purportedly "self-seal" lagoons to prevent groundwater contamination, some studies have shown otherwise. A study for the Iowa legislature published in 1999 indicates that leaking is part of design standards for earthen lagoons and that all lagoons should be expected to leak. A 1995 survey of hog and poultry lagoons in the Carolinas found that nearly two-thirds of the 36 lagoons sampled had leaked into the groundwater. Even clay-lined lagoons have the potential to leak, since they can crack or break as they age, and can be susceptible to burrowing worms. In a three-year study (1988-1990) of clay-lined swine lagoons on the Delmarva Peninsula, researchers found that leachate from lagoons located in well-drained loamy sand had a severe impact on groundwater quality.

Pollutant transport to groundwater is also greater in areas with high soil permeability and shallow water tables. Percolating water can transport pollutants to groundwater, as well as to surface waters via interflow. Contaminated groundwater can deliver pollutants to surface waters through hydrologic connections. Nationally, about 40 percent of the average annual stream flow is from groundwater. In the Chesapeake Bay watershed, the U.S. Geological Survey (USGS) estimates that about half of the nitrogen loads from all sources to nontidal streams and rivers originate from groundwater.

b. Discharge to the Air and Subsequent Deposition

Discharges to air can occur as a result of volatilization of both pollutants already present in the manure and pollutants generated as the manure decomposes. Ammonia is very volatile, and can have significant impacts on water quality through atmospheric deposition. Other ways that manure pollutants can enter the air is from spray application methods for land applying manure and as particulates wind-borne in dust. Once airborne, these pollutants can find their way into nearby streams, rivers, and lakes. The 1998 *National Water Quality Inventory* indicates that atmospheric deposition is the third greatest cause of water quality impairment for estuaries, and the fifth greatest cause of water quality impairment for lakes, ponds, and reservoirs.

The degree of volatilization of manure pollutants is dependent on the manure management system. For example, losses are greater when manure remains on the land surface rather than being incorporated into the soil, and are particularly high when spray application is performed. Environmental conditions such as soil acidity and moisture content also affect the extent of volatilization. Losses are reduced by the presence of growing plants. Ammonia also readily volatilizes from lagoons.

Particulate emissions from AFOs may include dried manure, feed, epithelial cells, hair, and feathers. The airborne particles make up an organic dust, which includes endotoxin (the toxic protoplasm liberated when a microorganism dies and disintegrates), adsorbed gases, and possibly steroids. At least 50 percent of dust emissions from swine operations are believed to be respirable (small enough to be inhaled deeply into the lungs).

3. A National Study of Nitrogen Sources to Watersheds

In 1994, the USGS analyzed nitrogen sources to 107 watersheds. Potential sources included manure (both point and nonpoint sources), fertilizers, point sources, and atmospheric deposition The "manure" source estimates include waste from both confined and unconfined animals. As may be expected, the USGS found that proportions of nitrogen originating from various sources differ according to climate, hydrologic conditions, land use, population, and physical geography. Results of the analysis for selected watersheds for the 1987 base year show that in some instances, manure nitrogen is a large portion of the total nitrogen added to the watershed. The study showed that, for following nine watersheds, more than 25 percent of nitrogen originates from manure: Trinity River, Texas; White River, Arkansas; Apalachicola River, Florida; Altamaha River, Georgia; Potomac River, Washington, D.C.; Susquehanna River, Pennsylvania; Platte River, Nebraska; Snake River, Idaho; and San Joaquin River, California. Of these, California, Texas, Florida, Arkansas, and Idaho have large populations of confined animals.

4. State Level Studies of Feedlot Pollutants Reaching Surface Waters

There are many studies demonstrating surface water impacts from animal feeding operations. These impacts have been documented for at least the past decade. For example, in 1991, the U.S. Fish and Wildlife Service (FWS) reported on suspected impacts from a large number of cattle feedlots on Tierra Blanca Creek, upstream of the Buffalo Lake National Wildlife Refuge in the Texas Panhandle. FWS found elevated aqueous concentrations of ammonia, chemical oxygen demand, coliform bacteria, chloride, nitrogen, and volatile suspended solids; they also found elevated concentrations of the feed additives copper and zinc in the creek sediment.

According to Arkansas' 1996 Water Quality Inventory Report, a publication of the Arkansas Department of Environmental Protection, water in the Grand Neosho basin only partially supports aquatic life. Land uses there, primarily confined animal feeding operations including poultry production and pasture management, are major sources of nutrients and chronic high turbidity. Pathogens sampled in the Muddy Fork Hydrologic Unit Area, in the Arkansas River basin, also exceed acceptable limits for primary contact recreation (swimming). This problem was reported in the 1994 water quality inventory, and it, too, was traced to extensive poultry, swine, and dairy operations in the Moore's Creek basin. Essentially, all parts of the subwatershed are impacted by these activities. Currently, the Muddy Fork Hydrologic Unit Area Project is a USDA agricultural assistance, technology transfer, and demonstration project. A section 319 water quality monitoring operation is also ongoing in the hydrologic unit area.

In 1997, the Hoosier Environmental Council documented the reduction in biodiversity due to AFOs in a study of three Indiana stream systems. That study found that waters downstream of animal feedlots (mainly hog and dairy operations) contained fewer fish and a limited number of species of fish in comparison with reference sites. It also found excessive algal growth, altered oxygen content, and increased levels of ammonia, turbidity, pH, and total dissolved solids.

C. What Are the Potential and Observed Impacts?

Pollutants in animal manures can impair surface waters. Such impairments have resulted in fish kills; eutrophication and algal blooms; contamination of shellfish, and subsequent toxin and pathogen transmission up the food chain; increased turbidity and negative impacts to benthic organisms; and reduced biodiversity when rivers and streams become uninhabitable by resident species. These manure pollutants can also deteriorate soil quality and make it toxic to plants. In addition to these ecological impacts, pollutants in animal manures can present a range of risks to human health when they contaminate drinking water or shellfish, and when they are present in recreational waters.

1. Ecological Impacts

a. Fish Kills and Other Fishery Impacts

Fish kills are one of the most dramatic impacts associated with manure reaching surface water. Spills, dry-weather discharges, and runoff can carry pollutants in manure to rivers and streams and can result in serious fish kills. During the years 1987 through 1997, at least 47 incidents of fish kills have been associated with hog manure. Another 8 fish kills were attributed to poultry waste, and 2 with beef/dairy manure. An additional 20 fish kills were associated with animal manure for which one specific animal type was not identified. These incidents were reported by the Iowa Department of Natural Resources, the Maryland Department of the Environment, the Natural Resources Defense Council, several citizen's groups, and numerous newspapers. These incidents are not reflective of all states. In Illinois alone, records indicate that 171 fish kills attributable to manure discharges were investigated by Illinois Environmental Protection Agency personnel between 1979 and 1998. Thousands of fish are typically killed by one of these events.

Ammonia is highly toxic to aquatic life and is a leading cause of fish kills. In a May 1997 incident in Wabasha County, Minnesota, ammonia in a dairy cattle manure discharge killed 16,500 minnows and white suckers. Ammonia and other pollutants in manure exert a direct biochemical oxygen demand (BOD) on the receiving water. As ammonia is oxidized, dissolved oxygen is consumed. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills.

Nitrites pose additional risks to aquatic life: if sediments are enriched with nutrients, the concentrations of nitrites on the overlying water may be raised enough to cause nitrite poisoning or "brown blood disease" in fish.

Excess nutrients result in eutrophication (see section V.C.1.b, which follows). Eutrophication is associated with blooms of a variety of organisms that are toxic to both fish and humans. This includes the estuarine dinoflagellate *Pfiesteria piscicida*, which is implicated in several fish kills and fish disease events. *Pfiesteria* has been implicated as the primary causative agent of many major fish kills and fish disease events in North Carolina estuaries and coastal areas, as well as in Maryland and Virginia tributaries to the Chesapeake Bay. In 1997, hog operations were identified as a potential cause of a *Pfiesteria* outbreak in North Carolina rivers that resulted in 450,000 fish killed. Also that same year, poultry operations were linked to *Pfiesteria* outbreaks in the Pokomoke River and Kings Creek (both in Maryland) and in the Chesapeake Bay, in which tens of thousands of fish were killed.

The presence of estrogen and estrogen-like compounds in surface water has caused much concern. These hormones have been found in animal manures and runoff from fields where manure has been applied. The ultimate fate of hormones in the environment is unknown, although early studies indicate that common soil or fecal bacteria cannot metabolize estrogen. When present in high enough concentrations in the environment, hormones and other endocrine disruptors including pesticides are linked to reduced fertility, mutations, and the death of fish. Estrogen hormones have been implicated in widespread reproductive disorders in a variety of wildlife. There is evidence that fish in some streams are experiencing endocrine disruption and that contaminants including pesticides may be the cause, though there is no evidence linking these effects to CAFOs.

b. Eutrophication and Algal Growth

Eutrophication is the process in which phosphorus and nitrogen over-enrich water bodies and disrupt the balance of life in that water body. As a result, the excess nutrients cause fast-growing algae blooms. The 1998 *National Water Quality Inventory* indicates that excess algal growth is the seventh leading stressor in lakes, ponds, and reservoirs. Rapid growth of algae can lower the dissolved oxygen content of a water body to levels insufficient to support fish and invertebrates. Eutrophication can also affect phytoplankton and zooplankton population diversity, abundance, and biomass, and increase the mortality rates of aquatic species. Floating algal mats can reduce the penetration of sunlight in the water column and thereby limit growth of seagrass beds and other submerged vegetation. This in turn reduces fish and shellfish habitat. This reduction in submerged aquatic vegetation adversely affects both fish and shellfish populations.

Increased algal growth can also raise the pH of waterbodies, as algae consume dissolved carbon dioxide to support photosynthesis. This elevated pH can harm the gill epithelium of aquatic organisms. The pH may then drop rapidly at night, when algal photosynthesis stops. In extreme cases, such pH fluctuations can severely stress aquatic organisms.

Eutrophication is also a factor in the growth of toxic microorganisms, such as cyanobacteria (a toxic algae) and *Pfiesteria piscicida*, which can affect human health as well. Decay of algal blooms and night-time respiration can further depress dissolved oxygen levels, potentially leading to fish kills and reduced biodiversity. In addition, toxic algae such as cyanobacteria release toxins as they die, which can severely impact wildlife as well as humans. Researchers have documented stimulation of *Pfiesteria* growth by swine effluent discharges, and have shown that the organism's growth can be highly stimulated by both inorganic and organic nitrogen and phosphorus enrichments.

c. Wildlife Impacts

As noted earlier, reduction in submerged aquatic vegetation due to algal blooms is the leading cause of biological decline in Chesapeake Bay, adversely affecting both fish and shellfish populations. In marine ecosystems, blooms known as red or brown tides have caused significant mortality in marine mammals. In freshwater, cyanobacterial toxins have caused many incidents of poisoning of wild and domestic animals that have consumed impacted waters.

Even with no visible signs of the algae blooms, shellfish such as oysters, clams and mussels can carry the toxins produced by some types of algae in their tissue. Shellfish are filter feeders which pass large volumes of water over their gills. As a result, they can concentrate a broad range of microorganisms in their tissues. Concentration of toxins in shellfish provides a pathway for pathogen transmission to higher trophic organisms. Information is becoming available to assess the health effects of contaminated shellfish on wildlife receptors. Earlier this year, the death of over 400 California sea lions was linked to ingestion of mussels contaminated by a bloom of toxic algae. Previous incidents associated the deaths of manatees and whales with toxic and harmful algae blooms.

In August 1997, the National Oceanic and Atmospheric Administration (NOAA) released *The 1995 National Shellfish Register of Classified Growing Waters*. The register characterizes the status of 4,230 shellfish-growing water areas in 21 coastal states, reflecting an assessment of nearly 25 million acres of estuarine and non-estuarine waters. NOAA found that 3,404 shellfish areas had some level of impairment. Of these, 110 (3 percent) were impaired to varying degrees by feedlots, and 280 (8 percent) were impaired by “other agriculture” which could include land where manure is applied.

Avian botulism and avian cholera have killed hundreds of thousands of migratory waterfowl in the past. Although outbreaks of avian botulism have occurred since the beginning of the century, most occurrences have been reported in the past twenty years, which coincides with the trend toward fewer and larger AFOs. The connection between nutrient runoff, fish kills, and subsequent outbreaks of avian botulism was made in 1999 at California’s Salton Sea, when almost 8 million fish died in one day. The fish kill was associated with runoff from surrounding farms, which carried nutrients and salts into the Salton Sea. Those nutrients caused algae blooms which in turn lead to large and sudden fish kills. Since the 1999 die off, the number of endangered brown pelicans infected with avian botulism increased to about 35 birds a day. In addition, bottom feeding birds can be quite susceptible to metal toxicity, because they are attracted to shallow feedlot wastewater ponds and waters adjacent to feedlots. Metals can remain in aquatic ecosystems for long periods of time because of adsorption to suspended or bed sediments or uptake by aquatic biota.

Reduction in biodiversity due to AFOs has been documented in a 1997 study of three Indiana stream systems. That study shows that waters downstream of animal feedlots (mainly hog and dairy operations) contained fewer fish and a limited number of species of fish in comparison with reference sites. The study also found excessive algal growth, altered oxygen content, and increased levels of ammonia, turbidity, pH, and total dissolved solids. Multi-generation animal studies have found decreases in birth weight, post-natal growth, and organ weights among mammals prenatally exposed to nitrite. Finally, hormones and pesticides have been implicated in widespread reproductive disorders in a variety of wildlife.

d. Other Aquatic Ecosystem Imbalances

Changes to the pH balance of surface water also threaten the survival of the fish and other aquatic organisms. Data from Sampson County, North Carolina show that "ammonia rain" has increased as the hog industry has grown, with ammonia levels in rain more than doubling between 1985 and 1995. In addition, excess nitrogen can contribute to water quality decline by increasing the acidity of surface waters.

In fresh waters, increasing salinity can also disrupt the balance of the ecosystem, making it difficult for resident species to remain. Salts also contribute to the degradation of drinking water supplies.

Trace elements (e.g., arsenic, copper, selenium, and zinc) may also present ecological risks. Antibiotics, pesticides, and hormones may have low-level, long-term ecosystem effects.

2. Drinking Water Impacts

Nitrogen in manure is easily transformed into nitrate form, which can be transported to drinking water sources and present a range of health risks. In 1990, PA found that nitrate is the most widespread agricultural contaminant in drinking water wells, and estimated that 4.5 million people are exposed to elevated nitrate levels from wells. In 1995, several private wells in North Carolina were found to be contaminated with nitrates at levels 10 times higher than the State's health standard; this contamination was linked with a nearby hog operation. The national primary drinking water standard (Maximum Contaminant Level, or MCL) for nitrogen (nitrate, nitrite) is 10 milligrams per liter (mg/L). In 1982, nitrate levels greater than 10 mg/L were found in 32 percent of the wells in Sussex County, Delaware; these levels were associated with local poultry operations. In southeastern Delaware and the Eastern Shore of Maryland, where poultry production is prominent, over 20 percent of wells were found to have nitrate levels exceeding 10 mg/L. Nitrate is not removed by conventional drinking water treatment processes. Its removal requires additional, relatively expensive treatment units.

Algae blooms triggered by nutrient pollution can affect drinking water by clogging treatment plant intakes, producing objectionable tastes and odors, and increasing production of harmful chlorinated byproducts (e.g., trihalomethanes) by reacting with chlorine used to disinfect drinking water. As aquatic bacteria and other microorganisms degrade the organic matter in manure, they consume dissolved oxygen. This can lead to foul odors and reduce the water's value as a source of drinking water. Increased organic matter in drinking water sources can also lead to excessive production of harmful chlorinated byproducts, resulting in higher drinking water treatment costs.

Pathogens can also threaten drinking water sources. Surface waters are typically expected to be more prone than groundwater to contamination by pathogens such as *Escherichia coli* and *Cryptosporidium parvum*. However, groundwater in areas of sandy soils, limestone formations, or sinkholes are particularly vulnerable. In a 1997 survey of drinking water standard violations in six states over a four-year period, the U.S. General Accounting Office noted in its 1997 report *Drinking Water: Information on the Quality of Water Found at Community Water Systems and Private Wells* that bacterial standard violations occurred in up to 6 percent of community water systems each year and in up to 42 percent of private wells. (Private wells are more prone than public wells to contamination, since they tend to be shallower and therefore more susceptible to contaminants leaching from the surface.) In cow pasture areas of Door County, Wisconsin, where a thin topsoil layer is underlain by fractured limestone bedrock, groundwater wells have commonly been shut down due to high bacteria levels.

Each of these impacts can result in increased drinking water treatment costs. For example, California's Chino Basin estimates a cost of over $1 million per year to remove the nitrates from drinking water due to loadings from local dairies. Salt load into the Chino Basin from local dairies is over 1,500 tons per year, and the cost to remove that salt by the drinking water treatment system ranges from $320 to $690 for every ton. In Iowa, Des Moines Water Works planned to spend approximately $5 million in the early 1990's to install a treatment system to remove nitrates from their main sources of drinking water, the Raccoon and Des Moines Rivers. Agriculture was cited as a major source of the nitrate contamination, although the portion attributable to animal waste is unknown. In Wisconsin, the City of Oshkosh has spent an extra $30,000 per year on copper sulfate to kill the algae in the water it draws from Lake Winnebago. The thick mats of algae in the lake have been attributed to excess nutrients from manure, commercial fertilizers, and soil. In Tulsa, Oklahoma, excessive algal growth in Lake Eucha is associated with poultry farming. The city spends $100,000 per year to address taste and odor problems in the drinking water.

3. Human Health Impacts

Human and animal health impacts are primarily associated with drinking contaminated water, contact with contaminated water, and consuming contaminated shellfish.

a. Nutrients

The main hazard to human health from nutrients is elevated nitrate levels in drinking water. In particular, infants are at risk from nitrate poisoning (also referred to as methemoglobinemia or "blue baby syndrome"), which results in oxygen starvation and is potentially fatal. Nitrate toxicity is due to its metabolite nitrite, which is formed in the environment, in foods, and in the human digestive system. In addition to blue baby syndrome, low blood oxygen due to methemoglobinemia has also been linked to birth defects, miscarriages, and poor health in humans and animals. These effects are exacerbated by concurrent exposure to many species of bacteria in water.

Studies in Australia compiled in a 1993 review by Bruning-Fann and Kaneene showed an increased risk of congenital malformations with consumption of high-nitrate groundwater. Multi-generation animal studies have found decreases in birth weight and post-natal growth and organ weights associated with nitrite exposure among prenatally exposed mammals. Nitrate- and nitrite-containing compounds also have the ability to cause hypotension or circulatory collapse. Nitrate metabolites such as N-nitroso compounds (especially nitrosamines) have been linked to severe human health effects such as gastric cancer.

Eutrophication can also affect human health by enhancing growth of harmful algal blooms that release toxins as they die. In marine ecosystems, harmful algal blooms such as red tides can result in human health impacts via shellfish poisoning and recreational contact. In freshwater, blooms of cyanobacteria (blue-green algae) may pose a serious health hazard to humans via water consumption. When cyanobacterial blooms die or are ingested, they release water-soluble compounds that are toxic to the nervous system and liver. Algal blooms can also increase production of harmful chlorinated byproducts (e.g., trihalomethanes) by reacting with chlorine used to disinfect drinking water. These substances can result in increased health risks.

b. Pathogens

Livestock manure has been identified as a potential source of pathogens by public health officials. Humans may be exposed to pathogens via consumption of contaminated drinking water and shellfish, or by contact and incidental ingestion during recreation in contaminated waters. Relatively few microbial agents are responsible for the majority of human disease outbreaks from water-based exposure routes. Intestinal infections are the most common type of waterborne infection, and affect the most people. A May, 2000 outbreak of *Escherichia coli* O157:H7 in Walkerton, Ontario resulted in at least seven deaths and 1,000 cases of intestinal problems; public health officials theorize that flood waters washed manure contaminated with *E. coli* into the town's drinking water well.

A study for the period 1989 to 1996 revealed that infections caused by the protozoa *Giardia sp.* and *Cryptosporidium parvum* were the leading cause of infectious water-borne disease outbreaks in which an agent was identified. *C. parvum* is particularly associated with cows, and can produce gastrointestinal illness, with symptoms such as severe diarrhea. Healthy people typically recover relatively quickly from gastrointestinal illnesses such as cryptosporidiosis, but such diseases can be fatal in people with weakened immune systems. This subpopulation includes children, the elderly, people with HIV infection, chemotherapy patients, and those taking medications that suppress the immune system. In Milwaukee, Wisconsin in 1993, *C. parvum* contamination of a public water supply caused more than 100 deaths and an estimated 403,000 illnesses. The source was not identified, but possible sources include runoff from cow manure application sites.

In 1999, an *E. coli* outbreak occurred at the Washington County Fair in New York State. This outbreak, possibly the largest waterborne outbreak of *E. coli* O157:H7 in U.S. history, took the lives of two fair attendees and sent 71 others to the hospital. An investigation identified 781 persons with confirmed or suspected illness related to this outbreak. The outbreak is thought to have been caused by contamination of the Fair's Well 6 by either a dormitory septic system or manure runoff from the nearby Youth Cattle Barn.

Contact with pathogens during recreational activities in surface water can also result in infections of the skin, eye, ear, nose, and throat. In 1989, ear and skin infections and intestinal illnesses were reported in swimmers as a result of discharges from a dairy operation in Wisconsin.

As discussed in the previous section, excess nutrients result in eutrophication, which is associated with the growth of a variety of organisms that are toxic to humans either through ingestion or contact. This includes the estuarine dinoflagellate *Pfiesteria piscicida.* While *Pfiesteria* is primarily associated with fish kills and fish disease events, the organism has also been linked with human health impacts through dermal exposure. Researchers working with dilute toxic cultures of *Pfiesteria* exhibited symptoms such as skin sores, severe headaches, blurred vision, nausea/vomiting, sustained difficulty breathing, kidney and liver dysfunction, acute short-term memory loss, and severe cognitive impairment. People with heavy environmental exposure have exhibited symptoms as well. In a 1998 study, such environmental exposure was definitively linked with cognitive impairment, and less consistently linked with physical symptoms.

Even with no visible signs of the algae blooms, shellfish such as oysters, clams and mussels can carry the toxins produced by some types of algae in their tissue. These can then affect people who eat the contaminated shellfish. *The 1995 National Shellfish Register of Classified Growing Waters* published by the National Oceanic and Atmospheric Administration (NOAA) identifies over 100 shellfish bed impairments (shellfish not approved for harvest) due to feedlots.

c. Trace Elements

Some of the trace elements in manure are essential nutrients for human physiology; however, they can induce toxicity at elevated concentrations. These elements include the feed additives zinc, arsenic, copper, and selenium. Although these elements are typically present in relatively low concentrations in manure, they are of concern because of their ability to persist in the environment and to bioconcentrate in plant and animal tissues. These elements could pose a hazard if manure is overapplied to land.

Trace elements are associated with a variety of illnesses. For example, arsenic is carcinogenic to humans, based on evidence from human studies; some of these studies have found increased skin cancer and mortality from multiple internal organ cancers in populations who consumed drinking water with high levels of inorganic arsenic. Arsenic is also linked with noncancer effects, including hyperpigmentation and possible vascular complications. Selenium is associated with liver dysfunction and loss of hair and nails, and zinc can result in changes in copper and iron balances, particularly copper deficiency anemia.

d. Odors

Odor is a significant concern because of its documented effect on moods, such as increased tension, depression, and fatigue. Odor also has the potential for vector attraction, and has been associated with a negative impact on property values. Additionally, many of the odor-causing compounds in manure can cause physical health impacts. For example, hydrogen sulfide is toxic, and ammonia gas is a nasal and respiratory irritant.

4. Recreational Impacts

As discussed above, CAFO pollutants contribute to the increase in turbidity, increase in eutrophication and algal blooms, and reduction of aquatic populations in rivers, lakes, and estuaries. Impaired conditions interfere with recreational activities and aesthetic enjoyment of these water bodies. Recreational activities include fishing, swimming, and boating. Fishing is reduced when fish populations decrease. Swimming is limited by increased risk of infection when pathogens are present. Boating and aesthetic enjoyment decline with the decreased aesthetic appeal caused by loss of water clarity and water surfaces clogged by algae. These impacts are more fully discussed in Section XI of this preamble.

VI. What Are Key Characteristics of the Livestock and Poultry Industries?

A. Introduction and Overview

1. Total Number and Size of Animal Confinement Operations

USDA reports that there were 1.1 million livestock and poultry farms in the United States in 1997. This number includes all operations that raise beef, dairy, pork, broilers, egg layers, and turkeys, and includes both confinement and non-confinement (grazing and rangefed) production. Only operations that raise animals in confinement will be subject to today's proposed regulations.

For many of the animal sectors, it is not possible to precisely determine what proportion of the total livestock operations are confinement operations and what proportion are grazing operations only. Data on the number of beef and hog operations that raise animals in confinement are available from USDA. Since most large dairies have milking parlors, EPA assumes that all dairy operations are potentially confinement operations. In the poultry sectors, there are few small non-confinement operations and EPA assumes that all poultry operations confine animals. EPA's analysis focuses on the largest facilities in these sectors only.