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Environmental and Economic Benefit Analysis of Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations

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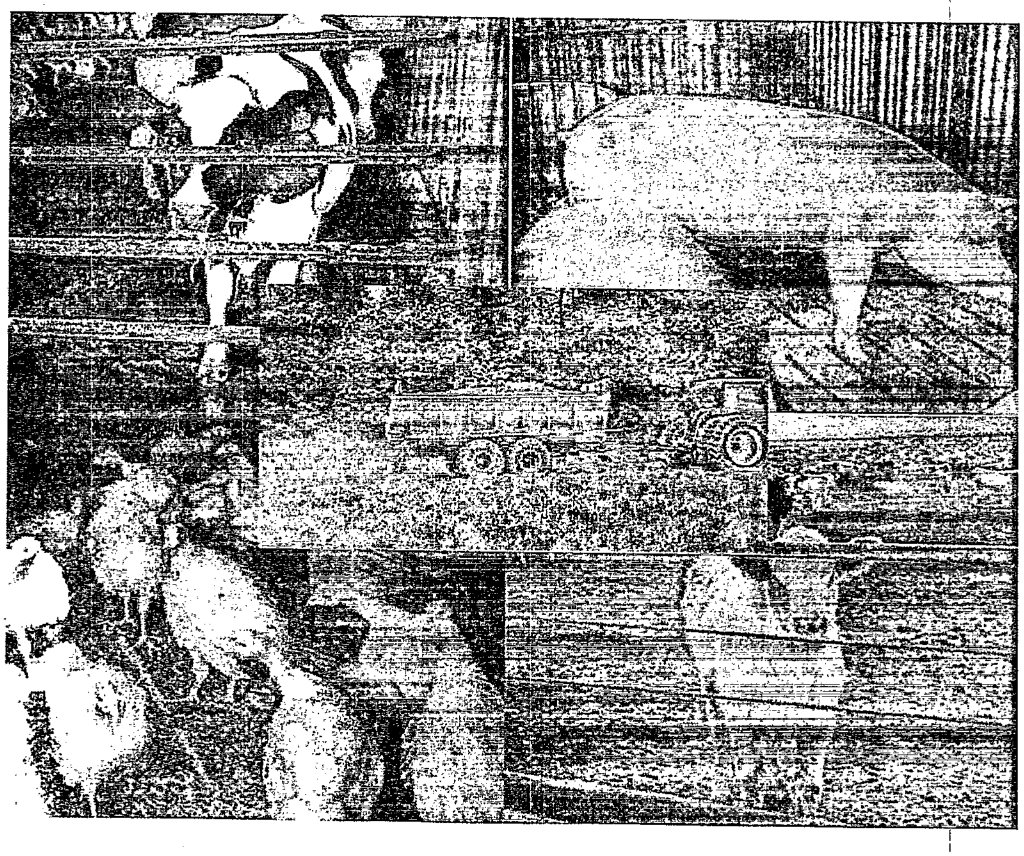

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ENVIRONMENTAL AND ECONOMIC BENEFIT ANALYSIS OF FINAL REVISIONS TO THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM REGULATION AND THE EFFLUENT GUIDELINES FOR CONCENTRATED ANIMAL FEEDING OPERATIONS

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EXECUTIVE SUMMARY

This report presents EPA's estimates of the environmental and human health benefits, including pollutant reductions, that will occur from the Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations (final rule).

A number of the practices used to manage animal wastes at concentrated animal feeding operations (CAFOs) can have adverse impacts on the environment. For example, waste lagoons that are not properly managed can leak or overflow; land application of manure can exceed the ability of the land to absorb nutrients; and management of large quantities of litter in uncovered outdoor stacks can allow excessive runoff during rain events. All of these practices can result in releases of manure to surface waters, where nutrients, solids, and pathogens in the waste cause damage to aquatic life (including large fish kills) and risks to human health from drinking or swimming in contaminated water. Releases can also cause degradation of groundwater and air-related impacts. The severity of potential environmental and health impacts can be exacerbated when operations are very large or are concentrated geographically. Recent industry trends have resulted both in larger operations (i.e., with more animals) and in greater regional concentration of facilities.

Several recent events, including large manure releases in North Carolina and incidences of drinking water contamination related to livestock, have highlighted the need to update regulations to improve management of animal wastes. Moreover, emerging research on the health effects of various compounds (e.g., hormones) found in manure suggests that the impact of manure on human and animal populations may be broader than previously understood.

USDA estimates that in 1997 manure generation from all livestock and poultry production totaled 1.1 billion tons — six times the waste generated by humans in the United States. Confined animals account for roughly half (500 million tons) of the animal waste produced. While strict pollutant discharge limits have been applied to human waste treatment facilities for years, regulation for animal waste, even of large CAFOs that generate as much waste as a small town, has typically been less stringent.

EPA's final rule expands the scope and extends the requirements of the current regulations addressing CAFOs. EPA has developed this rule to respond to pollution problems associated with animal waste management that have occurred even in the presence of existing regulations. Specifically, manure land application requirements under existing effluent guidelines do not ensure that manure is applied at rates that prevent excessive nutrients from migrating into surface waters. In addition, the current regulations do not address a number of facility types (e.g., dry poultry operations) that have emerged or become more prevalent due to changes in the industry since 1976. The final rule specifies more stringent animal waste management practices than are currently required at regulated facilities, and also extends these requirements to a number of facilities that are not currently regulated.

SUMMARY OF BENEFITS

EPA's economic analysis of the benefits of the revised CAFO standards focuses solely on the benefits attributable to changes in regulations governing Large CAFOs. Exhibit ES-1 summarizes these benefits on an annualized basis. The total benefits associated with requirements for Large CAFOs exceed the range of $204 + [B] million to $355 + [B] million. The values presented in the range represent those benefits for which EPA is able to quantify and determine an economic value. The factor "B" refers to the benefits identified by EPA that cannot be quantified at this time. EPA has identified substantial additional environmental benefits that will result from the rule, but is unable to attribute a specific economic value to these additional benefits.

Exhibit ES-1

ANNUALIZED BENEFITS OF THE REVISED REGULATORY STANDARDS FOR LARGE CAFOS*
(millions of 2001$)

Types of Benefits	3 Percent Discount Rate	7 Percent Discount Rate
Recreational and non-use benefits from improved water quality in rivers and streams	$166.2 - $298.6	$166.2 - $298.6
Reduced fish kills	$0.1	$0.1
Improved shellfish harvests	$0.3 - $3.4	$0.3 - $3.4
Reduced nitrate contamination of private wells	$45.7	$30.9
Reduced contamination of animal water supplies	$5.3	$5.3

Exhibit ES-1

ANNUALIZED BENEFITS OF THE REVISED REGULATORY STANDARDS FOR LARGE CAFOS*
(millions of 2001$)

Types of Benefits	3 Percent Discount Rate	7 Percent Discount Rate
Reduced eutrophication of estuaries and coastal waters	not monetized	not monetized
Case study of potential recreational fishing benefits to the Albemarle-Pamlico Estuary	$0.2	$0.2
Reduced public water treatment costs	$1.1 - $1.7	$1.1 - $1.7
Reduced pathogen contamination of private & public underground sources of drinking water	not monetized	not monetized
Reduced human & ecological risks from antibiotics, hormones, metals, salts	not monetized	not monetized
Improved soil properties	not monetized	not monetized
Other benefits	not monetized	not monetized
Total Benefits	$218.9 + [B] to $355.0 + [B]**	$204.1 + [B] to $340.2 + [B]**

* Benefit estimates do not include reduced impacts from medium-sized CAFOs.
** [B] represents non-monetized benefits of the rule.

KEY FEATURES OF THE FINAL RULE

EPA is revising both the National Pollutant Discharge Elimination System (NPDES) regulations for CAFOs and the Effluent Limitation Guidelines (ELGs) for feedlots. The revised NPDES regulations for CAFOs affect which animal feeding operations (AFOs) are defined as CAFOs and are therefore subject to the NPDES permit program. Changes to the ELGs for feedlots affect which technology-based requirements will apply to certain CAFOs.

Operations Regulated under Final Rule

USDA reports that there were 1.2 million livestock and poultry operations in the United States in 1997. This number includes all operations that raise beef or dairy cattle, hogs, chickens (broilers or layers), and turkeys, and includes both confinement and non-confinement (i.e., grazing and rangefed) production. Of these, EPA estimates that there are about 238,000 AFOs that raise or house animals in confinement. EPA has further estimated that 15,198 facilities will be CAFOs subject to the final rule, based on the number of facilities that discharge or have the potential to discharge to U.S. waters and which meet the minimum size thresholds (i.e., number of animals) defined by the revised regulations (Exhibit ES-2).

Exhibit ES-2

ESTIMATED NUMBER OF CAFOS SUBJECT TO REVISED REGULATIONS*

Production Sector	Currently Regulated	Regulated Under New Rule		
		Large CAFOs	Medium CAFOs	Total
Beef	1,940	1,766	174	1,940
Dairy	3,399	1,450	1,949	3,399
Heifers	0	242	230	472
Veal	0	12	7	19
Swine	5,409	3,924	1,485	5,409
Layers	433	1,112	50	1,162
Broilers	683	1,632	520	2,152
Turkeys	425	388	37	425
Horses	195	195	0	195
Ducks	21	21	4	25
Total	**12,505**	**10,742**	**4,456**	**15,198**

* AFOs that stable or confine animals in different sectors are counted more than once.

Definition of CAFO under the Final Rule

EPA's final rule defines CAFOs in three categories: Large, Medium, and Small (see Exhibit ES-3 for the size standards). The revised regulations require all large CAFOs to apply for an NPDES permit. This includes several types of operations that were previously not considered CAFOs, including: large facilities that discharge only as the result of a large storm event; large "dry" poultry operations; and stand-alone immature swine or heifer operations. In the rare event that a large CAFO has no potential to discharge, the new requirements provide a process for a demonstration to that effect, in lieu of obtaining a permit.

Medium-size AFOs are defined as CAFOs only if they meet one of two specific criteria governing the method of discharge:

- Pollutants are discharged into waters of the United States through a manmade ditch, flushing system, or other similar man-made device; or
- Pollutants are discharged directly into waters of the United States that originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the confined animals.

Exhibit ES-3

SIZE STANDARDS FOR LARGE, MEDIUM, AND SMALL CAFOS

Sector	**Large**	**Medium**[1]	**Small**[2]
Mature Dairy Cattle	more than 700	200 - 700	less than 200
Veal Calves	more than 1,000	300 - 1,000	less than 300
Cattle or Cow/Calf Pairs	more than 1,000	300 - 1,000	less than 300
Swine (weighing over 55 pounds)	more than 2,500	750 - 2,500	less than 750
Swine (weighing less than 55 pounds)	more than 10,000	3,000 - 10,000	less than 3,000
Horses	more than 500	150 - 500	less than 150
Sheep or Lambs	more than 10,000	3,000 - 10,000	less than 3,000
Turkeys	more than 55,000	16,500 - 55,000	less than 16,500
Chickens (liquid manure handling systems)- includes Laying Hens	more than 30,000	9,000 - 30,000	less than 9,000
Chickens Other than Laying Hens (other than liquid manure handling)	more than 125,000	37,500 - 125,000	less than 37,500
Laying Hens (other than liquid manure handling)	more than 82,000	25,000 - 82,000	less than 25,000
Ducks (dry operations)	more than 30,000	10,000 - 30,000	less than 10,000
Ducks (wet operations)	more than 5,000	1,500 - 5,000	less than 1,500

[1] Must also meet one of two criteria to be defined as a CAFO.
[2] Must be designated by EPA or the State permit authority.

Similarly, small facilities are considered CAFOs only if they are designated as such by EPA or the State NPDES permit authority. Such designation must be based on a determination that a facility is a significant contributor of pollutants to waters of the United States. On identical grounds, medium-size operations that are not CAFOs by definition may also be designated as CAFOs.

Under the final rule all CAFOs, regardless of size, must apply for an NPDES permit and must develop and implement a nutrient management plan. Such plans must identify practices necessary to demonstrate compliance with the effluent limitation guideline (if applicable), and include requirements to land apply manure and wastewater in a manner consistent with technical standards for nutrient management established to ensure appropriate utilization of nutrients.

Effluent Limitation Guidelines under the Final Rule

EPA's final rule also applies revised effluent guidelines to large CAFOs; for other permitted facilities, technology-based discharge limits will be established on the basis of the permit writer's best professional judgment. The key feature of these requirements is prohibition of discharge of manure and other process wastewater from the production area.[1] An exception to this restriction is made for rainfall-related overflows from facilities that are designed, constructed, operated, and maintained to contain all process wastewater and runoff from a 25-year, 24-hour (or more severe) rainfall event. In addition, the ELG requires all large CAFOs to comply with best management practices to ensure the proper application of manure, including a requirement to apply manure at rates based on technical standards for nutrient management.[2]

ENVIRONMENTAL IMPACTS ADDRESSED UNDER THE FINAL RULE

The release of pollutants in animal waste from CAFOs to surface water, groundwater, soil, and air is associated with a range of human health and ecological impacts, and contributes to the degradation of the nation's surface water. Data collected for EPA's 2000 *National Water Quality Inventory*, prepared under Section 305(b) of the Clean Water Act, identify agriculture (including irrigated and non-irrigated crop production, rangeland, feedlots, pastureland, and animal holding areas) as the leading contributor to identified water quality impairments in the nation's rivers and lakes, and the fifth leading contributor to identified water quality impairments in the nation's estuaries. The data indicate that the agricultural sector contributes to the impairment of at least 129,000 river miles, 3.2 million lake acres, and over 2,800 square miles of estuary. Animal feeding operations are only a subset of the agriculture category, but 29 states specifically identified animal feeding operations as contributing to water quality impairment. Finally, the data also identify the

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[1] The production area of an AFO includes the animal confinement area, the litter or manure storage area, the raw materials storage area, and the waste containment area.

[2] These requirements apply to any land under the control of the owner or operator of the production area — whether it is owned, rented, or leased — to which manure and wastewater from the production area is applied.

key pollutants and stressors that impair the nation's waters. Among the most problematic pollutants are several - including pathogens, nutrients, and oxygen depleting substances - that are associated commonly, although not exclusively, with animal waste.

Key Pollutants in Animal Waste

The primary pollutants associated with animal wastes 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. Exhibit ES-4 describes the key pollutants in animal waste, the pathways by which they reach the environment, and their potential impacts.

Exhibit ES-4

KEY POLLUTANTS IN ANIMAL WASTE

Pollutant	Description of Pollutant Forms in Animal Waste	Pathways	Potential Impacts
Nutrients			
Nitrogen	Exists in fresh manure in organic (e.g., urea) and inorganic forms (e.g., ammonium and nitrate). Microbes transform organic nitrogen to inorganic forms that may be absorbed by plants.	▸ Overland discharge ▸ Leachate into groundwater ▸ Atmospheric deposition as ammonia	▸ Eutrophication ▸ Animal, human health effects
Phosphorus	Exists in both organic and inorganic forms. As manure ages, phosphorus mineralizes to inorganic phosphate compounds that may be absorbed by plants.	▸ Overland discharge ▸ Leachate into groundwater (water soluble forms)	▸ Eutrophication
Potassium	Most potassium in manure is in an inorganic form available for absorption by plants; it can also be stored in soil for future uptake.	▸ Overland discharge ▸ Leachate into groundwater	▸ Increased salinity
Organic Compounds	Carbon-based compounds in manure that are decomposed by soil and surface water micro-organisms. Creates biochemical oxygen demand, or BOD, because decomposition consumes dissolved oxygen in the water.	▸ Overland discharge	▸ Depletion of dissolved oxygen ▸ Reduction in aquatic life ▸ Eutrophication
Solids	Includes manure itself and other elements (e.g., feed, bedding, hair, feathers, and corpses).	▸ Overland discharge ▸ Atmospheric deposition	▸ Turbidity ▸ Siltation
Pathogens	Includes range of disease-causing organisms, including bacteria, viruses, protozoa, fungi, and algae. Some pathogens are found in manure, others grow in surface water due to increased nutrients and organic matter.	▸ Overland discharge ▸ Growth in waters with high nutrient, organic materials	▸ Animal, human health effects

Exhibit ES-4

KEY POLLUTANTS IN ANIMAL WASTE

Pollutant	Description of Pollutant Forms in Animal Waste	Pathways	Potential Impacts
Salts	Includes cations sodium, potassium, calcium, and magnesium; and anions chloride, sulfate, bicarbonate, carbonate, and nitrate.	▸ Overland discharge ▸ Leachate into groundwater	▸ Reduction in aquatic life ▸ Human health effects ▸ Soil impacts
Trace Elements	Includes feed additives arsenic, copper, selenium, zinc, cadmium; and trace metals molybdenum, nickel, lead, iron, manganese, aluminum, and boron (pesticide ingredients).	▸ Overland discharge	▸ Toxicity at high levels
Volatile Compounds	Includes carbon dioxide, methane, nitrous oxide, hydrogen sulfide, and ammonia gases generated during decomposition of waste.	▸ Inhalation ▸ Atmospheric deposition of ammonia	▸ Human health effects ▸ Eutrophication ▸ Global warming
Other Pollutants	Includes pesticides, antibiotics, and hormones used in feeding operations.	▸ Overland discharge	▸ *Impacts unknown*

Pollutant Pathways

Pollutants in animal waste and manure enter the environment through a number of pathways, including surface runoff and erosion, direct discharges to surface water, spills and other dry-weather discharges, leaching into soil and ground water, and releases to air (including subsequent redeposition to land and surface waters). Releases of manure pollutants can originate from animal confinement areas, manure handling and containment systems, manure stockpiles, and from cropland where manure is spread.

Runoff and erosion occur during rainfall, when rain water carries pollutants over land to surface waters. Runoff of animal wastes is more likely when rainfall occurs soon after application and when manure is over-applied or misapplied. Erosion can be a significant transport mechanism for land applied pollutants, such as phosphorus, that are strongly bonded to soils.

Direct discharge of pollutants to surface water occurs when animals have access to water bodies and when manure storage areas overflow. Dry weather discharges to surface waters result from accidental (or intentional) discharges from lagoons and irrigation systems. Other discharges to surface waters include overflows from containment systems following rainfall, catastrophic spills from failure of manure containment systems, washouts from floodwaters, or equipment malfunction, such as pump or irrigation gun failure.

Discharge to groundwater occurs when water traveling through the soil to ground water carries with it pollutants (e.g., nitrates) from livestock and poultry wastes on the surface. Leaking lagoons are also a potential source of manure pollutants in ground water.

Air releases of CAFO pollutants result from volatilization of manure constituents and the products of manure decomposition. Alternatively, manure pollutants can enter the air through spray irrigation systems and as particulates wind-borne in dust. Once airborne, these pollutants can settle in nearby water bodies, or can be directly inhaled.

Impacts of Pollutants in Animal Waste

The most dramatic ecological impacts associated with manure pollutants in surface waters are massive fish kills. Incomplete records indicate that every year dozens of fish kills associated with AFOs result in the deaths of hundreds of thousands of fish. In addition, manure pollutants such as nutrients and suspended solids can seriously disrupt aquatic systems by over-enriching water (in the case of nutrients) or by increasing turbidity (in the case of solids). Excess nutrients cause fast-growing algae blooms that reduce the penetration of sunlight in the water column, and reduce the amount of available oxygen in the water, reducing fish and shellfish habitat and affecting fish and invertebrates. Manure pollutants can also encourage the growth of toxic organisms, including *Pfiesteria*, which has also been associated with fish kills and fish disease events. Reduction in biodiversity due to animal feeding operations has also been documented; for example, a study of three Indiana stream systems found fewer fish and more limited diversity of fish species downstream of CAFOs than were found downstream of study reference sites.

A variety of pollutants in animal waste can also affect human health. Manure contains over 100 human pathogens; contact with some of these pathogens during recreational activities in surface water can result in infections of the skin, eye, ear, nose, and throat. Eutrophication due to excess nutrients can also promote blooms of a variety of organisms that are toxic to humans either through ingestion or contact. This includes the 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. Finally, even with no visible signs of algae blooms, shellfish such as oysters, clams and mussels can carry toxins produced by some types of algae in their tissue. These can affect people who eat contaminated shellfish.

Contaminants from manure, including nitrogen, algae, and pathogens, can also affect human health through drinking water sources and can result in increased drinking water treatment costs. For example, nitrogen in manure can be transported to drinking water as nitrates, which are associated with human health risks. EPA has identified nitrate as the most widespread agricultural contaminant in drinking water wells. Algae blooms triggered by nutrient pollution can affect drinking water by clogging treatment plant intakes, producing objectionable tastes and odors; and reacting with the chlorine used to disinfect drinking water to produce harmful chlorinated byproducts (e.g., trihalomethanes).

REDUCTIONS IN POLLUTANT DISCHARGES UNDER THE FINAL RULE

EPA's analysis of pollutant discharges under the final rule addresses changes in pollutant discharges occurring at the production area, and also changes in the quantity of pollutants in runoff from land on which manure has been applied. Estimates of pollutant discharges from these manure application sites, or "edge-of-field" loadings, include nutrients, metals, pathogens, and sediment for both pre-rule conditions (baseline) and post-rule conditions. EPA estimated reductions in pollutant discharges using the Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model, which uses information on soil characteristics and climate, along with characteristics of the applied manure and commercial fertilizers, to estimate losses of nutrients, metals, pathogens, and sediment in surface runoff, sediment, and ground water leachate.

EPA used GLEAMS to quantify the reduction of nitrogen and phosphorus loads, and reductions of discharges of zinc, copper, cadmium, nickel, lead, and arsenic. Fecal coliform and Fecal streptococcus were used as surrogates to estimate pathogen reductions that would likely be achieved by this rule. Table ES-5 presents the results of these analyses.

Exhibit ES-5

EDGE OF FIELD LOADING REDUCTIONS FOR LARGE CAFOS: COMBINED TOTAL FOR ALL ANIMAL SECTORS

Parameter/Units	Baseline Pollutant Loading (Pre-regulation)	Post-regulation Pollutant Loading	Pollutant Reduction	
			Units	Percent
Nutrients (million lb.)	658	503	155	24
Metals (million lb.)	20	19	1	5
Pathogens (10^{19} cfu)	5,784	3,129	2,655	46
Sediment (million lb.)	35,493	33,434	2,059	6

APPROACHES TO ANALYZING BENEFITS OF THE FINAL RULE

EPA has analyzed the water quality improvements attributable to the regulation of large CAFOs under the final rule and has estimated the environmental and human health benefits of the pollutant reductions that will result. The monetized benefits generally reflect direct improvements in surface and groundwater quality, but the rule will also result in benefits associated with improved soil conditions, costs associated with increased energy consumption, and changes in emissions of air pollutants.

EPA's benefits analysis estimates the effect of pollutant reductions and other environmental improvements on human health and the ecosystem, and to the extent possible assigns a monetary value to these benefits. As previously noted, the analysis focuses solely on the benefits attributable to the revised standards for large CAFOs; the impacts of the final rule on medium-sized CAFOs are not considered. In addition, EPA has identified certain types of environmental improvements that will result from this rule that it is unable to quantify or value. Given the limitations in assigning monetary values to some of the improvements, the economic benefit values summarized in Exhibit ES-1 and described in the Benefits Analysis should be considered a subset of the total benefits of the new regulations. These monetized benefits should be evaluated along with descriptive qualitative assessments of the non-monetized benefits with the acknowledgment that even these may fall short of the real-world benefits that may result from this rule. For example, the benefits analysis assigns monetary values to water quality improvements due to reductions of nitrogen, phosphorus, pathogens and sediment, but does not include values for potential water quality improvements expected due to reduced discharges of metals or hormones.

To estimate the impacts of controlling animal waste from CAFOs, EPA conducted seven benefit studies. The first analysis employs a national water quality model (National Water Pollution Control Assessment Model) that estimates runoff from land application areas to rivers, streams, and, to a lesser extent, lakes in the U.S. This study estimates the value society places on improvements in surface water quality associated with the revised rule. The second analysis examines the expected improvements in shellfish harvesting resulting from improved water quality under the new CAFO rule. A third study looks at the fish kills that are attributed to animal feeding operations and estimates the benefits of reducing such incidents. The fourth analysis estimates the benefits associated with reduced contamination of groundwater for people who draw their water from private wells, while the fifth examines the benefits of reduced contamination of animal water supplies. The sixth analysis presents a case study of the benefits of reducing the discharge of nutrients to estuaries, focusing on North Carolina's Albemarle and Pamlico Sounds. Finally, the seventh study evaluates the beneficial impact of improved source water quality on the cost of treating public water supplies.

Research documented in the record and summarized in the Benefits Analysis shows that CAFO wastes affect the environment and human health in a number ways beyond those for which benefits have been monetized. Examples of other types of impacts or potential benefits include:

- **Reductions in loadings of metals, antibiotics, hormones, salts, and other pollutants** in animal waste from CAFOs, and reductions in associated human health and ecological effects;

- **Reduced eutrophication** of coastal and estuarine waters beyond the Albemarle and Pamlico Sounds region, due to reductions in nutrient-rich runoff from CAFOs and reductions in the deposition of NH_3 (ammonia) volatilized from CAFOs;

- **Reduced human exposure to pathogens** during recreational activities in estuaries and coastal waters;

- **Potential improvements to soil properties** due to reduced overapplication of manure and an increase in the acreage of land to which manure is applied at agronomic rates; and

- **Reduced pathogen contamination** in private drinking water wells.

EPA's benefits analysis does not include monetary values for these other areas of environmental improvements. In some cases, data limitations prevent the measurement of the magnitude of improvement. In other cases, the economic literature does not support the development of an economic value for these benefits. Nevertheless, these environmental benefits are tangible and result in improved ecological conditions and reduced risk to human health.

The U.S. Environmental Protection Agency (EPA) is revising and updating the two primary regulations that ensure that manure, litter, wastewater, and other process waters generated by concentrated animal feeding operations (CAFOs) do not impair water quality.[1] EPA's regulatory changes affect the existing National Pollutant Discharge Elimination System (NPDES) provisions that define and establish permit requirements for CAFOs, and the existing effluent limitations guidelines (ELGs) for feedlots, which establish the technology-based effluent discharge standard that is applied to specified CAFOs. Both of these existing regulations were originally promulgated in the 1970s. EPA is revising the regulations to address changes that have occurred in the animal industry sectors over the last 25 years, to clarify and improve implementation of CAFO requirements, and to improve the environmental protection achieved under these rules.

This report addresses the environmental and economic benefits of the revised regulations. It examines in detail several environmental quality improvements that EPA expects will result from the regulatory changes: improvements in the suitability of freshwater resources for recreational activities; reduced incidence of fish kills; improved commercial shellfishing; reduced contamination of private wells; reduced contamination of animal water supplies; reduced eutrophication of estuaries; and improvements in source water quality that will reduce drinking water treatment costs for pubic water supply systems. Because these are not the only beneficial impacts of the revised regulations — and because, in general, EPA takes a conservative approach to quantifying the benefits analyzed — the Agency believes that this report presents a lower-bound estimate of the beneficial impacts of the new CAFO rules.

This chapter first provides background information on animal feeding operations and EPA's previously established CAFO regulations. It then briefly summarizes the environmental problems and industry changes associated with animal feeding operations that EPA is addressing with its revised regulations. Finally, the chapter outlines the regulatory changes that EPA is implementing, and provides a summary of the methods and results of the detailed benefits analyses presented in

[1] As used throughout this report, the term manure is defined to include manure, litter, and other process wastewater generated by CAFOs.

subsequent chapters of the report. The detailed analyses and summary present the economic benefits of the standards promulgated by the Agency for the NPDES provisions and ELGs.

It is important to note that the analysis that EPA has conducted focuses solely on the economic benefits attributable to the revised standards for large CAFOs; the potential beneficial impact of the revised standards for medium-sized CAFOs is not addressed. The analysis assumes that affected CAFOs will land-apply manure, litter, and other process wastewater in accordance with a nutrient management plan that establishes application rates for each field based on the nitrogen requirements of the crop, or on the crop's phosphorus requirements where necessary because of soil or other field conditions. The promulgated regulation requires CAFOs to prepare and implement a site-specific nutrient management plan that establishes manure application rates for each field based on the technical standards for nutrient management established by the permitting authority's director. The promulgated standard is referred to throughout this report as the phosphorus-based standard. The report also presents results for a nitrogen-based regulatory alternative that the Agency considered but did not select.

1.1 BACKGROUND INFORMATION

1.1.1 Definition and Population of AFOs

The term CAFO is a regulatory designation that describes certain animal feeding operations (AFOs). AFOs are defined by federal regulation as lots or facilities where animals "have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility" (40 CFR 122.23(b)(1)). AFOs congregate animals on a small land area where feed must be brought to the animals. Winter feeding of animals on pasture or rangeland is not normally considered an AFO.

USDA reports that there were 1.2 million livestock and poultry operations in the United States in 1997. This number includes all operations that raise beef or dairy cattle, hogs, chickens (broilers or layers), and turkeys, and includes both confinement and non-confinement (i.e., grazing and rangefed) production. Of these, EPA estimates that there are about 238,000 AFOs that raise or house animals in confinement, as defined by the USDA. For many of the animal sectors, it is not possible to estimate from available data what proportion of the total livestock operations have feedlots (i.e., confinement) and what proportion are grazing operations only. For analytical purposes, EPA has therefore assumed that all dairy, hog, and poultry operations are AFOs. Exhibit 1-1 summarizes the estimated total number of AFOs of all sizes in each of the four major livestock categories, based on 1997 data.

Exhibit 1-1

NUMBER OF ANIMAL FEEDING OPERATIONS
(based on 1997 data)

Sector	Total AFOs
Beef operations, including both cattle and veal operations.	57,598
Dairy operations, including both milk and heifer operations.	98,630
Hog operations, including both "farrow to finish" and "grower to finish" operations.	51,772
Poultry operations, including broilers, layers (both wet and dry operations) and turkeys.	27,530
Sum Total	235,530
Total AFOs[1]	**237,821**

Source: EPA estimates derived from published USDA/NRCS data. For more information, see Robert L. Kellogg; *Profile of Farms with Livestock in the United States: A Statistical Summary*, USDA/NRCS, 2002.

[1] "Total AFOs" accounts for "specialty cases" defined as dairies that went out of business, farms with only feeder pigs, and egg hatching operations.

1.1.2 Existing Regulations for CAFOs

The regulations that EPA established in the 1970s identify three categories of AFOs that are subject to regulation as CAFOs. The first category of facilities includes any animal feeding operation where more than 1,000 "animal units" (AUs) are confined; such facilities are by definition CAFOs unless discharges from the operation occurred only as the result of a 25-year, 24-hour (or more severe) storm event.[2] The second group of facilities includes AFOs that confine 300 to 1000 AUs; these facilities are defined as CAFOs if:

- Pollutants were discharged into navigable waters through a manmade ditch, flushing system, or other similar man-made device; or
- Pollutants were discharged directly into waters that originate outside of and pass over, across, or through the facility or come into direct contact with the confined animals.

The established regulations do not extend the definition of a CAFO to operations with fewer than 300 AUs. Under certain circumstances, however (e.g., a facility causing significant surface water impairment), a permitting authority may designate such facilities as CAFOs.

[2] Animal units are defined in EPA's current regulations at 40 CFR 122 and vary by animal type. An AU is considered equivalent to one beef cow.

On the basis of the manure management or watering systems they employ, the established regulations do not define certain poultry operations as CAFOs. In addition, the CAFO definition considers only swine over 55 pounds and mature dairy cattle, assuming that immature swine and heifers would be raised in the same operations as adults. As a result, the regulatory definition does not address the "stand-alone" immature swine or heifer operations that have proliferated in the last two decades.

1.2 CURRENT ISSUES RELATED TO CAFOS

AFOs (including CAFOs) produce and manage large amounts of animal waste, most in the form of manure. USDA estimates that 710 billion pounds (322 million metric tons) of "as excreted" manure were generated in 1997 from major livestock and poultry operations. Despite the existing ELG and NPDES regulations that define CAFOs and regulate their discharges, the management of animal wastes at AFOs has continued to be associated with environmental problems, including large spills of manure, fish kills, and outbreaks of *Pfiesteria*. In addition, industry changes in recent years may contribute to and exacerbate the problems caused by releases of manure from AFOs. EPA is revising the existing regulations with the following goals:

- To address persistent reports of discharge and runoff of manure and manure nutrients from CAFOs;

- To update the existing regulations to reflect structural changes in the animal production industries over the last few decades; and

- To improve the effectiveness of the CAFO regulations in protecting or restoring water quality.

Below we summarize the potential environmental impacts of manure releases from AFOs, and outline the recent industry changes that may exacerbate these impacts.

1.2.1 <u>Potential Environmental Impacts of CAFOs</u>

Manure management practices at AFOs can include storage in piles or in open waste lagoons, followed by land application to agricultural fields as fertilizer. While some discharges from regulated CAFOs are governed as point sources, unregulated releases of manure from waste piles or lagoons and over-application of manure to agricultural lands can also affect nearby surface and groundwater. National and local studies have confirmed the presence of manure pollutants in surface waters. Once contaminants from manure have reached surface waters they can cause a variety of ecological and human health problems, including water quality impairments, ecological impacts, and human health effects from recreational exposure or from contaminated drinking water.

1.2.1.1 Water Quality Impairments

EPA's *National Water Quality Inventory: 2000 Report* identifies agricultural operations, including CAFOs, as the leading contributor to identified water quality impairments in the nation's rivers, streams, lakes, ponds, and reservoirs, and the fifth leading contributor to identified water quality impairments in the nation's estuaries.[3] The report also identifies the key pollutants and stressors that impair the nation's waters. Among the most problematic pollutants are several - including pathogens, nutrients, sediment/siltation, metals, and oxygen depleting substances - that are associated commonly, although not exclusively, with animal feeding operations.[4]

1.2.1.2 Ecological Impacts

The most dramatic ecological impacts associated with manure pollutants in surface waters are massive fish kills. Incomplete records indicate that every year dozens of fish kills associated with AFOs result in the deaths of hundreds of thousands of fish. In addition, manure pollutants such as nutrients and suspended solids can seriously disrupt aquatic systems by over-enriching water (in the case of nutrients) or by increasing turbidity (in the case of solids). Excess nutrients cause fast-growing algae blooms that reduce the penetration of sunlight in the water column, and reduce the amount of available oxygen in the water, reducing fish and shellfish habitat and affecting fish and invertebrates. Manure pollutants can also encourage the growth of toxic organisms, including *Pfiesteria*, which has been associated with fish kills and fish disease events. Reduction in biodiversity due to animal feeding operations has also been documented; for example, a study of three Indiana stream systems found fewer fish and more limited diversity of fish species downstream of CAFOs than were found downstream of study reference sites.

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[3] EPA prepares this report every two years, as required under Section 305(b) of the Clean Water Act. It summarizes State reports of water quality impairment and the suspected sources and causes of such impairment.

[4] The *National Water Quality Inventory: 2000 Report* notes that the agricultural sector contributes to the impairment of at least 129,000 river miles, 3.2 million lake acres, and over 2,800 square miles of estuary. Forty-eight states and tribes reported that agricultural activities contributed to water quality impacts on rivers, 40 states identified such impacts on lakes, ponds, and reservoirs, and 14 states reported such impacts on estuaries. Animal feeding operations are only a subset of the agriculture category, but 29 states specifically identified animal feeding operations as contributing to water quality impairment.

1.2.1.3 Human Health Effects

Manure contains over 100 human pathogens; contact with some of these pathogens during recreational activities in surface water can result in infections of the skin, eye, ear, nose, and throat. Eutrophication due to excess nutrients can also promote blooms of a variety of organisms that are toxic to humans either through ingestion or contact. This includes the 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. Finally, even with no visible signs of algae blooms, shellfish such as oysters, clams and mussels can carry toxins produced by some types of algae in their tissue. These can affect people who eat contaminated shellfish.

Contaminants originating from manure pollutant loadings, including nitrogen, pathogens, and algae (whose growth can be stimulated by manure nutrient loadings), can also affect human health through drinking water sources and can result in increased drinking water treatment costs. For example, nitrogen in manure can be transported to drinking water as nitrates, which are associated with human health risks. EPA has identified nitrate as the most widespread agricultural contaminant in drinking water wells. Algae blooms triggered by nutrient pollution can affect drinking water by clogging treatment plant intakes, producing objectionable tastes and odors, and reacting with the chlorine used to disinfect drinking water to produce harmful chlorinated byproducts (e.g., trihalomethanes).

1.2.1.4 Air Emissions

CAFOs are also sources of air pollutants. Animal feeding operations generate various types of animal wastes, including manure (feces and urine), waste feed, water, bedding, and dust, which can become airborne or generate emissions. Air emissions occur as a result of manure decomposition throughout the process of waste management and treatment. The rate at which emissions are generated varies as a result of a number of operational variables (e.g., animal species, type of housing, waste management system) and weather conditions (e.g., temperature, humidity, wind, time of release). Chapter 13 of EPA's Technical Development Document provides further discussion and references relating to air emissions from CAFOs.

1.2.2 Recent Industry Trends

Since EPA promulgated the existing ELG and NPDES regulations governing CAFOs in the 1970s, a number of trends in the livestock and poultry industries have influenced the nature of pollution from AFOs and the potential for contamination of surface and groundwater. These trends include a combination of industry growth and concentration of animals on fewer, larger farms; location of farms closer to population centers; and advances in farm production practices and waste management techniques. The changes in the industry have limited the effectiveness of the current regulations that define and govern releases from CAFOs.

1.2.2.1 Increased Production and Industry Concentration

U.S. livestock and poultry production has risen sharply since the 1970s, resulting in an increase in the amount of manure and wastewater generated annually. The Census of Agriculture reports 1997 turkey sales of 299 million birds, compared to 141 million sold in 1978. Sales of broilers increased to 6.4 billion in 1997 from 2.5 billion in 1974.[5] Red meat production also rose during the 1974-1997 period; the number of hogs and pigs sold in 1997 totaled 142.6 million, compared to 79.9 million in 1974.

As production has increased, the U.S. livestock and poultry sectors have also consolidated animal production into a smaller number of larger-scale, highly specialized operations that concentrate more animals (and manure) in a single location. At the same time, significant gains in production efficiency have increased per-animal yields and the rate of turnover of animals between farm and market. These large AFOs can present considerable environmental risks because of the large amount of manure they produce and because they often do not have an adequate land base to dispose of the manure through land application. As a result, large facilities must incur the risks associated with storing significant volumes of manure, attempt to maximize the application of manure to the limited land they have available, or arrange for the use of manure on other farms. By comparison, smaller AFOs manage fewer animals and tend to concentrate less manure at a single location. These operations are more likely to have sufficient cropland and fertilizer needs to land apply manure nutrients generated at a livestock or poultry business.

1.2.2.2 Location of Animal Operations Closer to Consumer Markets

Since the 1970s, the combined forces of population growth and re-location of operations closer to consumer markets and processing sectors have resulted in more AFOs located near densely populated areas. Surface waters in these areas face additional stresses from urban runoff and other point sources. The proximity of large AFOs to human populations thus increases the potential for human health impacts and ecological damage if manure or wastewater at AFOs is improperly discharged.

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[5] This more than two-fold increase in the number of broilers raised annually signals the need to review the existing CAFO regulations, which effectively do not cover broiler operations since virtually no such operations use wet manure management systems.

1.2.2.3 Advances in Agriculture Production Practices to Manage and Dispose Manure

Continued research by USDA, state agencies and universities has led to advances in technologies and management practices that minimize the potential environmental degradation attributable to discharge and runoff of manure and wastewater. Today, there are many more practicable options to properly collect, store, treat, transport, and utilize manure and wastewater than there were in the 1970s, when the existing regulations were instituted. As a result, current regulations do not reflect the full range of management practices and technologies that may be implemented to achieve greater protection of the environment (e.g., by more effectively treating certain constituents present in animal manure or by converting manure into a more marketable form). In addition, during the time since promulgation of the existing regulation, certain practices have proven to be relatively less protective of the environment. There is documented evidence that lagoons may leak if not properly maintained, and evidence of over-application of manure and nutrient saturation of soils in some parts of the country.

1.3 REVISIONS TO CAFO REGULATIONS

In response to persistent reports of environmental problems, and to changes in the industries and technologies associated with AFOs, EPA is revising both the NPDES regulations for CAFOs and the ELG regulations for feedlots. The revisions to the NPDES regulations for CAFOs affect which animal feeding operations are defined as CAFOs and are therefore subject to the NPDES permit program. Changes to the ELG regulations for feedlots affect which technology-based requirements will apply to certain CAFOs. Additional detail on the revisions to the NPDES and ELG regulations is provided below.

1.3.1 <u>Changes to NPDES Regulations</u>

EPA's revised rule retains some of the basic elements of the existing structure for determining which AFOs are CAFOs, but with important exceptions for large facilities (see Exhibit 1-2 for the size standards for Large, Medium, and Small CAFOs).[6] Under the revised regulations, all large CAFOs have a mandatory duty to apply for an NPDES permit. This change has two important effects. First, it removes ambiguity over whether a large facility needs an NPDES permit, even if it discharges only as the result of a large storm event. Second, large poultry operations are covered, regardless of the type of watering system used or whether the litter is managed in wet or dry form. In addition, the revised CAFO definition includes size standards for operations that stable or confine immature dairy cattle or veal calves, cow/calf pairs, or swine weighing less than 55 pounds, thus extending the regulations to address stand-alone immature swine or heifer operations. In the rare

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[6] Note that the new size standards are specified with respect to the number of animals confined; they no longer reference "animal units."

event that a large CAFO has no potential to discharge, the new requirements provide a process for a demonstration to that effect, in lieu of obtaining a permit.

Exhibit 1-2

SIZE STANDARDS FOR LARGE, MEDIUM, AND SMALL CAFOS

Sector	Large	Medium[1]	Small[2]
Mature Dairy Cattle	more than 700	200 - 700	less than 200
Veal Calves	more than 1,000	300 - 1,000	less than 300
Cattle or Cow/Calf Pairs	more than 1,000	300 - 1,000	less than 300
Swine (weighing over 55 pounds)	more than 2,500	750 - 2,500	less than 750
Swine (weighing less than 55 pounds)	more than 10,000	3,000 - 10,000	less than 3,000
Horses	more than 500	150 - 500	less than 150
Sheep or Lambs	more than 10,000	3,000 - 10,000	less than 3,000
Turkeys	more than 55,000	16,500 - 55,000	less than 16,500
Chickens (liquid manure handling systems)- includes Laying Hens	more than 30,000	9,000 - 30,000	less than 9,000
Chickens Other than Laying Hens (other than liquid manure handling)	more than 125,000	37,500 - 125,000	less than 37,500
Laying Hens (other than liquid manure handling)	more than 82,000	25,000 - 82,000	less than 25,000
Ducks (dry operations)	more than 30,000	10,000 - 30,000	less than 10,000
Ducks (wet operations)	more than 5,000	1,500 - 5,000	less than 1,500

[1] Must also meet one of two criteria to be defined as a CAFO.
[2] Must be designated by EPA or the State permit authority.

The factors that lead smaller AFOs to be classified as CAFOs are largely unchanged. As with the existing regulations, medium-size AFOs are defined as CAFOs only if they meet one of two specific criteria governing the method of discharge:

- Pollutants are discharged into waters of the United States through a manmade ditch, flushing system, or other similar man-made device; or

- Pollutants are discharged directly into waters of the United States that originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the confined animals.

Similarly, small facilities are considered CAFOs only if they are designated as such by EPA or the State NPDES permit authority. Such designation must be based on a determination that a facility is a significant contributor of pollutants to waters of the United States. On identical grounds, medium-size operations that are not CAFOs by definition may also be designated as CAFOs.

Under the new regulations, all CAFOs, regardless of size, must be covered by an NPDES permit and are required to develop and implement a nutrient management plan. Such plans must identify practices necessary to demonstrate compliance with the effluent limitation guideline (if applicable), and include requirements to land apply manure and wastewater in a manner consistent with the appropriate agricultural utilization of nutrients.

1.3.2 Changes to ELGs

As with the previous CAFO regulations, EPA's revised effluent guidelines will apply only to large CAFOs; for other permitted facilities, technology-based discharge limits will continue to be established on the basis of the permit writer's best professional judgment. The revised regulations, however, introduce differing requirements for existing sources and new sources. The key features of these requirements are as follows:

- **Existing Sources** — In the case of existing sources, the effluent limitation guideline will continue to prohibit the discharge of manure and other process wastewater from the production area.[7] An exception to this prohibition allows the discharge of process wastewater in overflow whenever rainfall causes an overflow from a facility designed, constructed, operated, and maintained to contain all process wastewater and runoff from a 25-year, 24-hour (or more severe) rainfall event. The ELG also establishes certain best management practices (BMPs) that apply to the production area. In addition, the ELG requires Large CAFOs to prepare and implement a site-specific nutrient management plan that establishes manure application rates for each field based on the technical standards for nutrient management established by the permitting authority's director. Large CAFOs also must implement certain other BMPs that apply to the land application area.[8]

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[7] The production area of an AFO includes the animal confinement area, the litter or manure storage area, the raw materials storage area, and the waste containment area.

[8] These requirements apply to any land under the control of the owner or operator of the production area — whether it is owned, rented, or leased — to which manure and wastewater from

- **New Sources** — For new sources in the beef and dairy sector, the requirements for managing the production area are the same as for existing sources. In contrast, the discharge of process wastewater from the production area of new sources in the swine, veal, and poultry sectors is prohibited, except for facilities designed to contain all process wastewater and the direct precipitation and runoff from a 100-year, 24-hour rainfall event. The land application requirements for new sources are identical to those for existing sources.

1.3.3 Number of Regulated Operations

EPA has estimated the likely number of AFOs that would be regulated under the revised CAFO rules. EPA analyzed data from the USDA's 1997 Census of Agriculture to identify AFOs and CAFOs. EPA first determined the number of operations that raise animals under confinement by using available data on the total number of livestock and poultry facilities. Next, EPA determined the number of CAFOs based on the number of facilities that discharge or have the potential to discharge to U.S. waters and which meet the minimum size thresholds (i.e., number of animals) defined by the revised regulations. Exhibit 1-3 shows the number of CAFOs estimated to be subject to the new rules.

1.4 ANALYTIC METHODS AND RESULTS

To determine the economic benefits of the revised regulations, EPA performed several analyses of expected changes in environmental quality that would likely result from reduced AFO pollution, focusing solely on the impact of the revised standards for Large CAFOs. The detailed analyses addressed the following issues:

- **Improvements in Water Quality and Suitability for Recreational Activities:** this analysis estimates the economic value of improvements in inland surface water quality that would increase opportunities for recreational boating, fishing, and swimming;

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the production area is or may be applied.

Exhibit 1-3

ESTIMATED NUMBER OF CAFOS SUBJECT TO REVISED REGULATIONS*

Production Sector	Currently Regulated	Regulated Under New Rule		
		Large CAFOs	Medium CAFOs	Total
Beef	1,940	1,766	174	1,940
Dairy	3,399	1,450	1,949	3,399
Heifers	0	242	230	472
Veal	0	12	7	19
Swine	5,409	3,924	1,485	5,409
Layers	433	1,112	50	1,162
Broilers	683	1,632	520	2,152
Turkeys	425	388	37	425
Horses	195	195	0	195
Ducks	21	21	4	25
Total	**12,505**	**10,742**	**4,456**	**15,198**

* AFOs that stable or confine animals in different sectors are counted more than once.

- **Reduced Incidence of Fish Kills:** this analysis estimates the economic value of a potential reduction in the number of fish kills caused by AFO-related waste;

- **Improved Commercial Shellfishing:** this analysis characterizes the impact of pollution from AFOs on access to commercial shellfish growing waters, and values the potential increase in commercial shellfish harvests that may result from improved control of that pollution;

- **Reduced Contamination of Private Wells:** this analysis examines the impact of the revised regulations on groundwater quality, and values predicted improvements in the quality of aquifers that supply private wells;

- **Reduced Contamination of Animal Water Supplies:** this analysis characterizes the impact of pollution from AFOs on livestock mortality, and values the potential impact of the revised regulations in reducing mortality rates;

- **Reduced Eutrophication of Estuaries:** this analysis examines the impact of the revised regulations on nutrient loadings to selected estuaries, and presents a case study illustrating the potential economic benefits of the anticipated reduction in such loads; and

- **Reduced Water Treatment Costs:** this analysis examines the revised regulations' beneficial effect on source water quality and the consequent reduction in treatment costs for public water supply systems.

Exhibit 1-4 summarizes the results of these studies for the final rule, reflecting the following requirements: zero discharge from a facility designed, maintained, and operated to hold manure, litter, and other process wastewater, including direct participation and runoff from a 25-year, 24-hour rainfall event; implementation of feedlot best management practices, including storm water diversions; lagoon and pond depth markers; periodic inspections; elimination of manure application within 100 feet of any surface water, tile drain inlet, or sinkhole; compliance with mortality-handling, nutrient management planning, and record keeping guidelines; and phosphorus-based agronomic application rates. The exhibit also presents analytic results for the final rule assuming nitrogen-based agronomic application rates, rather than the proposed phosphorus-based standard. It is important to note that these results are not intended to represent the total value of all benefits associated with a reduction in AFO pollutants; they include only the subset of benefits that is addressed by EPA's analyses. Moreover, EPA's analyses generally take a conservative approach to quantifying benefits; therefore, the results are likely to reflect conservative estimates of the specific benefits that EPA has examined.

EPA also considered how today's rule would affect the amount and form of compounds released to air, as well as the energy that is required to operate the CAFO. In addition to the water quality impacts and benefits discussed above, EPA's evaluated non-water quality environmental impacts, including changes in air emissions from CAFOs and changes in energy use at CAFOs. EPA's estimates of changes in air emissions and energy use are described in more detail in the *Technical Development Document*. In addition, during the rulemaking, EPA evaluated a number of regulatory options and, as part of those analyses, also considered the potential air quality benefits associated with changes in ammonia emissions. For further discussion of those analyses, refer to Chapter 13 of the *Technical Development Document* and Section 22 of the rulemaking record.

1.5 ASSESSMENT OF DATA USED TO ESTIMATE BENEFITS

The majority of the data EPA used to estimate the environmental and economic benefits associated with the revised standards for CAFOs are from existing sources. As defined in the Office of Water 2002 Quality Management Plan (USEPA 2002), existing (or secondary) data are data that were not directly generated by EPA to support the decision at hand. Existing data were used to identify animal feeding operations that are defined as CAFOs and subject to the NPDES permit program under the final rule, and to model the effects of changes to the effluent guidelines for feedlots.

Exhibit 1-4

ESTIMATED ANNUALIZED BENEFITS OF THE REVISED CAFO REGULATIONS UNDER ALTERNATE DISCOUNT RATES[1]
(2001 dollars, millions)

	Phosphorus-Based			Nitrogen-Based		
Benefits Category	**3%**	**5%**	**7%**	**3%**	**5%**	**7%**
Improved Surface Water Quality	$166.2 - $298.6	$166.2 - $298.6	$166.2 - $298.6	$102.4 - $182.6	$102.4 - $182.6	$102.4 - $182.6
Reduced Incidence of Fish Kills	$0.1	$0.1	$0.1	$0.0 - $0.1	$0.0 - $0.1	$0.0 - $0.1
Improved Commercial Shell Fishing	$0.3 - $3.4	$0.3 - $3.4	$0.3 - $3.4	$0.1 - $2.0	$0.1 - $2.0	$0.1 - $2.0
Reduced Contamination of Private Wells	$45.7	$37.1	$30.9	$49.3	$40.0	$33.3
Reduced Contamination of Animal Water Supplies	$5.3	$5.3	$5.3	$4.7	$4.7	$4.7
Reduced Eutrophication of Estuaries	not monetized	not monetized	not monetized	not monetized	not monetized	not monetized
Albemarle-Pamlico Case Study	$0.2	$0.2	$0.2	$0.1	$0.1	$0.1
Reduced Water Treatment Costs	$1.1 - $1.7	$1.1 - $1.7	$1.1 - $1.7	$0.7 - $1.0	$0.7 - $1.0	$0.7 - $1.0
All Categories[2]	$218.9 + [B] - $355.0 + [B]	$210.3 + [B] - $346.4 + [B]	$204.1 + [B] - $340.2 +[B]	$157.3 + [B] - $239.8 + [B]	$148.0 + [B] - $230.5 + [B]	$141.3 + [B] - $223.8 + [B]

[1] The analysis accounts for benefits associated with the revised regulations for Large CAFOs only. The impact of revised standards on Medium CAFOs is not included.
[2] Discrepancies between these totals and the sum of the figures in each column are due to rounding. Values are rounded to the nearest $100 thousand.
[B] Represents non-monetized benefits of the rule.

In keeping with the graded approach to quality management embodied in the quality management plan, EPA must assess the quality of existing data relative to their intended use. The procedures EPA used to assess existing data for use in estimating the benefits associated with the revised standards for CAFOs varied with the specific type of data. In general, EPA's assessment included:

- Reviewing a description of the existing data that explains how the data were collected or produced (e.g., who collected and uses the data; what data were collected; when, why, and how the data were collected; whether the data were gathered as part of a one-time or long-term effort; and the level of review the data have received from others);

- Specifying the intended use of the existing data relative to the CAFO final rule;

- Developing a rationale for accepting data from the source, either as a set of acceptance criteria or as a narrative discussion; and

- Describing any known data limitations and their impact on EPA's use.

Brief descriptions of the data and their limitations are presented later in this document, as each data source is introduced.

In searching for existing data sources and determining their acceptability, EPA generally used a hierarchical approach designed to identify and utilize data with the broadest representation of the industry sector or topic of interest. EPA began by searching for national-level data from surveys and studies by USDA and other federal agencies. When survey or study data did not exist, EPA considered other types of data from federal agencies.

Where national data did not exist, as the second tier, EPA searched for data from land grant universities. Such data are often local or regional in nature. EPA assessed the representativeness of the data relative to a national scale before deciding to use the data. When such data came from published sources, EPA gave greater consideration to peer-reviewed professional journals than to publications lacking a formal review process.

The third tier was data supplied by industry. Prior to publication of proposed changes to the rule, EPA requested data from a variety of industry sources, including trade associations and large producers. The level of review applied to data supplied by industry depended on the level of supporting detail that was provided. For example, if the industry supplied background information regarding how the data were collected, such as the number of respondents and the total number of potential respondents, EPA reviewed the results, comparing them to data from other potential sources to determine their suitably for use in this rulemaking. If the data provided by industry originated from an identifiable non-industry source (e.g., a state government agency), EPA reviewed the original source before determining the acceptability of the data. In a limited number of instances, EPA conducted site visits to substantiate information supplied by industry. In contrast, data supplied by industry without any background information were given much less weight and generally were not used by EPA. Further, some data that were supplied by industry prior to the proposal were included in the proposal for comment. In the absence of any negative comments, such data were relied on to a greater extent than data submitted by industry during the comment period itself.

1.6 ORGANIZATION OF REPORT

The remainder of this report presents EPA's analysis of the benefits of the revised CAFO regulations. Specifically:

- Chapter 2 provides a detailed description of the potential impacts of CAFOs on environmental quality and human health;
- Chapter 3 describes the range of benefits that would result from decreased CAFO loadings, and outlines EPA's general approach to quantifying and valuing the subset of benefits analyzed;
- Chapter 4 assesses the value of changes in surface water quality that would result from the estimated reduction in CAFO loadings arising from the final regulation, focusing on changes in the quality of freshwater resources that would improve their suitability for recreational activities;
- Chapter 5 assesses the value of a reduced incidence of fish kills attributable to pollution from CAFOs, as estimated under the final rule;
- Chapter 6 assesses the value of improved commercial shellfishing resulting from decreased CAFO loadings, as estimated under the final rule;
- Chapter 7 assesses the value of reduced contamination of private wells associated with reductions in the pollution of groundwater by CAFOs;
- Chapter 8 estimates the economic benefits associated with reductions in livestock mortality that are predicted to occur under the final rule as a result of reduced contamination of animal water supplies;
- Chapter 9 examines the impact of the revised regulations on nutrient loadings to selected estuaries, and presents a case study illustrating the potential economic benefits of the anticipated reduction in such loads;

- Chapter 10 evaluates the impact of the revised regulations on source water quality and estimates the subsequent reduction in treatment costs for public water supply systems; and

- Chapter 11 summarizes the benefits analysis for the final rule.

1.7 REFERENCES

Kellogg, Robert L. 2002. *Profile of Farms with Livestock in the United States: A Statistical Summary*. U.S. Department of Agriculture, Natural Resources Conservation Service.

Kellogg, Robert L. et al. 2000. *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States.* U.S. Department of Agriculture, Natural Resources Conservation Service and Economic Research Service. December.

USDA/USEPA (U.S. Department of Agriculture and U.S. Environmental Protection Agency). 1999. *Unified National Strategy for Animal Feeding Operations*, Section 4.2. Available on EPA's web site at: http://www.epa.gov/owm/finafost.htm#1.0.

USEPA. 2002. Office of Water Quality Management Plan. April 2002. EPA 821-X-02-001.

Animal manure, the primary cause of pollution related to AFOs, contains a variety of pollutants that can cause environmental degradation, particularly when released to surface waters in large quantities.[1] Documented releases from AFOs have been associated with a number of adverse human health and ecological impacts, including fish kills, disease outbreaks, and degradation of water quality and aquatic life.

EPA's *National Water Quality Inventory: 2000 Report* identifies agricultural operations, including CAFOs, as the leading contributor to identified water quality impairments in the nation's rivers, streams, lakes, ponds, and reservoirs, and the fifth leading contributor to identified water quality impairments in the nation's estuaries.[2] The report also identifies the key pollutants and stressors that impair the nation's waters. Among the most problematic pollutants are several - including pathogens, nutrients, sediment/siltation, metals, and oxygen depleting substances - that are associated commonly, although not exclusively, with animal feeding operations.[3]

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[1] This document uses the term manure to refer to both "solid" manure and urine, since these wastes are typically managed together. Additional animal wastes associated with AFOs (e.g., hair, feathers, bedding material and carcasses) are identified separately in the discussion.

[2] EPA prepares this report every two years, as required under Section 305(b) of the Clean Water Act. It summarizes State reports of water quality impairment and the suspected sources and causes of such impairment.

[3] The *National Water Quality Inventory: 2000 Report* notes that the agricultural sector contributes to the impairment of at least 129,000 river miles, 3.2 million lake acres, and over 2,800 square miles of estuary. Forty-eight states and tribes reported that agricultural activities contributed to water quality impacts on rivers, 40 states identified such impacts on lakes, ponds, and reservoirs, and 14 states reported such impacts on estuaries. Animal feeding operations are only a subset of the agriculture category, but 29 states specifically identified animal feeding operations as contributing to water quality impairment.

The animal waste management practices and pollutant transport pathways that can lead to contamination of surface waters are well known. Animal wastes at AFOs are typically managed by land application and/or storage in waste piles or lagoons. Land application and storage of manure are centuries-old farming practices. In small or low-density farming operations these methods pose minimal pollution potential. AFOs, however, manage large amounts of manure in a concentrated area. Under these circumstances, the following waste management failures pose an increased potential for pollution:

- **Over-application of manure:** While land application of manure can provide valuable nutrients to soil and crops, the capacity of soil and crops to absorb nutrients over any given period is limited. Excess manure applied to cropland can damage crops and soil, and is more likely to run off into surface waters or be released to air through volatilization or erosion (for example, through spray application).

- **Runoff from uncovered manure piles:** Manure piles are frequently used for temporary storage of animal wastes. Precipitation may wash pollutants from uncovered manure piles into nearby surface waters.

- **Lagoon failures:** AFOs frequently store large quantities of manure in lagoons prior to land application or other disposal. While lagoons are designed to prevent the release of wastes into the environment, they are subject to various types of failure, including spills due to overfilling; washouts in floods; liner failures; failures of dikes, pipes, or other above-ground structures; and accidental and intentional operator-related releases.

This chapter briefly describes the pathways, pollutants, and environmental and human health effects associated with releases from AFOs. More detailed information is available in *Environmental Assessment of the Proposed Effluent Limitation Guidelines for Concentrated Animal Feeding Operations*.

2.1 PATHWAYS FOR THE RELEASE OF POLLUTANTS FROM AFOS

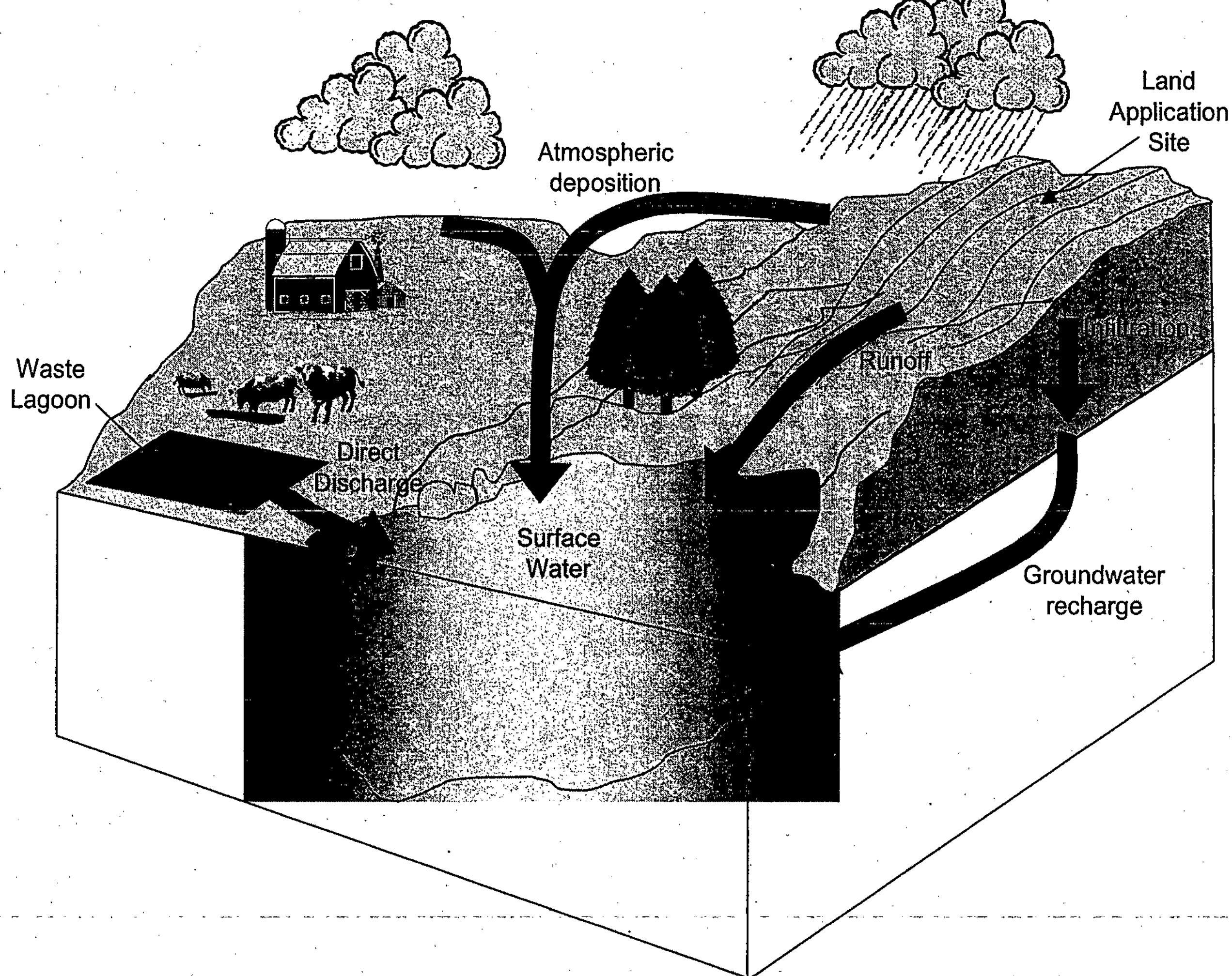
Pollutants in animal wastes can reach surface waters by several pathways, including overland discharge, migration through groundwater, and atmospheric deposition. The most common pathway is overland discharge, which includes surface runoff (i.e., land-applied or piled manure that is washed into surface waters by rain), soil erosion, and acute events such as spills or impoundment failures. Contamination can also occur when pollutants leach through soil into groundwater and then to surface water through groundwater recharge. In addition, airborne pollutants created by volatilization or by spray-application of manure to land can contaminate surface water through atmospheric deposition. Exhibit 2-1 illustrates the various pathways by which AFO releases can affect surface waters and groundwater. The following discussion describes these pathways in greater detail.

2.1.1 Overland Discharge

Contamination from manure often reaches surface water though overland discharge; that is, by flowing directly into surface waters from land application sites or lagoons. There are three distinct types of overland discharge: surface runoff, soil erosion, and direct discharge of manure to surface water during acute events. For example, a single flood event might include lagoon "washouts," soil erosion and surface runoff. This section describes the various types of overland discharge in more detail.

Exhibit 2-1

PATHWAYS FOR AFO-RELATED POLLUTANTS



2.1.1.1 Surface Runoff

Surface runoff occurs whenever rainfall or snowmelt is not absorbed by soil and flows overland to surface waters.[4] Runoff from land application sites or manure piles can transport pollutants to surface waters, especially if rainfall occurs soon after application, if manure is over-applied, or if it is misapplied.[5] The potential for runoff of animal wastes varies considerably with climate, soil conditions, and management practices. For example, manure applied to saturated or frozen soils is more likely to runoff the soil surface (ODNR, 1997). 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. Surface runoff is a particularly significant transport mechanism for water soluble pollutants, including nitrogen compounds. Runoff can also carry solids.

Runoff of manure pollutants has been identified 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 1996 and 1997, runoff problems were identified for several cattle operations in numerous counties in Minnesota (CWAA, 1998; ODNR, 1997).

2.1.1.2 Soil Erosion

In addition to simple surface runoff, pollutants from animal wastes can enter surface water through erosion, in which the soil surface itself is worn away by the action of water or wind. Soil erosion often occurs in conjunction with surface runoff as part of rainfall events, but it represents a transport mechanism for additional pollutants that are strongly sorbed (i.e., chemically bound) to soils. The most important of these pollutants is phosphorus. Because of its tendency to sorb to soils, many agricultural phosphorus control measures focus on soil erosion control. However, soils do not have infinite adsorption capacity for phosphorus or other pollutants, and dissolved pollutants (including phosphates) can still enter waterways through runoff even if soil erosion is controlled (NRC, 1993).

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[4] Surface discharges can also result from direct contact between confined animals and surface waters. Certain animals, particularly cattle, will wade into the surface waters to drink, and will often urinate and defecate there as well. This practice is now restricted for CAFOs, but may still occur at other types of AFOs.

[5] Experiments show that for all animal wastes, application rates have a significant effect on runoff concentrations of pollutants. See Daniel *et al.,* 1995.

In spite of control efforts, soil erosion remains a serious challenge for agriculture. For example, in 1997 the USDA Natural Resources Conservation Service (NRCS) reviewed the connection between manure production, soil erosion, and water quality in a watershed in South Carolina. NRCS calculated that soil erosion from the 13,000 acres of cropland in the watershed ranged from 9.6 to 41.5 tons per acre per year. The report further found that manure and erosion-related pollutants such as bacteria, nutrients, and sediment are the primary contaminants affecting streams and ponds in the watershed (USEPA, 1997).

Catastrophic Release of Manure: New River, North Carolina, 1995

On June 21, 1995, a breach in the dike of a 30 million gallon hog waste lagoon discharged over 25 million gallons of waste into tributaries of the New River in Onslow County, North Carolina.

Within a week of the event, North Carolina state officials estimated that roughly 2,600 fish were destroyed, though monitoring indicated that oxygen levels had recovered in the river within a week of the event. JoAnne Burkholder, a North Carolina State University marine scientist, noted that the initial waste deluge probably smothered many fish. Others were killed more slowly by declining oxygen levels and the toxic effects of ammonia and bacteria in the water.

Two days after the spill scientists sampling in some of the affected areas found ammonia levels of about 20 times the lethal limit for most fish.

Though oxygen levels recovered rapidly, Burkholder noted that it could take years for the upper New ecosystem to fully recover and support the range of fish, clams and other creatures that existed before the spill. In addition to immediate problems, longer term problems caused by the breach would include rains churning up settled pollution and potential algae blooms.

State environmental officials also confirmed that high levels of fecal coliform bacteria were detected in the river, and Onslow County health officials posted warnings in public recreation areas to prevent people from swimming. According to local newspaper reports, in some places fecal coliform levels were 10,000 times the state standard for swimming.

Sources: *Warrick and Stith, 1995b; Warrick 1995b, 1995c, 1995d.*

2.1.1.3 Acute Events

In addition to surface runoff and erosion, acute events such as spills, floods, or other lagoon or application failures can affect surface waters. Unlike runoff and erosion, which generally affect land-applied wastes, acute events frequently affect waste management lagoons. Spills can result from mechanical malfunctions (e.g., pump failures, manure irrigation gun malfunctions, and failures in pipes or retaining walls), overfilling, or washouts during flood events. There are even indications that some operators discharge wastes into surface waters deliberately in order to reduce the volume of waste in overfull lagoons (CWAA, 1998). Acute events frequently result in large waste discharges and are often associated with immediate ecological effects such as fish kills. In addition to immediate fish kills, large releases can be linked with eutrophication, sedimentation, and the growth of pathogens. All of these impacts can also cause acute mortality in fish and other aquatic species.

2.1.2 Leaching to Groundwater

Pollutants from animal waste can migrate to groundwater and subsequently contaminate surface waters through the process of "groundwater recharge," in which hydrological connections between aquifers and surface waters allow transfer of water (and pollutants). Groundwater contamination itself can result from leaching of land-applied pollutants into the soil, or from leaking lagoons. Although most lagoons are lined with clay or are designed to be "self-sealed" by manure solids that prevent infiltration of pollutants into groundwater, these methods are not always effective. For example, a survey of hog and poultry lagoons in the Carolinas found that the contents of nearly two-thirds of the 36 lagoons sampled had leaked into the groundwater (Meadows, 1995). Similarly, clay-lined lagoons can crack or break as they age, and are susceptible to burrowing worms. In a three-year study of clay-lined swine lagoons on the Delmarva Peninsula, researchers found that leachate from lagoons located in well-drained loamy sand adversely affected groundwater quality (Ritter *et al.,* 1990).

Surface water contamination from groundwater is most likely to occur in areas with high soil permeability and shallow water tables, and is most likely to involve water soluble contaminants such as nitrate (Smith *et al.,* 1997). Overall, the potential for contamination by this pathway may be considerable. For example, in the Chesapeake Bay watershed, the USGS estimates that about half of the nitrogen loads from all sources to non-tidal streams and rivers originates from groundwater (ASCE, 1998). In addition, about 40 percent of the average annual stream flow in the United States results from groundwater recharge (USEPA, 1993).

2.1.3 Discharges to the Air and Subsequent Deposition

Discharges to the air from AFOs include both volatile pollutants (e.g., ammonia and various by-products of manure decomposition) and particulate matter from dried manure, feed, hair, and feathers. The degree of volatilization of pollutants from manure depends on environmental conditions and the manure management system employed. For example, spray application of manure increases the potential for volatilization, as does the practice of spreading manure on the land without incorporating it into the soil. Volatilization is also affected by climate and soil conditions, (e.g., soil acidity and moisture content), and is reduced by the presence of growing plants (Follett, 1995).

Particulate matter from manure forms an organic dust made up of dried manure, feed, and epithelial cells. These airborne particles can contain adsorbed gases, endotoxin (the toxic protoplasm liberated when a microorganism dies and disintegrates), and possibly steroids from animal waste. According to information presented to the Centers for Disease Control, at least 50 percent of the dust emissions from swine operations are believed to be respirable and may therefore be associated with inhalation-related human health effects (Thu, 1998).[6]

In addition to creating the potential for air-related health effects, both volatilized pollutants and particulate matter can contaminate nearby surface waters through atmospheric deposition. Volatilization of the ammonia originating from animal waste, in particular, has been linked with atmospheric deposition of nitrogen (Lander *et al.,* 1998). While it is not clear what percentage of total deposition of pollutants can be linked to AFOs, EPA's *National Water Quality Inventory: 2000 Report* indicates that atmospheric deposition from all sources is among the leading causes of water quality impairment in estuaries, lakes, reservoirs and ponds.

2.2 POTENTIAL ECOLOGICAL HAZARDS POSED BY AFO POLLUTANTS

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. The concentration of particular pollutants in manure varies with animal species, the size, maturity, and health of the individual animal, and the composition (e.g., protein content) of animal feed.[7] The range of pollutants associated with manure is evident in a 1991 U.S. Fish and Wildlife Service (USFWS) report on suspected water quality impacts from cattle feedlots on Tierra Blanca Creek in the Texas Panhandle. The water quality impacts the USFWS reported included elevated concentrations of ammonia, coliform bacteria, chloride, nitrogen, and suspended solids, as well as reduced concentrations of dissolved oxygen. In addition, USFWS found elevated concentrations of the feed additives copper and zinc in creek sediment (USFWS, 1991).

The ecological impacts of animal waste releases to surface water can range from minor, temporary fluctuations in water quality (e.g., associated with limited surface runoff) to chronic degradation of ecosystems (e.g., associated with consistently poor management practices such as over-application), to dramatic impacts such as extensive fish or wildlife kills (e.g., associated with acute events such as spills and consequent oxygen depletion, increased ammonia concentrations, or toxic algae blooms). In some cases, individual pollutants associated with animal waste are the clear and direct cause of observable ecological effects. In other cases, ecological effects such as declines in aquatic populations are the result of complex systemic changes that are linked directly or indirectly to pollution from AFOs.

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[6] "Respirable" generally refers to particles less than 10 microns in diameter, or PM10; these particles are responsible for the majority of human health effects related to air pollution because they are small enough to travel through the nasal passage and into the lungs.

[7] For more detailed discussion of the pollutants associated with animal waste, see Phillips *et al.,* 1992.

Exhibit 2-2 lists the key pollutants associated with AFO waste, and notes their potential impacts. The remainder of this section describes in more detail the relationship between AFO pollutants and observed ecological effects. Section 2.3 focuses on the specific impacts of AFO pollutants on human health.

2.2.1 Nutrients and Eutrophication

EPA's *National Water Quality Inventory: 2000 Report* indicates that nutrients from all sources comprise the leading stressor in impaired lakes, ponds, and reservoirs, and are among the most frequent stressors in impaired rivers, streams, and estuaries. Nutrients are naturally occurring elements that are necessary for plant growth. However, when excess nutrients enter surface waters they can stimulate overgrowth of algae and bacteria, changing ecosystems in a process called "eutrophication." In addition, nutrients (nitrogen, in particular) in high concentrations can be toxic to animals and humans.

The two nutrients of most concern related to AFOs are nitrogen and phosphorus.[8] Each of these elements exists in several forms in the environment, and is involved in several phases of uptake and digestion by animals and plants. This section briefly describes the processes by which nitrogen and phosphorus enter aquatic ecosystems, then discusses the process and impacts of eutrophication.

2.2.1.1 Nitrogen and Nitrogen Compounds

Nitrogen, an element essential to plant growth, moves through the environment in a series of chemical reactions known as the nitrogen cycle. Nitrogen in manure exists in both organic forms (e.g., urea) and inorganic forms (e.g., ammonium and nitrate) (NCAES, 1982). In fresh manure, 60 to 90 percent of total nitrogen is present in the organic form. Inorganic nitrogen can enter the environment by volatilizing in the form of ammonia, or through soil or water microbe processes that transform organic nitrogen to an inorganic form that can be used by plants (i.e., as fertilizer). Both ammonia and ammonium are toxic to aquatic life, and ammonia in particular reduces the dissolved oxygen in surface waters that is necessary for aquatic animals. Nitrites pose additional risks to aquatic life: if sediments are enriched with nutrients, nitrite concentrations in the water may be raised enough to cause nitrite poisoning or "brown blood disease" in fish (USDA, 1992).

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[8] 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, however, are unlikely to pose hazards to human health or aquatic life. For more information see Wetzel, 1983.

Exhibit 2-2 KEY POLLUTANTS IN ANIMAL WASTE			
Pollutant	**Description of Pollutant Forms in Animal Waste**	**Pathways**	**Potential Impacts**
Nutrients			
Nitrogen	Exists in fresh manure in organic (e.g., urea) and inorganic forms (e.g., ammonium and nitrate). Microbes transform organic nitrogen to inorganic forms that may be absorbed by plants.	▸ Overland discharge ▸ Leachate into groundwater ▸ Atmospheric deposition as ammonia	▸ Eutrophication ▸ Animal, human health effects
Phosphorus	Exists in both organic and inorganic forms. As manure ages, phosphorus mineralizes to inorganic phosphate compounds that may be absorbed by plants.	▸ Overland discharge ▸ Leachate into groundwater (water soluble forms)	▸ Eutrophication
Potassium	Most potassium in manure is in an inorganic form available for absorption by plants; it can also be stored in soil for future uptake.	▸ Overland discharge ▸ Leachate into groundwater	▸ Increased salinity
Organic Compounds	Carbon-based compounds in manure that are decomposed by soil and surface water micro-organisms. Creates biochemical oxygen demand, or BOD, because decomposition consumes dissolved oxygen in the water.	▸ Overland discharge	▸ Depletion of dissolved oxygen ▸ Reduction in aquatic life ▸ Eutrophication
Solids	Includes manure itself and other elements (e.g., feed, bedding, hair, feathers, and corpses).	▸ Overland discharge ▸ Atmospheric deposition	▸ Turbidity ▸ Siltation
Pathogens	Includes range of disease-causing organisms, including bacteria, viruses, protozoa, fungi, and algae. Some pathogens are found in manure, others grow in surface water due to increased nutrients and organic matter.	▸ Overland discharge ▸ Growth in waters with high nutrient, organic materials	▸ Animal, human health effects
Salts	Includes cations sodium, potassium, calcium, and magnesium; and anions chloride, sulfate, bicarbonate, carbonate, and nitrate.	▸ Overland discharge ▸ Leachate into groundwater	▸ Reduction in aquatic life ▸ Human health effects ▸ Soil impacts
Trace Elements	Includes feed additives arsenic, copper, selenium, zinc, cadmium; and trace metals molybdenum, nickel, lead, iron, manganese, aluminum, and boron (pesticide ingredients).	▸ Overland discharge	▸ Toxicity at high levels
Volatile Compounds	Includes carbon dioxide, methane, nitrous oxide, hydrogen sulfide, and ammonia gases generated during decomposition of waste.	▸ Inhalation ▸ Atmospheric deposition of ammonia	▸ Human health effects ▸ Eutrophication ▸ Global warming
Other Pollutants	Includes pesticides, antibiotics, and hormones used in feeding operations.	▸ Overland discharge	▸ *Impacts unknown*

A 1975 study found that 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 (Vanderholm, 1975). Ammonia is highly volatile, and ammonia losses from animal feeding operations can be considerable. In North Carolina, animal agriculture is responsible for over 90 percent of all ammonia emissions; ammonia composes more than 40 percent of the total estimated nitrogen emissions from all sources. Once airborne, these volatile pollutants may be deposited onto nearby streams, rivers, and lakes. 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 (Aneja *et al.*, 1998).

National Study of Nitrogen Sources to Watersheds

In 1994, the USGS analyzed potential nitrogen sources to 107 watersheds, including manure (from both confined and unconfined animals), fertilizers, point sources, and atmospheric deposition. While the study found that proportions of nitrogen originating from various sources differ according to climate, hydrologic conditions, land use, population, and physical geography, results for selected watersheds for the 1987 base year showed that in some instances, nitrogen from manure represents a large portion of the total nitrogen added to the watershed. For example, in nine study watersheds more than 25 percent of nitrogen originates from manure.

Source: *Puckett, 1994.*

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 (CWAA, 1998). In addition, 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 (USFWS, 1991).

2.2.1.2 Phosphorus

Like nitrogen, phosphorus is necessary for the growth of plants, but is damaging in excess amounts. 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 (USDA, 1992). As manure ages, phosphorus mineralizes to inorganic phosphate compounds that are available to plants. Organic phosphorus compounds are generally water soluble and may leach through soil to groundwater or runoff into surface waters. In contrast, inorganic phosphorus tends to adhere to soils and is less likely to leach into groundwater, though it can reach surface waters through erosion or over-application. A report by the Agricultural Research Service noted that phosphorus bound to eroded sediment particles makes up 60 to 90 percent of phosphorus transported in surface runoff from cultivated land (USDA/ARS, 1999). Animal wastes typically have lower nitrogen-to-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 exhibit excessive levels of phosphorus (Sims, 1995).

Available Nitrogen and Phosphorus
1998 U.S. Department of Agriculture Study

In 1998, the USDA studied the amount of manure nitrogen and phosphorus produced by 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 1992 Census of Agriculture. The analyses did not consider manure from grazing animals in pasture. When calculating available nutrients, USDA also corrected for unrecoverable manure, nutrient losses that occur during storage and treatment, and losses to the environment that can occur through runoff, erosion, leaching to groundwater, and volatilization (especially for nitrogen in the form of ammonia). Considering typical management systems, USDA estimates 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.

USDA's study examined the potential for available manure nitrogen and phosphorus generated to meet or exceed plant uptake in each of the 3,141 mainland counties, considering harvested non-legume cropland and hayland. Based on the 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 expected because 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 with respect to crop requirements (Sims, 1995).

These analyses do not evaluate environmental transport of applied manure nutrients. Therefore, an excess of nutrients 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.

Source: *Lander et al., 1998.*

2.2.1.3 Eutrophication

Eutrophication is a process in which excess phosphorus or nitrogen over-enriches water bodies and disrupts aquatic ecosystems. Excess nutrients cause overgrowth of plants, including fast-growing algae "blooms." Eutrophication can affect the population diversity, abundance, and biomass of phytoplankton and zooplankton, and can increase the mortality rates of aquatic species (USEPA, 1991). Even when algae are not themselves directly harmful to aquatic life, floating algal mats can reduce the penetration of sunlight in the water column and limit growth of seagrass beds and other submerged vegetation. Reduction in submerged aquatic vegetation adversely affects both fish and shellfish populations, and is the leading cause of biological decline in Chesapeake Bay (Carpenter *et al.*, 1998). The *National Water Quality Inventory: 2000 Report* indicates that excess algal growth alone is among the leading causes of impairment in lakes, ponds, and reservoirs.

Increased algal growth can also raise the pH of water bodies as algae consume dissolved carbon dioxide to support photosynthesis. This elevated pH can harm the gills 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 species. In addition, excess nitrogen can contribute to water quality decline by increasing the acidity of surface waters (USEPA, 1995, 1991).

Damage from eutrophication increases when algae blooms die and are digested by bacteria in a decomposition process that depletes the level of oxygen in the water. Dissolved oxygen is necessary for the survival of aquatic life in a healthy ecosystem, and depressed levels of dissolved oxygen can cause widespread morbidity and mortality among aquatic species. Algal decay and night-time respiration can lower the dissolved oxygen content of a water body to levels insufficient to support fish and invertebrates. Severe reductions in dissolved oxygen can result in dramatic fish kills (Carpenter *et al.*, 1998).

In addition to reducing plant diversity and dissolved oxygen, eutrophication can encourage the growth of toxic microorganisms such as cyanobacteria (a toxic algae) and the dinoflagellate *Pfiesteria piscicida*. These organisms can be toxic to both wildlife and humans. Researchers have documented stimulation of *Pfiesteria* growth by swine effluent spills, and have shown that the organism's growth can be highly stimulated by both inorganic and organic nitrogen and phosphorus enrichment (NCSU, 1998).

2.2.2 Pathogens

Pathogens are organisms that cause disease in humans and other species; they include certain species of bacteria, viruses, protozoa, fungi, and algae. Animal waste itself contains hundreds of species of microorganisms, including bacteria, viruses, protozoa, and parasites (USDA, 1998; Jackson *et al.*, 1987; Boyd, 1990). Pathogens may be transmitted directly from manure to surface water, and pathogens already in surface water may increase in number due to loadings of animal manure nutrients and organic matter. Of particular concern are certain pathogens associated with algae blooms. EPA's *National Water Quality Inventory: 2000 Report* focuses on bacterial pathogens and notes that they are the leading stressor in impaired rivers and streams and the fourth-leading stressor in impaired estuaries.

Over 150 pathogens in livestock manure are associated with risks to humans; these include the bacteria *Escheria coli* and *Salmonella* species. and the protozoa *Cryptosporidium parvum* and *Giardia* species. A recent study by the USDA revealed that about half the cattle at the nation's feedlots carry *E. coli* (NAS, 2000). The pathogens *C. parvum*, *Giardia*, and *E. coli* are able to survive and remain infectious in the environment for long periods of time (Stehman, 2000). In addition, some bacteria in livestock waste cause avian botulism and avian cholera, which have in the past killed tens of thousands of migratory waterfowl annually (USEPA, 1993).

Eutrophication is associated with blooms of a variety of organisms that can be toxic to fish. This includes the dinoflagellate *Pfiesteria piscicida*, which is believed to be the primary cause 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 (NCSU, 1998; USEPA, 1993). In 1997, hog operations were linked to a *Pfiesteria piscicida* outbreak in North Carolina rivers in which 450,000 fish died (U.S. Senate, 1997). That same year, poultry operation wastes caused *Pfiesteria* outbreaks that killed tens of thousands of fish in Maryland waters, including the Pokomoke River, King's Creek, and Chesapeake Bay (Shields, 1997; Shields and Meyer, 1997; New York Times, 1997).

The generation of toxins associated with eutrophication can also threaten other species. In freshwater, cyanobacterial toxins have caused many incidents of poisoning of wild and domestic animals that have consumed contaminated waters (Health Canada Environmental Health Program, 1998; Carpenter *et al.*, 1998). In coastal waters, visible algae blooms known as red or brown tides have caused significant mortality in marine mammals. Even when algae blooms are not visible, shellfish such as oysters, clams and mussels can carry the toxins from certain algae in their tissue. Shellfish are filter feeders, and pass large volumes of water over their gills to obtain nutrients. As a result, they can concentrate a broad range of microorganisms in their tissues, and provide a pathway for pathogen transmission from surface water to higher trophic organisms (Chai *et al.*, 1994). Information is becoming available to assess the health effects of contaminated shellfish on wildlife receptors. In 1998, the death of over 400 California sea lions was linked to ingestion of mussels contaminated by a bloom of toxic algae (Scholin *et al.*,

1995 Algae Blooms and Pfiesteria Outbreaks: Neuse River, North Carolina

Algae blooms and Pfiesteria outbreaks on the Neuse River in North Carolina during the summer and fall of 1995 were the identified causes of three major fish kills and the suspected causes of several incidents of human illness.

Heavy rains in June of 1995 caused overflows of wastewater treatment plants and hog lagoons in the watershed. Within weeks, large mats of algae and aquatic weeds were reported near the town of New Bern on the Trent River, a tributary of the Neuse. By July, historically low levels of dissolved oxygen were recorded in a stretch of the Neuse downstream from New Bern, coinciding with the deaths of over 100,000 fish. A second fish kill in August on another Neuse tributary numbered in the thousands.

In September and October a third major fish kill occurred along a 35-mile stretch of the Neuse River itself; the dead fish were covered with sores, and the cause of the outbreak was determined to be the dinoflagellate Pfiesteria. After multiple reports of similar welts and sores on the bodies of those who went swimming or fishing in contaminated areas, state officials declared a health warning, urging people not to swim, boat, or fish in the affected area. In addition, the area was closed to commercial fishing for two weeks.

Source: *Leavenworth, 1995a, 1995b.*

2000). Previous incidents associated the deaths of manatees and whales with toxic and harmful algae blooms (Anderson, 1998).

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 (NOAA, 1997).

2.2.3 Organic Compounds and Biochemical Oxygen Demand (BOD)

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. EPA's *National Water Quality Inventory: 2000 Report* indicates that oxygen-depleting substances are the third leading stressor in estuaries. They are also the fourth leading stressor in impaired rivers and streams and the fifth leading stressor in impaired lakes, ponds, and reservoirs.

Carbon compounds and associated biochemical oxygen demand (BOD) can deplete oxygen and affect the health of aquatic ecosystems in the absence of any other pollutants (e.g., due to decaying vegetation).[9] When carbon compounds enter aquatic ecosystems in conjunction with nutrients (which is generally the case in manure-related pollution), the impacts of BOD are compounded by eutrophication and the presence and growth of pathogens. The result is often a rapid decrease in biodiversity. A study of three Indiana stream systems documents such a reduction in biodiversity due to AFOs (Hoosier Environmental Council, 1997). The 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.

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[9] Biochemical oxygen demand (BOD) is an indirect measure of the concentration of biodegradable substances present in an aqueous solution. Anaerobic lagoon effluent from AFOs typically contains BOD values 10 to 200 times higher than treated domestic sewage. See NCAES, 1982; USDA, 1992; USDA/NRCS, 1992/1996.

2.2.4 Solids and Siltation

Solids from animal manure include the manure itself and any other elements that have been mixed with it, such as spilled feed, bedding, hair, feathers, and corpses. Smaller solids with less weight remain in the water column as "suspended solids" while heavier solids sink to the bottom of receiving waters in the gradual process of "siltation."

Solids entering surface water can degrade aquatic ecosystems to the point of non-viability. Suspended particles can reduce the depth to which sunlight can penetrate, decreasing photosynthetic activity and the resulting oxygen production by plants and phytoplankton. The increased turbidity also limits the growth of aquatic plants, which serve as critical habitat for fish, crabs, shellfish, and other aquatic organisms upon which these animals feed. In addition, suspended particles can clog fish gills, reduce visibility for sight feeders, and disrupt migration by interfering with a fish's ability to navigate using chemical signals (Goldman and Horne, 1983; Abt, 1993). EPA's *National Water Quality Inventory: 2000 Report* indicates that suspended solids from all sources are the fourth leading stressor in lakes, ponds, and reservoirs.

A major source of siltation is erosion from agricultural lands, including AFOs, cropland, and grazing lands (USEPA, 1992b). Silt can contain heavier manure particles as well as the soil particles carried by erosion. Such sediment can smother fish eggs and otherwise interrupt the reproduction of aquatic species (Boyd, 1990). It can also alter or destroy habitat for benthic organisms. Solids can also degrade drinking water sources, thereby increasing treatment costs.

Arkansas Water Quality Inventory Report: Agricultural Activities and Turbidity

Arkansas' 1996 Water Quality Inventory Report *discussed a sub-watershed in northwestern Arkansas. Land uses in that area, primarily poultry production and pasture management, are major sources of nutrients and chronic high turbidity, and water in the area only partially supports aquatic life.*

Source: *USEPA, 1993.*

2.2.5 Salts and Trace Elements

Animal manure contains a number of salts and trace elements such as metals. While these contaminants do not directly alter or interfere with ecosystem processes such as oxygen availability, they are toxic in high concentrations, both to animals and plants. For example, bottom feeding birds may be susceptible to metal toxicity because they are attracted to shallow feedlot wastewater ponds and waters adjacent to feedlots. In addition, metals can remain in aquatic ecosystems for long periods of time because of adsorption to suspended or bed sediments or uptake by aquatic biota.

The salinity of animal manure is due 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.[10] Salinity tends to increase as the volume of manure decreases during decomposition, and can have an adverse effect on aquatic life and drinking water supplies (Gresham *et al.*, 1990). Repeated application of manure can lead to increased soil salinity in the root zone and on top of the soil, where it can damage crops; to reduce salinity farmers apply excess water, and salts are washed into surface waters in runoff. In fresh waters, increasing salinity can disrupt the ecosystem, making it difficult for resident species of plants and animals to remain. For example, laboratory experiments have linked increased salinity with inhibited growth and slowed molting in mallard ducklings (USFWS, 1992).

Trace elements in manure can 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 (Sims, 1995). Trace metals may also end up in manure through use of pesticides that are applied to livestock to suppress houseflies and other pests (USDA/ARS, 1998).

A recent Iowa investigation of chemical and microbial contamination near large scale swine operations demonstrated the presence of trace elements 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 (CDCP, 1998). Similarly, USFWS has 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. USFWS found elevated concentrations of the feed additives copper and zinc in the creek sediment (USFWS, 1991).

2.2.6 Odorous/Volatile Compounds

Sources of volatile compounds and odor from AFOs include animal confinement buildings, manure piles, waste lagoons, and land application sites, where decomposition of animal wastes by microorganisms produces gases. The four main gases generated are carbon dioxide, methane, hydrogen sulfide, and ammonia. Aerobic conditions yield mainly carbon dioxide, while anaerobic conditions that dominate in typical, unaerated animal waste lagoons generate both methane and carbon dioxide. Anaerobic conditions 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 (USDA, 1992; Bouzaher *et al*, 1993).

Volatile compounds affect aquatic ecosystems through atmospheric deposition; ammonia (discussed in Section 2.2.1.1) is the most important AFO-related volatile because it is itself toxic and also contributes to eutrophication as a source of nitrogen. Other compounds are less clearly associated with broad ecological impacts, but may have localized impacts.

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[10] See Boyd, 1990 and NCAES, 1982. Other major cations contributing to manure salinity are calcium and magnesium; the major anions are chloride, sulfate, bicarbonate, carbonate, and nitrate. See NRC, 1993.

2.2.7 Other Pollutants and Ecosystem Effects

In addition to the pollutants discussed above, pesticides, antibiotics, and hormones used in animal feeding operations may exist in animal wastes and may be present in increased levels in the environment (USDA/ARS, 1998). These compounds may pose risks such as chronic aquatic toxicity (from pesticides) and reproductive impairment (from hormones). While there is limited information on the quantities of these compounds that reach surface waters from AFOs, some research suggests that manure-related runoff may be a significant source of these contaminants.

- **Pesticides:** Pesticides are used to suppress houseflies and other livestock pests. There is little information on the rate at which pesticides in manure enter surface water, but a 1999 literature review by the University of Minnesota notes a 1994 study that links quantities of cyromazine (used to control flies in poultry litter) in runoff to the rate of manure application and rainfall intensity. The review also identifies a 1995 study finding that roughly one percent of all applied pesticides enter surface water. The impacts of these compounds on aquatic ecosystems are unclear, but there is some concern that pesticides may contribute to endocrine disruption (Mulla, 1999).

- **Hormones:** Animal operations use a variety of hormones such as steroids (e.g., estrogen, progesterone, testosterone) and proteins (e.g., prolactin, growth hormone) to improve animal health and productivity. Studies have identified hormones in animal manures. Naturally high hormone concentrations in birds contribute to higher hormone levels in poultry manure, including measurable amounts of estrogen and testosterone. When present in high concentrations, hormones in the environment are linked to reduced fertility, mutations, and the death of fish. There is evidence that fish in some streams are experiencing endocrine disruption (Shore *et al.*, 1995; Mulla, 1999).[11]

- **Antibiotics** The majority of livestock (roughly 60 to 80 percent) receive antibiotics during their productive life span. Some of these agents are used only therapeutically (e.g., to treat illness), but in both the swine and poultry industries, most antibiotics are administered as feed additives to promote growth or to improve feed conversion efficiency. Essentially all of an

[11] The presence of estrogen and estrogen-like compounds in surface water has been the focus of recent research. While their ultimate fate in the environment is unknown, studies indicate that no common soil or fecal bacteria can metabolize estrogen (Shore *et al.*, 1995). Estradiol, an estrogen hormone, was found in runoff from a field receiving poultry litter at concentrations up to 3.5 micrograms per liter (ug/L). Fish exposed to 0.25 ug/L of estradiol can undergo gender changes, and exposures at levels above 10 ug/L can be fatal (Mulla, 1999).

antibiotic administered is eventually excreted, either unchanged or in metabolite form (Tetra Tech, 2000). Little information is available regarding the concentrations of antibiotics in animal wastes, or on the fate and transport of antibiotics in the environment. However, the key concern related to antibiotics in animal manure is the potential emergence of antibiotic-resistant pathogens in surface and drinking water. As antibiotics use has increased, more strains of antibiotic resistant pathogens are emerging (Mulla, 1999).

Finally, manure pollutants of all types can affect terrestrial as well as aquatic ecosystems. Over-application of manure, in particular, can have terrestrial effects. High oxygen depletion rates due to microbial activity have been reported in manure-amended agricultural soils. In addition, elevated microbial populations can affect crop growth by competing with plant roots for soil oxygen and nutrients. Trace elements (e.g., feed additives such as arsenic, copper, and selenium) and salts in animal manure can accumulate in soil and become toxic to plants (USDA, 1992 and USFWS, 1991).

2.3 HUMAN HEALTH IMPACTS RELATED TO AFO POLLUTANTS

Human health impacts from waterborne manure-related contaminants are primarily associated with drinking contaminated water, contact with contaminated water, and consuming contaminated shellfish. The most common causes of health effects are ingestion of nitrates in drinking water, ingestion of water containing pathogens from manure, and contact with or ingestion of harmful algae or toxic algal by-products. The ingestion of elevated concentrations of trace elements (e.g., arsenic, copper, selenium, and zinc) may also affect human health, and certain gases associated with AFOs may directly and indirectly (i.e., through the formation of secondary particulate matter) pose inhalation risks for nearby residents.

While some recorded human health effects stem from contamination of public drinking water supplies and ingestion of shellfish, more frequently health effects are caused by contamination of private wells, or recreational ingestion or contact. Public water supplies are generally protected by monitoring and treatment, though contaminants and algae blooms may increase treatment costs and affect system operation. Ingestion of contaminated shellfish is reduced by monitoring and closure of shellfish beds in response to excessive levels of contaminants.

2.3.1 <u>Health Impacts Associated with Nitrates</u>

Nitrogen in manure is easily transformed into nitrate form, which can be transported to drinking water sources (e.g., through leaching to groundwater) and presents a range of health risks. EPA found that nitrate is the most widespread agricultural contaminant in drinking water wells, and estimates that 4.5 million people served by wells are exposed to elevated nitrate levels (USEPA, 1990). Elevated nitrate levels can cause nitrate poisoning, particularly in infants (this is known as methemoglobinemia or "blue baby syndrome"), in which potentially fatal oxygen starvation gives a "blue" appearance to the skin. In addition to blue baby syndrome, low blood oxygen due to methemoglobinemia has been linked to birth defects, miscarriages, and poor health in humans and animals.[12]

Reported cases of methemoglobinemia are most often associated with wells that were privately dug and that may have been badly positioned in relation to the disposal of human and animal excreta (Addiscott *et al.*, 1991). Reported cases of methemoglobinemia are rare, though the incidence of actual cases may be greater than the number reported. Studies in South Dakota and Nebraska have indicated that most cases of methemoglobinemia are not reported. Under-reporting may result from the fact that methemoglobinemia can be difficult to detect in infants because its symptoms are similar to other conditions. In addition, doctors are not always required to report it (Michel, 1996; Meyer, 1994).

In 1995, several private wells in North Carolina were found to be contaminated with nitrates at levels 10 times higher than the health standard; this contamination was linked with a nearby hog operation (Warrick 1995c, 1995d). In 1982, nitrate levels greater that 10 milligrams per liter were found in 32 percent of the wells in Sussex County, Delaware; these levels were associated with local poultry operations (Chapman, 1996). 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 EPA's maximum contaminant level (MCL) (Ritter *et al.*, 1989). Nitrate is not removed by conventional drinking water treatment processes. Its removal requires additional, relatively expensive treatment units.

2.3.2 Health Impacts Associated with Algal Blooms

Eutrophication can affect human health by encouraging the formation of algal blooms. Some algae release toxins as they die and may affect human health through dermal contact or through consumption of contaminated water or shellfish. In marine ecosystems, algal blooms such as red tides form toxic byproducts that can affect human health through recreational contact or consumption of contaminated shellfish (Thomann and Muller, 1987). In freshwater, blooms of cyanobacteria (blue-green algae) may pose a serious health hazard to those who consume the water. When cyanobacterial blooms die or are ingested, they release water-soluble compounds that are toxic to the nervous system and liver (Carpenter *et al.*, 1998).

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[12] See USEPA, 1991. In addition, studies in Australia found an increased risk of congenital malformations with consumption of high-nitrate groundwater. 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. See Bruning-Fann and Kaneene, 1993.

Non-toxic algae blooms triggered by nutrient pollution can also affect drinking water by clogging treatment plant intakes and by producing objectionable tastes and odors. In addition, increased algae in drinking water sources can increase production of harmful chlorinated byproducts (e.g., trihalomethanes) by reacting with chlorine used to disinfect drinking water.

Impacts of Manure Pollutants on Water Treatment Costs

Public water providers may incur considerable expenses associated with removing manure-related contaminants and algae from public water supplies. For example:

- *In California's Chino Basin, it could cost over $1 million per year to remove the nitrates from drinking water due to loadings from local dairies.*
- *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.*

Sources: *For more details on these examples, see USEPA, 1993; Behm, 1989; Lassek, 1998; and Lassek, 1997.*

2.3.3 Health Impacts Associated with Pathogens

Over 150 pathogens in livestock manure are associated with risks to humans (Juranek, 1991; CAST, 1992). Although human contact can occur through contaminated drinking water, adequate treatment of public water supplies generally prevents exposure. Most exposure occurs through incidental ingestion during recreation in contaminated waters or through ingestion of contaminated shellfish (Stelma and McCabe, 1992). 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, but contact recreation with pathogens can also result in infections of the skin, eye, ear, nose, and throat (Juranek, 1995; and Stehman, 2000). In 1989, ear and skin infections and intestinal illnesses were reported in swimmers as a result of discharges from a dairy operation in Wisconsin (Behm, 1989).

A study for the period 1989 to 1996 revealed that *Cryptosporidium parvum* (a pathogen associated with cows) was one of the leading causes of infectious water-borne disease outbreaks in which an agent was identified. *C. parvum* can produce gastrointestinal illnesses such as cryptosporidiosis, with symptoms that include severe diarrhea (Stehman, 2000). While otherwise healthy people typically recover quickly from illnesses such as cryptosporidiosis, these diseases can be fatal in certain subpopulations, including children, the elderly, people with HIV infection, chemotherapy patients, and those taking medications that suppress the immune system.[13] 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 speculated sources include runoff from cow manure application sites (Casman, 1996). More recently, 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 (Brooke, 2000).

Algae blooms are associated with a variety of organisms that are toxic to humans, including the algae associated with "red tide" and a number dinoflagellates. One pathogen of particular concern is 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 or inhalation exposure. Researchers working with dilute toxic cultures of *Pfiesteria* have 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. In addition, 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 (NCSU, 1998; Morris *et al.*, 1998).

While many soil types prevent most pathogens from reaching aquifers, groundwater in areas of sandy soils, limestone formations, or sinkholes is more vulnerable to contamination. Private wells, in particular, are prone to contamination because they tend to be shallower than public wells and therefore more susceptible to contaminants leaching from the surface.[14] While the general extent of groundwater contamination from AFOs is unknown, there are incidents that indicate a connection between livestock waste and contaminated well water. For example, 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 (Behm, 1989).

2.3.4 Health Impacts Associated with Trace Elements and Salts

Trace elements in manure include feed additives such as zinc, arsenic, copper, and selenium. While these are necessary nutrients, they are toxic at elevated concentrations, and tend to persist in

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[13] By the year 2010, about 20 percent of the human population (especially infants, the elderly, and those with compromised immune systems) will be classified as particularly vulnerable to the health effects of pathogens (Mulla, 1999).

[14] In a 1997 survey of drinking water standard violations in six states over a four-year period, the U.S. General Accounting Office reported 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. See USGAO, 1997.

the environment and to bioconcentrate in plant and animal tissues. Trace elements are associated with a variety of illnesses. For example, over-exposure to selenium can cause liver dysfunction and loss of hair and nails, while ingestion of too much zinc can produce changes in copper and iron balances, particularly copper deficiency anemia (IRIS, 2000).

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 that EPA allows in land-applied sewage sludge (Sims, 1995). 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 that EPA considers safe, potentially affecting 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 North Carolina hog farm (Warrick and Stith, 1995b).

Salts in manure can also affect the salinity of drinking water. Increased salts in drinking water can in turn increase blood pressure in salt-sensitive individuals, increasing the risk of stroke and heart attack (Anderson, 1998; Boyd, 1990).

2.3.5 <u>Other Health Impacts</u>

Potential health effects associated with other contaminants in manure include inhalation-related risks associated with volatile organic chemicals and odors, and the effects of hormones, antibiotics, and pesticides that are found in animal feed.

Volatile Compounds

In 1996, the Minnesota Department of Health found levels of hydrogen sulfide gas at residences near AFOs that were high enough to cause symptoms such as headaches, nausea, vomiting, eye irritation, respiratory problems (including shallow breathing and coughing), achy joints, dizziness, fatigue, sore throats, swollen glands, tightness in the chest, irritability, insomnia, and blackouts (Hoosier Environmental Council, 1997). In an Iowa study, neighbors within two miles of a 4,000-sow swine facility reported more physical and mental health symptoms than a control group (Thu, 1998). These symptoms included chronic bronchitis, hyperactive airways, mucus membrane irritation, headache, nausea, tension, anger, fatigue, and confusion. Odor is itself a significant concern because of its documented effect on moods, such as increased tension, depression, and fatigue (Schiffman *et al.*, 1995). Heavy odors are the most common complaint from neighbors of swine operations (Agricultural Animal Waste Task Force, 1996).

Pesticides

Various ingredients in pesticides have been linked to a variety of human health effects, such as systemic toxicity and endocrine disruption (see below). However, information linking pesticide levels in surface and drinking water to human exposure and to animal manure is currently limited. It is therefore unclear what health risks are posed by pesticide concentrations in AFO wastes.

Hormones and Endocrine Disruption

Hormones in the environment can act as endocrine disruptors, altering hormone pathways that regulate reproductive processes in both human and animal populations. Estrogen hormones have been implicated in the drastic reduction in sperm counts among European and North American men (Sharpe and Skakkebaek, 1993) and widespread reproductive disorders in a variety of wildlife (Colburn *et al.*, 1993). A number of agricultural chemicals have also been demonstrated to cause endocrine disruption as well, including pesticides (Shore *et al.*, 1995). The effects of these chemicals on the environment and their impacts on human health through environmental exposures are not completely understood, but they are currently being studied for evidence that they cause neurobiological, developmental, reproductive, and carcinogenic effects (Tetra Tech, 2000). No studies exist on the human health impact of hormones from manure watersheds.

Antibiotics and Antibiotic Resistance

While antibiotics themselves are not generally associated with human health impacts, antibiotic resistance poses a significant health threat. In April 2000, the New England Journal of Medicine published an article that discussed the case of a 12-year old boy infected with a strain of *Salmonella* that was resistant to no fewer than 13 antimicrobial agents (Fey, 2000). The cause of the child's illness is believed to be exposure to the cattle on his family's Nebraska ranch. The Centers for Disease Control, the Food and Drug Administration, and the National Institutes of Health issued a draft action plan in June, 2000, to address the increase in antibiotic resistant diseases (CDCP, 2000). The plan is intended to combat antimicrobial resistance through surveys, prevention and control activities, research, and product development. Some actions are already underway.

2.4 REFERENCES

Abt Associates Inc. 1993. *Human Health Risk Assessment for the Use and Disposal of Sewage Sludge: Benefits of Regulation*. Prepared for Health and Ecological Criteria Division, Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency. January.

Addiscott, T.M., A.P. Whitmore, and D.S. Powlson. 1991. *Farming, Fertilizers, and the Nitrate Problem*. Rothamsted Experimental Station. C-A-B International: Oxon, United Kingdom.

Anderson, Don. 1998. "Why are outbreaks of *Pfiesteria* and red tides suddenly threatening our oceans?" *Scientific American* online at: http://www.sciam.com/askexpert/environment/environment21/environment21.html.

Aneja, Viney, George C. Murray, and James Southerland. April 1998. Atmospheric Nitrogen Compounds: Emissions, Transport, Transformation, Deposition, and Assessment. *EM, Air & Waste Management Association's Magazine for Environmental Managers*, 22-25. Available at: online.awma.org/em/april98/features/aneja/aneja.htm.

ASCE (American Society of Civil Engineers). February 1998. Bay Pollution Flows Underground. *Civil Engineering*, p. 13-14.

Behm, Donald. 1989. "Ill Waters: The Fouling of Wisconsin's Lakes and Streams." *The Milwaukee Journal Sentinel.* Special Report: A series of articles and an editorial published November 5 - 10, 1989.

Bouzaher, A., P.G. Lakshminarayan, S.R. Johnson, T. Jones, and R. Jones. 1993. *The Economic and Environmental Indicators for Evaluating the National Pilot Project on Livestock and the Environment, Livestock Series Report 1.* Center for Agricultural and Rural Development (CARD) at Iowa State University and Texas Institute for Applied Environmental Research at Tarleton State University. Staff Report 93-SR 64. October.

Boyd, W. 1990. *Effects of Poultry Waste on Ground and Surface Water.* In Blake, J., and R.M. Hulet, eds. Proceedings of the 1990 National Poultry Waste Management Symposium. October.

Brooke, James. 2000. Few left untouched after deadly E. coli flows through an Ontario town's water. *The New York Times.* July 10, 2000.

Bruning-Fann, C. S. and J. B. Kaneene. 1993. The Effects of Nitrate, Nitrite, and N-Nitroso Compounds on Human Health: A Review. *Vet. Human. Toxicol.* 35(6). December.

Carpenter, Stephen, N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998. Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. *Issues in Ecology*, Number 3. Published by the Ecological Society of America, Washington, D.C. Summer. (Also available at: esa.sdsc.edu/).

Casman, Elizabeth A. 1996. Chemical and Microbiological Consequences of Anaerobic Digestion of Livestock Manure, A Literature Review. Interstate Commission on the Potomac River Basin, ICPRB Report #96-6.

CAST (Council for Agricultural Science and Technology). 1992. *Water Quality: Agriculture's Role*. Report 120. December.

CDCP (Centers for Disease Control and Prevention). 1998. *Report to the State of Iowa Department of Public Health on the Investigation of the Chemical and Microbial Constituents of Ground and Surface Water Proximal to Large-Scale Swine Operations.*

CDCP (Centers for Disease Control and Prevention). 2000. *A Public Health Action Plan to Combat Antimicrobial Resistance.* June Draft. available at: http://www.cdc.gov/drugresistance/actionplan/aractionplan.pdf.

Chai, T.J., Tj. Han and R.R. Cockey. 1994. Microbiological quality of shellfish-growing waters in Chesapeake Bay. *J. Food Protect.* 57:229-234.

Chapman, S.L. 1996. Soil and Solid Poultry Waste Nutrient Management and Water Quality. *Poultry Science* 75:862-866.

CWAA (Clean Water Action Alliance). 1998. Minnesota Manure Spills and Runoff.

Daniel, T.C., D.R. Edwards, and D.J. Nichols. 1995. Edge-of-Field Losses of Surface-Applied Animal Manure. In: *Animal Waste and the Land-Water Interface,* edited by Kenneth Steele.

Fey, Paul D.; Safranek, Thomas J.; Rupp, Mark E.; Dunne, Eileen F.; Ribot, Efrain; Iwen, Peter C.; Bradford, Patricia A.; Angulo, Frederick J.; Hinrichs, Steven H. Ceftriaxone. 2000. "Resistant Salmonella Infection Acquired by a Child from Cattle." *The New England Journal of Medicine*; 342 (17), pp 1242-1249.

Follett, Ronald F. 1995. *Fate and Transport of Nutrients: Nitrogen.* Working Paper No. 7. U.S. Department of Agriculture, Agricultural Research Service, Soil-Plant-Nutrient Research Unit, Fort Collins, Colorado. September.

Goldman, C., and A. Horne. 1983. *Limnology*. New York: McGraw-Hill Publishing, Co.

Gresham, C.W., *et al.* 1990. *Composting of Poultry Litter, Leaves, and Newspaper.* Rodale Research Center.

Health Canada Environmental Health Program. 1998. Blue-green Algae (Cyanobacteria) and their Toxins. Publication of the Canadian federal government. Available on the Internet at http://www.hc-sc.gc.ca/ehp/ehd/catalogue/general/iyh/algea.htm.

Hoosier Environmental Council. 1997. Internet home page. Available at: www.envirolink.org/orgs/hecweb/monitorspring97/confined.htm.

IRIS (Integrated Risk Information System). 2000. *Chemical Files and Background Documents and Papers*. Washington, DC. Available at: www.epa.gov/iris/subst/index.html. March.

Jackson, G., *et al.* 1987. *Agricultural Management Practices to Minimize Groundwater Contamination.* University of Wisconsin Environmental Resources Center (July).

Jordan, Herbert C., and Robert E. Graves. 1987. *Poultry Manure Management, Pennsylvania State University.* Prepared under the direction of the Manure Management Work Group of the Agricultural Advisory Committee to the PA Department of Environmental Resources.

Juranek, D.D. 1995. Cryptosporidiosis: sources of infection and guidelines for prevention. *Clin Infect Dis.* 21 (Sup. 1): S57-61.

Lander, Charles H., David Moffitt, and Klaus Alt. 1998. *Nutrients Available from Livestock Manure Relative to Crop Growth Requirements.* U.S. Department of Agriculture. Natural Resources Conservation Service. Washington, DC. Available at: www.nhq.nrcs.usda.gov/land/pubs/nlweb.html.

Lassek, P.J. 1997. Lake Eucha drowning in algae. *The Tulsa World.* August 17.

Lassek, P.J. 1998. Tulsa Officials Seek Long-Term Solution to Protect Watershed. *The Tulsa World,* March 16.

Leavenworth, Stuart. 1995a. "Airborne threats rain down on Neuse." *The News and Observer*, May 8. Available at: www.nando.net.

Leavenworth, Stuart. 1995b. "Half-million fish die in Neuse River." *The News and Observer*, September 22. Available at: www.nando.net.

Meadows, R. 1995. Livestock Legacy. *Environmental Health Perspectives* 103(12):1096-1100.

Meyer, M. October 1994. *How Common is Methemoglobinemia from Nitrate Contaminated Wells? A South Dakota Perspective*. Paper presented at the 39th Annual Midwest Ground Water Conference, Bismarck, ND. Cited in: Michel, *et al.*, 1996.

Michel, Kristin, J.R. Bacon, C.M. Gempesaw II, and J.H. Martin, Jr. August 1996. *Nutrient Management by Delmarva Poultry Growers: A Survey of Attitudes and Practices.* University of Delaware, College of Agricultural Sciences, Department of Food and Resource Economics.

Morris, J. Glenn Jr., *et al.* 1998. University of Maryland School of Medicine, Baltimore, Maryland. As reported by David Brown: "Pfiesteria Linked to Thinking Problems," *The Washington Post*, August 14.

Mulla, David; A. Sekely, A. Birr, J. Perry, B. Vondracek, E. Bean, E. Macbeth, S. Goyal, B. Wheeler, C. Alexander, G. Randall, G. Sands, and J. Linn. 1999. *Generic Environmental Impact Statement on Animal Agriculture: A Summary of the Literature Related to the Effects of Animal Agriculture on Water Resources (G).* Prepared for the Environmental Quality Board by the University of Minnesota, College of Agriculture, Food, and Environmental Sciences.

NAS (National Academy of Sciences), 2000. *Proceedings of the National Academy of Sciences.* April.

NCAES (North Carolina Agricultural Extension Service). 1982. *Best Management Practices for Agricultural Nonpoint Source Control: Animal Waste.* North Carolina State University. Biological and Agricultural Engineering Department. Raleigh, NC.

NCSU (North Carolina State University). 1998. Aquatic Botany Laboratory *Pfiesteria piscicida homepage.* Available at: www.pfiesteria.org/pfiestr/pfiestr.html.

New York Times (editorial). 1997. Why the Fish Are Dying. *The New York Times*, September 22. Available at: www.nytimes.com.

NOAA (National Oceanic and Atmospheric Administration). August 1997. The 1995 National Shellfish Register of Classified Growing Waters. Office of Ocean Resources Conservation and Assessment. National Ocean Service, U.S. Department of Commerce.

NRC (National Research Council). 1993. *Soil and Water Quality: An Agenda for Agriculture.* National Academy Press: Washington, D.C.

ODNR (Ohio Department of Natural Resources). 1997. Division of Wildlife Pollution Investigation Report - Manure Related Spills and Fish and Wildlife Kills. June 9.

Phillips, J. M., H. D. Scott, and D. C. Wolf. 1992. Environmental Implications of Animal Waste Application to Pastures. In: *Proceedings from the South Pasture Forage Crop Improvement Conference.* USDA/Agricultural Research Service (September). pp. 30-38.

Puckett, L.J. 1994. *Nonpoint and point sources of nitrogen in major watersheds of the United States*. U.S. Geological Survey, National Water Quality Assessment.

Ritter, W.F., A.E.M. Chirnside, and R.W. Lake. 1989. Influence of Best Management Practices on Water Quality in the Appoquinimink Watershed. *J. Environ. Sci. Health*, A24(8):897-924.

Ritter, W. F., and A. E. M. Chirnside. 1990. Impact of Animal Waste Lagoons on Groundwater Quality. *Biological Wastes*. 34:39-54.

Schiffman, S.S., E.A. Sattely Miller, M.S. Suggs, and B.G. Graham. 1995. The Effect of Environmental Odors Emanating from Commercial Swine Operations on the Mood of Nearby Residents. *Brain Research Bulletin*, 37:369-375.

Scholin, Christopher A., *et al.* 2000. "Mortality of sea lions along the central California coast linked to a toxic diatom bloom." *Nature* 403, 80 - 84.

Shields, T. 1997. Fish Kills Seen as 'Alarm Bell' For Chesapeake, Tributaries. *The Washington Post*, 17 August. B1.

Shields, T. and E.L. Meyer. 1997. New Fish Kills Found Miles from Pocomoke. *The Washington Post*, September 11. A1.

Sims, J. Thomas. 1995. "Characteristics of Animal Wastes and Waste-Amended Soils: An Overview of the Agricultural and Environmental Issues" in *Animal Waste and the Land-Water Interface*. Kenneth Steele, ed., CRC Press/Lewis Publishers, Boca Raton.

Smith, R., G. Schwarz, and R. Alexander. 1997. "Regional Interpretation of Water-Quality Monitoring Data." *Water Resources Research*. Vol. 33(12): 2781-2798. December.

Stehman, Susan M. 2000. "Ag-Related water borne pathogens" in *Managing Nutrients and Pathogens from Animal Agriculture, Proceedings of a Conference for Nutrient Management Consultants, Extension Educators, and Producer Advisors*. Natural Resource, Agriculture, and Engineering Service (NRAES). pp. 93-107. March 28-30.

Tetra Tech. 2000. *Literature Review and Assessment of Pathogens, Heavy Metals, and Antibiotic Content of Waste and Wastewater Generated by CAFOS*. Unpublished report prepared at the request of U.S. Environmental Protection Agency, Office of Water, EPA Contract 68-C-99-263.

Thomann, R. V., and J.A. Muller. 1987. *Principles of Surface Water Quality Modeling and Control*. Harper Collins Publishers.

Thu, Kendall. 1998. Information presented at the Center for Disease Control Workshop on Public Health Issues Related to Concentrated Animal Feeding Operations, June 23-24.

USDA (U.S. Department of Agriculture). 1992. *Agricultural Waste Management Field Handbook.* 210-AWMFH. April.

USDA (U.S. Department of Agriculture). 1998. *Agricultural Uses of Municipal, Animal, and Industrial Byproducts.* Agricultural Research Service. January.

USDA/ARS (U.S. Department of Agriculture/Agricultural Research Service). 1998. *Agricultural Uses of Municipal, Animal, and Industrial Byproducts.* Conservation Research Report Number 44. January.

USDA/NRCS (U.S. Department of Agriculture/Natural Resources Conservation Service). 1992 and 1996 revisions. *Agricultural Waste Management Field Handbook.* 210-AWMFH.

USEPA (U.S. Environmental Protection Agency). 1990. *National Survey of Pesticides in Drinking Water Wells,* Phase I Report. EPA-570990015.

USEPA (U. S. Environmental Protection Agency). 1991. *Nitrogen Action Plan.* Draft (March). PM-221. 40 0/90/003. Nitrogen Work Group.

USEPA (U. S. Environmental Protection Agency). 1992b. *Managing Nonpoint Source Pollution: Final Report to Congress.* Office of Water.

USEPA (U. S. Environmental Protection Agency). 1993. *The Report of the EPA/State Feedlot Workgroup.* Office of Wastewater Enforcement and Compliance.

USEPA (U. S. Environmental Protection Agency). 1995. *National Water Quality Inventory: 1994 Report to Congress.* Office of Water. EPA 841-R-95-005. December.

USEPA (U.S. Environmental Protection Agency). 1997. *Section 319 Success Stories: Volume II. Highlights of State and Tribal Nonpoint Source Programs* (Online). Office of Water. Washington, D.C. EPA-R-97-001. October. Available at: www.epa.gov/owow/NPS/Section319II.

USEPA (U.S. Environmental Protection Agency). 2002. *National Water Quality Inventory: 2000 Report.* Forthcoming.

USFWS (U.S. Fish and Wildlife Service). 1991. Contaminants in Buffalo Lake National Wildlife Refuge, Texas. Report by the Arlington Field Office. October.

USFWS (U.S. Fish and Wildlife Service). 1992. *"An Overview of Irrigation Drainwater Techniques, Impacts on Fish and Wildlife Resources, and Management Option."* Prepared for USEPA, OPPE by U.S. Fish and Wildlife Service May, 1992. Cited in: Industrial Economics, Incorporated, 1993. "Irrigation Return Flow Fee Feasibility Study," unpublished memorandum prepared for USEPA, Office of Policy Analysis, October.

USGAO (U.S. General Accounting Office). 1997. *Drinking Water: Information on the Quality of Water Found at Community Water Systems and Private Wells.* Report to Congressional Requesters. GAO/RCED-97-123. Available at: www.gao.gov/AIndexFY97/abstracts/rc97123.htm. June.

U.S. Senate. 1997. *Animal Waste Pollution in America: An Emerging National Problem.* Report Compiled by the Minority Staff of the United States Senate Committee on Agriculture, Nutrition and Forestry for Senator Tom Harkin.

Vanderholm, D.H. 1975. *Nutrient Losses from Livestock Waste During Storage, Treatment, and Handling.* Managing Livestock Wastes, p. 282.

Warrick, Joby. 1995b. Hog farm is fined $110,000 for spill. *The News and Observer,* August 23. Available at: www.nando.net.

Warrick, Joby. 1995c. Contaminated wells linked to Robeson hog operation. *The News and Observer,* October 14. Available at: www.nando.net.

Warrick, Joby. 1995d. Tainted wells, poisoned relations. *The News and Observer.* October 15. Available at: www.nando.net.

Warrick, Joby and Pat Stith. 1995a. Boss Hog: North Carolina's Pork Revolution. *The News and Observer.* Five part series published from February 19-26. Available at: www.nando.net/sproject/hogs/hoghome.html.

Warrick, Joby and Pat Stith. 1995b. Metals present new concern for livestock producers. *The News and Observer.* September 17. Available at: www.nando.net.

Wetzel, R.G. 1983. *Limnology.* 2nd Edition. Saunders College Publishing.

Pollutants associated with AFOs can have a range of harmful impacts on water quality, on aquatic and shoreline ecosystems, and on the range of uses (or services) that water resources provide. While some pollutants pose a direct threat to human health (e.g., pathogens that prevent drinking or contact with contaminated water), AFO-related pollutants can also contribute to the decline of recreational and commercial activities, injury to species that live in or depend on contaminated waters (e.g., aquatic shorebirds), and even a reduction in the intrinsic "existence" value that people place on a pristine or well-protected ecosystem.

The benefits of a regulation that reduces AFO pollution are reflected by identifiable changes in environmental quality that result from the regulation, and by the related improvements in the range of potential uses of the resource. The value of the regulation is then measured according to the value that people place on the changes in these potential uses. EPA characterizes these changes by considering the use and non-use benefits that water resources provide under baseline conditions, and contrasting these benefits with the enhanced benefits realized under each of the regulatory scenarios.

This chapter describes the general approach that EPA uses to value environmental quality improvements associated with reduced AFO pollution. The first section describes the types of environmental improvements and benefits to humans that would likely result from changes in water quality due to the regulation of CAFOs. The chapter then identifies the key environmental changes and benefits that are the focus of the evaluation of EPA's proposed regulations, and describes EPA's approaches to measuring and valuing the selected benefits. The broad methods outlined in this chapter form the basis of the specific benefits analyses described in Chapters 4 through 10.

3.1 POSSIBLE ENVIRONMENTAL IMPROVEMENTS AND RESULTING BENEFITS

Groundwater and surface water resources (including rivers, lakes, estuaries, and oceans) provide a range of benefits to humans and other species that reflect the actual and potential "uses" that they support. Potential uses can include active consumption or diversion of water for industry, agriculture, or drinking water, and can also include a range of active and passive "in-place" uses such as swimming, fishing, and aesthetic enjoyment.

Water resources also provide intrinsic (or non-use) benefits that reflect the importance of protecting environmental quality regardless of any specific use that humans may enjoy or intend. Intrinsic benefits include "existence value," i.e., the sense of well-being that people derive from the existence of pristine water resources, even when they do not expect to see or use these resources.[1] The protection of resources for future generations (intergenerational equity) or for non-human species (ecological benefits) are other key intrinsic benefits.

Degradation of a water resource may restrict its use or the intrinsic benefits it provides, and therefore reduce its value. Conversely, improvement in environmental quality provides benefits associated with an increase in the range of potential uses and intrinsic benefits that a resource can support. Exhibit 3-1 provides a summary of the potential benefits associated with an improvement in the quality of aquatic resources.

Exhibit 3-1

POTENTIAL BENEFITS OF WATER QUALITY IMPROVEMENTS

	Use Benefits
In-Stream	• Commercial fisheries, shell fisheries, and aquaculture; navigation • Recreation (fishing, boating, swimming, etc.) • Subsistence fishing • Human health risk reductions
Near Stream	• Water-enhanced non-contact recreation (picnicking, photography, jogging, camping, etc.) • Nonconsumptive use (e.g., wildlife observation)
Option Value	• Premium for uncertain future demand • Premium for uncertain future supply
Diversionary	• Industry/commercial (process and cooling waters) • Agriculture/irrigation • Municipal/private drinking water (treatment cost savings and/or human health risk reductions)
Aesthetic	• Residing, working, traveling and/or owning property near water, etc.
	Intrinsic (Non-Use) Benefits
Bequest	• Intergenerational equity
Existence	• Stewardship/preservation • Vicarious consumption
Ecological	• Reduced mortality/morbidity for aquatic and other species • Improved reproductive success for aquatic and other species • Increased diversity of aquatic and other species • Improved habitat, etc.

[1] A common example of intrinsic value is the broad public support for the preservation of National Parks, even by people who do not expect to visit them.

AFO pollutants have impacts on a broad range of water resource services. Pollution by nutrients, for example, can reduce the value of both groundwater and surface water as a drinking water source, and algae in eutrophied surface water can reduce recreational and aesthetic uses (due to foul odor and appearance), as well as clog municipal and industrial intakes. Acute nitrogen loadings and decaying algae cause fish kills, which affect commercial and recreational fishing, and indicate injury to natural resources; some of these injuries may require restoration in order to achieve full recovery of the ecosystem. Both chronic and acute nutrient loadings can reduce aquatic populations and the shoreline species that depend on them; this affects both opportunities to view wildlife and ecological "existence" values. Finally, nutrient-related red tide and *Pfiesteria* events can restrict access to shellfish and beaches, affecting shellfishing and recreational opportunities.

Other AFO pollutants have similar impacts or can cause additional effects (e.g., turbidity from solids, human health effects from pathogens). In addition, any pollutant that reduces the quality of an environmental resource may adversely affect intrinsic values, such as bequest values (i.e., preserving environmental quality for future generations). While the beneficial impacts of improved control of any one pollutant can be difficult to isolate, AFO-related pollution generally involves a broad range of impacts that, taken together, affect to some degree most of the potential uses and intrinsic benefits of water resources.

3.2 SPECIFIC BENEFITS ANALYZED

The benefits of water quality improvements are a function of the specific pollutants reduced, the water resources affected, and the improvements in the potential uses of these resources. The key challenge of a benefits calculation is to establish a clear link between the implementation of a regulation, the reduction of a pollutant, the resulting improvement in environmental quality, and the value of that improvement.

While AFO-related pollutants can affect most potential uses of surface and groundwater, EPA has identified a set of environmental quality changes that meet three criteria: 1) they represent identifiable and measurable changes in water quality; 2) they can be linked with the proposed CAFO regulations; and 3) together, they represent a broad range of potential human uses and benefits and are likely to capture important environmental changes that result from the rule. Specifically, EPA implements the following analyses:

- **Improvements in Water Quality and Suitability for Recreational Activities:** this analysis addresses increased opportunities for recreational boating, fishing, and swimming, as well as the potential increase in non-use values associated with improvements in inland surface water quality;

- **Reduced Incidence of Fish Kills:** this analysis assesses the value of reducing the incidence of fish kills attributable to pollution from AFOs;

- **Improved Commercial Shell Fishing:** this analysis characterizes the impact of pollution from AFOs on access to commercial shellfish growing waters, and values the potential increase in commercial shellfish harvests that may result from improved control of that pollution;

- **Reduced Contamination of Private Wells:** this analysis values the impact of the revised regulations in reducing the concentration of nitrates in water drawn from private wells;

- **Reduced Contamination of Animal Water Supplies:** this analysis characterizes the effect of pollution from AFOs on livestock mortality, and values the potential impact of the revised regulations in reducing mortality rates;

- **Reduced Eutrophication of Estuaries:** this analysis examines the impact of the revised regulations on nutrient loadings to selected estuaries, and presents a case study illustrating the potential economic benefits of the anticipated reduction in such loads; and

- **Reduced Water Treatment Costs:** this analysis examines the revised regulations' beneficial effect on source water quality and the consequent reduction in treatment costs for public water supply systems.

EPA's analysis does not attempt to comprehensively identify and value all potential environmental changes associated with proposed revisions to the CAFO regulations. For example, the analysis of the suitability of water resources for recreational use excludes most estuarine or marine waters. In addition, the analysis does not value the potential impact of improvements in water quality on near-stream activities, such as birdwatching or camping, nor does it consider non-water related benefits, such as potential reductions in odor from waste management areas.

While changes in water quality resulting from CAFO regulations may have real impacts on these types of uses, and may even be associated with significant benefits, several factors make it difficult to measure the specific impacts of the regulation and identify related changes in value. For example, analysis of potential changes in estuarine or marine water quality nationwide is currently beyond the capabilities of the water quality model employed in this study. In addition, while EPA's proposed CAFO regulations will contribute to improvements in environmental quality beyond surface waters, it is difficult to establish clear relationships between regulation of CAFOs and certain environmental quality changes, such as reductions in odor or improvements in the health of shorebirds. Although these benefits are not specifically addressed by the analysis, they likely represent additional benefits of the regulation.

3.3 PREDICTING CHANGE IN ENVIRONMENTAL QUALITY AND RESULTING BENEFICIAL USE

To calculate the benefits associated with new regulations, an analysis must explore the difference between present conditions (i.e., the baseline scenario) and the likely future conditions that would result from the regulation. The baseline scenario is typically assessed using the best and most recently collected data that characterize existing environmental quality. Because likely future conditions are theoretical, the characterization of environmental quality under the new regulations must be evaluated through environmental modeling or other approaches designed to simulate possible future conditions. The anticipated difference in environmental quality under present and future conditions thus represents the marginal environmental quality gains or human benefits that the new regulations are expected to produce.

EPA's analysis of the new CAFO regulations examines the difference between the baseline and expected future conditions once the new regulations have taken effect. Ideally, the baseline scenarios would be constant across benefit categories and analyses; however, data limitations forced EPA to define baseline conditions based on the most up to date record of existing conditions for each analysis. For instance, the analysis of increased commercial shellfish supply benefits relies upon 1995 data on shellfish bed closures to define baseline conditions, whereas the analysis of fish kill events relies upon data collected between 1980 and 1999. Detailed information on the time frame used to define baseline scenarios for each of the selected environmental benefit categories is provided for each of the analyses addressed in Chapters 4 through 10.

For each of the benefit categories analyzed, conditions following implementation of the new regulations are assessed using modeling approaches most applicable to the specific analysis. For each of the selected benefit categories, EPA models anticipated future conditions as follows:

- **Improvements in Water Quality and Suitability for Recreational Activities:** EPA relies on a national water quality model to predict changes in the ambient concentration of pollutants attributable to changes in pollutant loadings from CAFOs. Under each regulatory scenario, the model determines whether estimated changes in pollutant concentrations would improve the suitability of water resources for recreational uses such as boating, fishing, and swimming.

- **Reduced Incidence of Fish Kills:** Through modeling of nitrogen and phosphorus loading reductions, the analysis estimates changes in the frequency of fish kill events under each regulatory scenario.

- **Improved Commercial Shell Fishing:** EPA employs data on the impact of agricultural pollution on commercial shellfish harvesting, combined with modeled estimates of the change in pathogen loadings from CAFOs, to estimate the potential increase in annual shellfish harvests under each regulatory scenario.

- **Reduced Contamination of Private Wells:** EPA employs data from the U.S. Geological Survey (USGS), EPA, and the Bureau of Census to model the relationship between nitrate concentrations in private domestic wells and sources of nitrogen to aquifers. EPA uses this model, combined with estimates of the change in nitrogen loadings following implementation of the new regulations, to predict changes in well nitrate concentrations nationally.

- **Reduced Contamination of Animal Water Supplies:** EPA employs data on livestock mortality at CAFOs, combined with modeled reductions in the loadings of nitrates and pathogens to animal water supplies, to estimate reductions in livestock mortality attributable to the consumption of contaminated water.

- **Reduced Eutrophication of Estuaries:** EPA relies on its national water quality model to estimate the impact of the final rule on loadings of nutrients to 10 estuaries.

- **Reduced Water Treatment Costs:** EPA employs its national water quality model to estimate the impact of the final rule on the concentration of suspended solids in the source waters serving public water supply systems.

3.4 VALUING BENEFITS

The final step of the benefits analyses is to estimate the economic value of the modeled physical changes in environmental quality. This section provides a brief overview of economic valuation concepts and discusses the valuation approach applied in the studies performed for the CAFO rule.

3.4.1 Overview of Economic Valuation

Economists define benefits by focusing on measures of individual satisfaction or well-being, referred to as measures of welfare or utility. A fundamental assumption in economic theory is that individuals can maintain the same level of utility while trading-off different "bundles" of goods, services, and money. The tradeoffs individuals make reveal information about the value they place on these goods and services.

The willingness to trade-off compensation for goods or services can be measured by an individuals' willingness to pay. While these measures can be expressed in terms of goods, services, or money, economists generally express willingness to pay in monetary terms. In the case of an environmental policy, willingness to pay represents the amount of money an individual would give up to receive an improvement (or avoid a decrement) in environmental quality.[2]

The use of willingness to pay to measure benefits is closely related to the concept of consumer surplus. Resource economists generally rely on consumer surplus as a measure of overall economic welfare for benefits to individuals. The concept of consumer surplus is based on the principle that some consumers benefit at current prices because they are able to purchase goods (or services) at a price that is less than their total willingness to pay for the good. For example, if a consumer is willing to pay $4 for an additional gallon of clean drinking water that costs the consumer only $1.50, then the marginal consumer surplus is $2.50.

3.4.2 Primary Approaches for Measuring Benefits

Economists generally define the economic benefits provided by a natural resource as the sum of individuals' willingness to pay for the goods and services the resource provides, net of any costs associated with enjoying these services.[3] In some cases (e.g., commercial fishing), natural resource products are traded in the marketplace, and willingness to pay information can be directly obtained from demand for these commodities. In other cases, when natural resource goods or services are not traded in the market, economists use a variety of analytic techniques to value them, or to estimate the economic benefits of improvements in environmental quality.[4] These non-market methods, which are grounded in the theory of consumer choice, utility maximization, and welfare economics, attempt to determine individuals' willingness to pay for natural resource services directly, through survey research, or indirectly, through the examination of behavior in related markets. Descriptions of market and non-market methods for analyzing benefits follow below.

- **Market Methods:** To measure the economic value of environmental improvements, market methods rely upon the direct link between the quality or stock of an environmental good or service and the supply or demand for

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[2] Economists also sometimes consider a similar concept of "willingness to accept compensation"; i.e., the amount of monetary compensation that would make the individual indifferent between having an environmental improvement and foregoing the improvement.

[3] In the case of goods and services traded in the marketplace, net benefits also include producer surplus: the excess of producer revenues over costs. For simplicity, we leave aside for now any discussion of producer surplus in assessing the benefits associated with enjoyment of natural resource services.

[4] These same techniques can be applied to estimate the economic damages attributable to a decline in environmental quality.

that market commodity. Market methods can be used, for example, to characterize the effect of an increase in commercial fish and shellfish harvests on market prices. In turn, these market changes affect the welfare of consumers and producers in quantifiable ways.

- **Revealed Preference:** Revealed preference approaches are premised on the assumption that the value of natural resource services to users of those services can be inferred by indirect economic measures. For example, willingness to pay for recreational beach services can be estimated by observing how the number of visits individuals make to a beach varies with the cost of traveling to the beach. Similarly, property values can be influenced by proximity to an environmental amenity or disamenity; econometric analysis can estimate the nature and magnitude of such effects, providing a basis for valuing natural resource services.

- **Stated Preference:** Stated preference models involve the direct elicitation of economic values from individuals through the use of carefully designed and administered surveys. Contingent valuation techniques are the most widely used stated preference approach, and rely on surveys designed to derive people's willingness to pay for an amenity (e.g., improved water quality) described in the study. This method can be used to estimate both use and non-use values.

- **Averted Cost:** Changes in environmental quality can impose additional costs on the users of an affected resource. For example, contamination of drinking water supplies might lead homeowners to purchase in-home water filters. A potential proxy measure of the benefits of preventing pollution of the resource is the averted cost of these expenditures.

3.4.3 Valuation of CAFO Regulatory Benefits Based on Previous Studies

Because of their high resource demands, the use of primary approaches is beyond the scope of this analysis. Instead, the analysis draws on previous studies that evaluated similar water quality benefits issues. This approach—typically referred to as "benefits transfer"—involves the application of values, functions, or data from existing studies to estimate the benefits of the resource changes currently being considered, and is commonly used in analyzing the benefits of new environmental regulations. The primary research material and analytic approach used for the valuation of each benefit category are summarized below; more detailed descriptions of the methods applied are provided in subsequent chapters of this report.

- **Improvements in Water Quality and Suitability for Recreational Activities:** To determine how people value improvements in the suitability of water resources for recreational activities (e.g., boating, fishing, swimming), the analysis relies on the results of a contingent valuation survey conducted by Carson and Mitchell (1993). Based on this study, the analysis estimates the economic benefits attributable to projected reductions in pollution of the nation's rivers and streams.

- **Reduced Incidence of Fish Kills:** The valuation of benefits from the reduced incidence of fish kills employs two approaches – an estimate based solely on fish replacement costs, as reflected in an American Fisheries Society (1990) report, and an estimate that takes into account potential recreational use values.

- **Improved Commercial Shell Fishing:** To value the economic benefit of increased shellfish harvests, the analysis relies on available literature that models consumers' demand for shellfish. Based on the demand equations from these primary sources, EPA determines the increase in consumer surplus that would result from increased harvests.

- **Reduced Contamination of Private Wells:** The analysis surveys the literature concerning the values people place on avoiding or reducing nitrate contamination in private domestic wells. Based on this review, it develops estimates of people's willingness-to-pay to reduce nitrate concentrations to certain levels, and applies these estimates to value predicted changes in the quality of water that supplies private wells.

- **Reduced Contamination of Animal Water Supplies:** To value reductions in livestock mortality, EPA employs estimates of livestock replacement costs.

- **Reduced Eutrophication of Estuaries:** To characterize the benefits of reduced eutrophication of estuaries, EPA conducts a case study of North Carolina's Albemarle and Pamlico Sounds. The case study estimates the economic benefits of changes in nutrient loadings in this region based on revealed preference studies of the relationship between water quality and willingness to pay for recreational fishing opportunities.

- **Reduced Water Treatment Costs:** EPA relies on estimates of averted drinking water treatment costs to value predicted improvements in source water quality.

3.4.4 Aggregating Benefits

The final step in determining the benefits of the revised CAFO regulations is aggregation of the benefits calculated for each of the benefit categories. To avoid over-estimation, this requires consideration of the extent to which underlying analyses may double-count certain benefits. For this analysis, however, the benefits that each of the underlying studies explore are relatively distinct. As a result, the potential for double-counting appears to be small.

Another consideration in aggregating benefits is ensuring that all values are reported on a comparable basis, taking into account the effects of inflation on real dollar values. For purposes of this analysis, all values are reported in 2001 dollars. The price indices employed in converting source data to 2001 dollars vary, depending on which index is most appropriate. Further information on these adjustments is provided in the detailed discussion of each analysis.

The detailed analyses presented in Chapters 4 through 10 report benefits on an annual basis. To determine the present value of these benefits, EPA employs three alternative discount rates: a 7 percent real discount rate, which is representative of the real rate of return on private investments and consistent with the rate mandated by the Office of Management and Budget for analysis of proposed regulations; a 3 percent real discount rate, which is representative of the social rate of time preference for consumption of goods and services, and consistent with the rate recommended by many economists for analysis of environmental benefits; and a 5 percent real discount rate, which represents the mid-point of the 3 to 7 percent range.

In calculating the present value of benefits at the time new regulations are implemented, EPA assumes an infinite time frame; i.e., as long as the regulations remain in effect, the associated benefits will be enjoyed in perpetuity. EPA further assumes that its estimates of beneficial impacts on most water resources will be fully realized in the year immediately following implementation of the revised regulations. This assumption reflects EPA's judgment that reductions in the loadings of pollutants from CAFOs will quickly yield improvements in water quality. With respect to reduced contamination of private wells, however, EPA assumes that several years will pass before the full benefits of the regulation are realized. To permit consistent comparison of these benefits to the annual benefits estimated for other water resources, EPA presents the benefits of reduced contamination of private wells on an annualized basis, as well as on a present value basis. The calculation of an annualized value for this benefits category indicates the constant flow of benefits over time that would generate the same present value as the anticipated, uneven, flow of benefits.

Additional information on the calculation of present values and the aggregation of benefits is presented in Chapter 11.

3.5 SUMMARY

Exhibit 3-2 summarizes EPA's approach to measuring and valuing the anticipated benefits of the revised CAFO regulations. Additional information on the methods employed is provided in the detailed discussion of each analysis that follows.

3.6 REFERENCES

AFS. 1990. American Fisheries Society Socioeconomics Section, *A Handbook of Monetary Values of Fishes and Fish-Kill Counting Guidelines,* Draft, July 1990.

Carson, Richard T. and Robert Cameron Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Water Quality." *Water Resources Research*, Vol. 29, No. 7.

Exhibit 3-2

SUMMARY OF APPROACH TO ESTIMATING REGULATORY BENEFITS

Benefit Category	Human Use	Measurement Approach	Valuation Approach
Improvements in Water Quality and Suitability for Recreational Activities	Recreational boating, fishing, swimming, and non-use benefits associated with freshwater resources.	Model potential changes in water quality based on estimated changes in loadings of CAFO-related pollutants.	Stated preference approach assessing willingness-to-pay for water quality that supports recreation.
Reduced Incidence of Fish Kills	Recreational fishing, near-stream use and non-use benefits.	Estimate changes in the frequency of fish kill events based on estimated reductions in nutrient loadings.	Avoided damages based on fish replacement costs and estimates of recreational use value.
Improved Commercial Shell Fishing	Commercial shell fishing.	Estimate increased access to shellfish growing waters and resulting increase in annual shellfish harvests, based on modeled changes in fecal coliform concentrations.	Market estimate of increased consumer surplus.
Reduced Contamination of Private Wells	Drinking water.	Model potential changes in private domestic well water quality based on estimated changes in loadings of CAFO-related pollutants.	Stated preference approach assessing willingness-to-pay to reduce the concentration of nitrates in water drawn from private domestic wells.
Reduced Contamination of Animal Water Supplies	Livestock production	Model potential reductions in animal mortality based on estimated changes in exposure to CAFO-related pollutants.	Averted costs of cattle replacement.
Reduced Eutrophication of Estuaries	Recreational fishing	Case study of estimated changes in nutrient loadings to North Carolina's Albemarle and Pamlico Sounds.	Revealed preference-based estimate of relationship between water quality and willingness to pay for recreational fishing opportunities in the region.
Reduced Water Treatment Costs	Drinking water	Estimate reductions in the concentration of total suspended solids in surface waters that supply community drinking water systems.	Averted costs of drinking water treatment.

MODELING OF IMPROVEMENTS IN SURFACE WATER QUALITY AND BENEFITS OF ACHIEVING RECREATIONAL USE LEVELS

CHAPTER 4

4.1 INTRODUCTION AND OVERVIEW

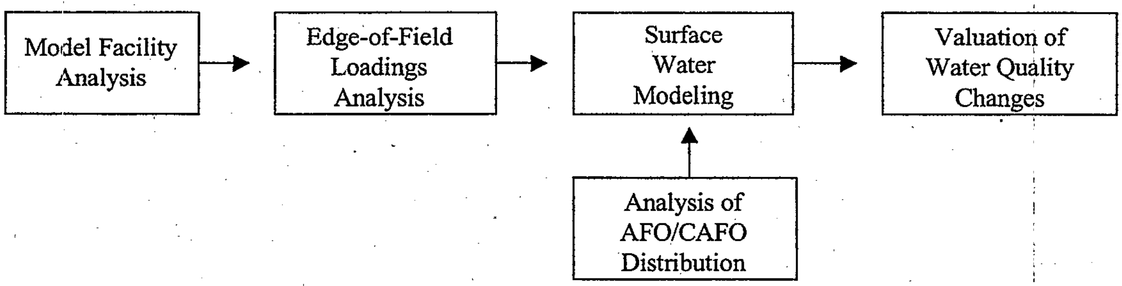
A major component of EPA's CAFO benefits analysis is an assessment of how water quality in freshwater rivers and lakes would be influenced by reduced CAFO pollution, accompanied by an evaluation of the economic value of these changes to society. EPA has developed a comprehensive analysis of these benefits using the methodology summarized in Exhibit 4-1. As shown, key components of the analysis include:

- Development of model facilities that typify conditions across different production sectors, facility sizes, and geographic regions;
- Modeling of "edge-of-field" pollutant releases that take into account manure management practices, manure constituents, and physical conditions (e.g., soil characteristics);
- Calculation of the number of AFOs in the various production sectors/size categories to allow extrapolation of the model facility loadings estimates;
- Modeling of the change in surface water pollutant concentrations as determined by changes in loadings; and
- Valuation of the water quality changes through a benefits transfer analysis focused primarily on the public's willingness to pay for improved water conditions necessary to support recreation.

EPA implements this set of analyses for baseline conditions as well as the various regulatory scenarios under consideration to allow estimation of overall water quality benefits. The following sections summarize the five analytic components and the resulting estimates.

Exhibit 4-1

OVERVIEW OF RECREATIONAL BENEFITS ANALYSIS



4.2 MODEL FACILITY ANALYSIS

Assessing the impacts of CAFO regulatory scenarios requires that EPA recognize the diversity of animal feeding operations across the country. Exhibit 4-2 provides an overview of the analysis used to define model facilities and their associated pollution potential.[1] For detailed information regarding the development of model facilities, see Chapters 4 and 11 of the *Technical Development Document of Proposed Effluent Limitations Guidelines for Animal Feeding Operations* (EPA, 2000a), hereafter referred to as the "TDD".

First, EPA disaggregates the universe of AFOs according to a suite of characteristics directly affecting manure generation, manure management, and pollutant loadings. AFOs are grouped into five geographic regions, as shown in Exhibit 4-3. To establish geographic regions, EPA developed algorithms to estimate the number of facilities by size (number of animals), using a combination of inventory and sales data. NASS applied the algorithms to 1997 Census of Agriculture data to generate the output by which EPA estimated facility counts. Due to disclosure criteria established by NASS to protect respondent-level census data, the regions were aggregated into broader production regions.

[1] Note that for this analysis, the term agriculture facility, facility, or operation includes the feedlot and the land application area under the control of the feedlot operator.

Exhibit 4-2

MODEL FACILITY ANALYSIS

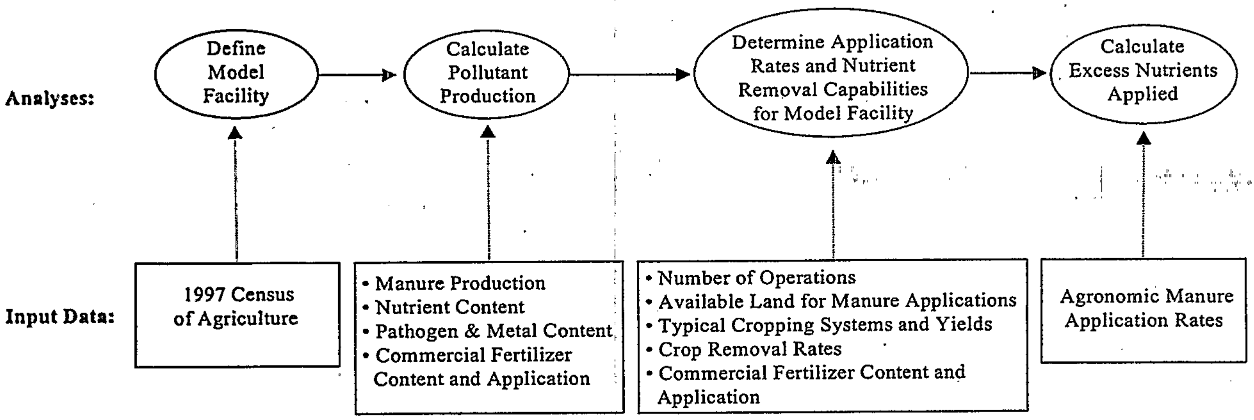
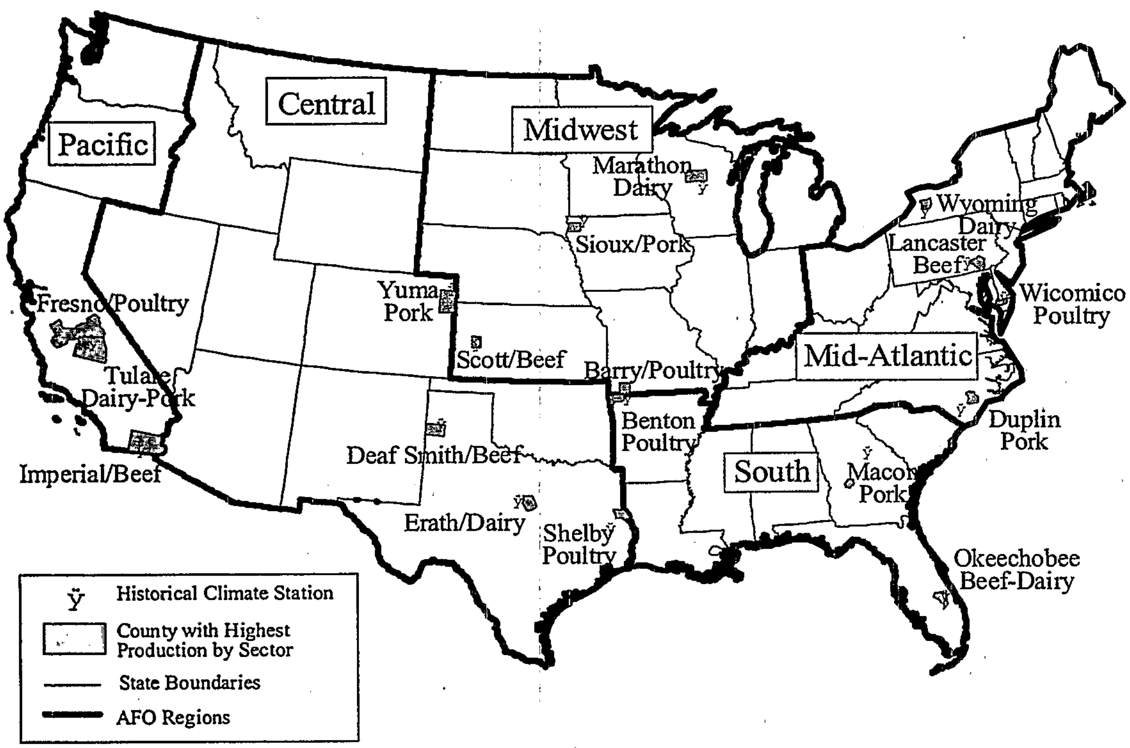


Exhibit 4-3

GEOGRAPHIC REGIONS FOR GROUPING AFOS



Within each geographic region, EPA defines model facilities by production sector, subsector, and size (number of animals). Based on these various dimensions, an example of a model facility would be a large beef facility with more than 8,000 head in the Midwest region. Exhibit 4-4 summarizes the key dimensions on which model facilities are defined. In all, EPA considered 200 different model facilities. The key model facilities are those that reflect the majority of production, resulting in approximately 76 different model facilities used for further analysis.

Exhibit 4-4

SUMMARY OF MODEL FACILITY DIMENSIONS

Production Sector	Facility Size	Regions
Beef, cattle Beef, veal Dairy, milk Dairy, heifers Swine, farrow-finish Swine, grower-finish Layer, wet manure system Layer, dry manure system Broiler Turkey	>1,800 Animal Units 1,000-1,800 Animal Units 750-1,000 Animal Units 500-750 Animal Units 300-500 Animal Units	Pacific Central Midwest South Mid-Atlantic

To guide the selection of modeling parameters related to fields and soils, EPA must identify a specific location for each model facility in a given geographic region. For these purposes, the analysis assumes that the model facility is located in the highest animal-production county of the region's highest production state for a given animal type.

EPA calculates manure production and the associated production of pollutants for each model facility using a process developed by Lander et al. (1998), and refined by Kellogg et al. (2000). The number of animals per operation is converted to USDA animal units[2] using conversion factors standardized to a 1,000-pound beef cow. EPA multiplies the number of animal units per model facility by the manure production per animal unit to determine total manure production. Manure production is adjusted to reflect the fraction that is recoverable, i.e., the portion of manure that is collected, stored, or otherwise managed so as to be available for land application. Finally, EPA calculates total generation of nutrients based on the typical nitrogen and phosphorus concentrations

[2] The USDA animal unit is based on average liveweight of the animal, and is markedly different from the animal unit definition in EPA's regulations at 40 CFR 122 and 412.

per unit of recoverable manure for each animal type, e.g., pounds of nitrogen per ton of manure from finishing pigs in the swine sector.[3]

Next, EPA defines land application practices for each model facility and the capacity for soil and crop removal of nutrients applied to the land. This analysis entails several steps. The analysis first considers the total nitrogen and phosphorus generated in manure at the model facility. EPA divides these figures by the average total acreage available for land application of manure for an operation in the given region, size class, and production sector; this average acreage is drawn from a recent NRCS study (Kellogg et al., 2000).

EPA then considers the likely cropping systems at the model facilities and relates the quantity of nutrients applied annually to the nutrient requirements of the cropland and pastureland. For example, typical cropping systems for the Mid-Atlantic AFO Region are corn, soybean, and wheat in two-year rotation. The ratio of nutrients applied to crop nutrient requirements provides a measure of the excess nutrients applied in the manure.[4] This in turn forms the foundation for loadings analyses of regulatory scenarios that call for adherence to agronomic rates of nutrient application. To characterize land application practices, the analysis considers three categories of facilities:

- Category 1 facilities include CAFOs with sufficient crop- or pastureland on-site to apply the manure they generate at agronomic rates. The analysis assumes that these facilities apply all manure on-site (i.e., no manure is shipped off-site) under both baseline and post-regulatory conditions.

- Category 2 facilities include those with insufficient crop- or pastureland on-site to apply the manure they generate at agronomic rates. For the baseline scenario, the analysis assumes that these facilities apply all the manure they generate on-site. (An exception to this approach is made in the case of dry poultry operations. The baseline analysis assumes that these operations apply the manure they generate on-site, up to a limit of five times the agronomic rate; any manure in excess of this limit is assumed to be transported off-site for application to crop- or pastureland.) For the post-regulatory scenario, the analysis assumes that on-site manure application is limited to the agronomic rate, and that the remaining manure is shipped off-site for application to crop- or pastureland at agronomic rates. EPA's model captures the pollutant

[3] Metal production (zinc, copper, cadmium, nickel, lead) is calculated in terms of pounds of metals excreted per animal unit, while pathogen production (fecal coliform and fecal streptococcus) is calculated in terms of colonies per animal unit.

[4] EPA assumes that 30 percent of the animal waste's nitrogen content volatilizes during and shortly after land application. The analysis also assumes that facilities use no fertilizers other than manure.

loadings associated with both on-site and off-site application of the manure generated by Category 2 facilities.[5]

- Category 3 facilities include CAFOs without crop- or pastureland for manure application. EPA assumes that these facilities transfer all manure off-site for use or disposal. The pollutant loadings associated with this manure are captured in modeling baseline conditions and the impacts of the final rule..

4.3 EDGE-OF-FIELD LOADINGS ANALYSIS

The second major component of the water quality analysis is the estimation of pollutant loadings leaving the model facility, i.e., edge-of-field loadings. EPA estimates the loadings associated with: (1) application of manure and commercial fertilizer; (2) lagoons and other storage structures; and (3) feedlots. The sections below review the methods applied for each of these analyses.

4.3.1 Loadings from Manure Application

EPA's loadings analysis first examines loadings from manure application to cropland and pastureland. The analysis combines information on manure generation and land application practices (see above) with data on the timing of application, hydrological conditions, geological conditions, and weather patterns (see Exhibit 4-5). EPA integrates these data using the Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model. This field-scale model simulates hydrologic transport, erosion, and biochemical processes such as chemical transformation and plant uptake. The model uses information on soil characteristics and climate, along with nutrient production data, to model losses of nutrients in surface runoff, sediment, and groundwater leachate. Loadings are modeled for the pre- and post-regulatory scenarios to estimate changes in loadings attributable to the proposed standards.

The data used in the GLEAMS model runs include the following:

- **Soils Data**: GLEAMS uses data from the State Soil Geographic (STATSGO) data base maintained by USDA's Natural Resources Conservation Service. Key soil parameters drawn or estimated from the data base include permeability, soil porosity, baseline organic matter content, percent clay, and percent silt. EPA employs data on these parameters, in combination with

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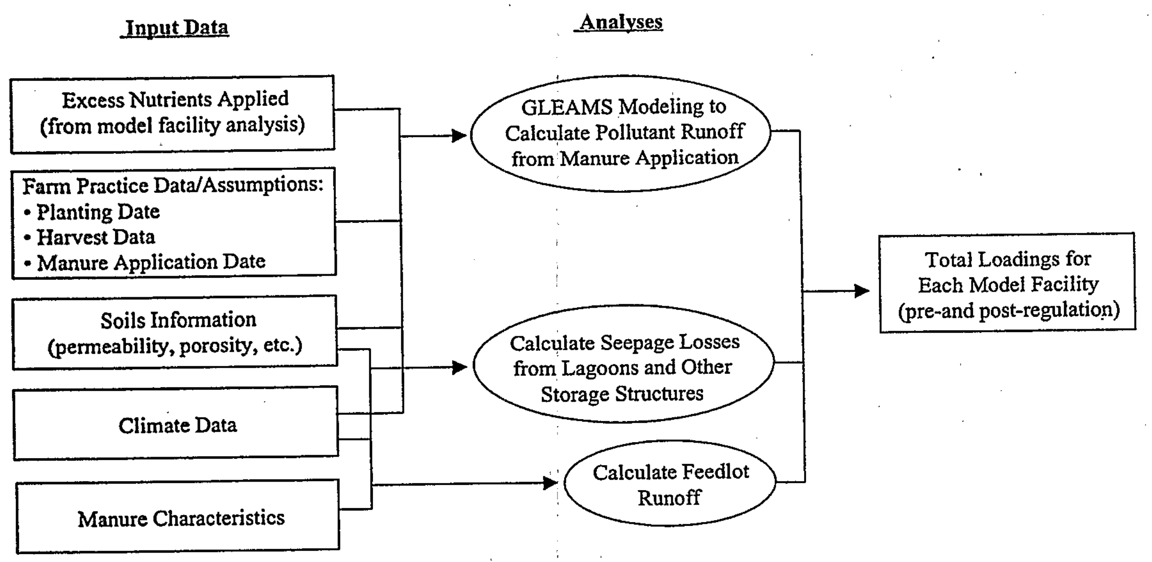
[5] For consistency, pollutant loadings from the off-site cropland to which these facilities are assumed to ship manure are also captured in the baseline analysis. The modeling of baseline conditions assumes the application of commercial fertilizer to this land.

Exhibit 4-5

EDGE-OF-FIELD LOADINGS ANALYSIS FOR MODEL FACILITIES



data on other factors (see below), to characterize soil erosion, surface runoff, and groundwater leaching at model facilities.

- **Climate Data**: EPA prepared climate data using CLIGEN, a synthetic climate generator commonly used in conjunction with a variety of agricultural runoff models. CLIGEN simulates weather patterns based on 25 or more years of precipitation and temperature data.

- **Crop Planting and Harvest Dates**: EPA developed assumptions for crop planting and harvesting using USDA reports and determined likely manure application dates for model facilities based on contacts with USDA Extension Agents in relevant locations. The application dates are a function of the crops grown. Some single-cycle crops (e.g., corn) allow only one application per year, while other crops (e.g., alfalfa) allow multiple applications.

4.3.2 Loadings from Lagoons and Other Storage Structures

Lagoons and other manure storage structures at animal feedlots are also potential pollution sources, posing risks primarily through seepage to groundwater and subsequent discharge to surface water. For the purposes of this analysis, EPA assumes that all lagoons and other storage structures leak. Storage structure seepage estimates were obtained from Ham and DeSutter (1999), who measured nitrogen that leaked from three established swine-waste lagoons in Kansas. From these results, it was assumed that 2,000 pounds per acre per year leaked from manure storage structures lined with silt loam soils. EPA scales seepage estimates for clay and sandy soils from these estimates as described in the TDD.

For most storage structures, EPA models transport of pollution through groundwater and estimates the associated attenuation of pollutants. However, conditions in some cases (as defined by Sobecki and Clipper, 1999) suggest that leaks from lagoons or other storage structures may seep directly to surface water, i.e., hydrologic conditions are such that pollutant concentrations are not attenuated by dilution in groundwater. This might occur, for example, in the presence of sandy soils or karst-like terrain. To characterize the potential for leaks from lagoons or other storage structures to seep directly to surface water, EPA evaluated soil and hydrological conditions in each AFO region. Based on this evaluation, EPA determined the percentage of the region's area in which the potential for direct contamination of surface water is high. EPA's analysis assumes that this percentage of storage leaks in each region would result in direct contamination of surface water.

Finally, distinct from seepage losses, EPA modeled overflow losses and resulting pollutant loads associated with lagoons. Specifically, loads were modeled for swine and poultry liquid containment systems that may experience overflow losses attributable to improper management, precipitation, and other factors. EPA developed these estimates using a variety of design (e.g., lagoon depth) and operational (e.g., removals for land application) assumptions. EPA combined data on the estimated overflow quantities and animal-specific waste characteristics to model mass pollutant discharges for each relevant facility. These discharges were weighted according to the number of facilities in each sector and region, yielding total industry pollutant loadings for the swine and poultry/wet layers sectors.

4.3.3 Loadings from Feedlots

Another pollution source that EPA analyzes is runoff from feedlots. These loadings can be particularly significant in the beef sector because the animals are typically housed in open lots.

To estimate feedlot runoff loadings, EPA first calculates the volume of runoff from the feedlot at the model facility. The annual depth of runoff from the feedlot is calculated for each of the five AFO regions using average precipitation from the National Climatic Data Center. The volume of runoff is calculated using this depth of runoff and the estimated area of the dry lot and feedlot handling areas for each model facility.[6]

To characterize the loadings of pollutants in feedlot runoff, EPA assumes a solids content of 1.5 percent. The composition of these solids is estimated based on the characteristics of dry manure, which varies across production sectors. Annual loadings of specific pollutants are then

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[6] EPA assumes that only surface runoff occurs from the feedlot.

determined, based on the estimated composition of solids, the assumed percentage of solids in feedlot runoff, and the estimated annual volume of runoff from the feedlot.

4.3.4 Model Loadings Under Baseline and Post-Regulatory Conditions

EPA applies the data and methods described above to analyze loadings under baseline conditions and under the revised CAFO standards. In the latter case, the analysis assumes that regulated facilities modify current activities to comply with feedlot best management practices, mortality handling requirements, nutrient management planning/recordkeeping, and elimination of manure application within 100 feet of surface water. The GLEAMS model simulates the effects of feedlot BMPs and nutrient management planning on edge-of-field pollutant losses. The surface water quality model that EPA employs in subsequent stages of this analysis (see Section 4.5) simulates the effects of eliminating manure application within the setback area.

4.4 ANALYSIS OF AFO/CAFO DISTRIBUTION

To develop a national estimate of baseline pollutant loadings from AFOs, as well as estimates of the change in loadings under the revised regulations, EPA must determine the number of operations governed by the CAFO standards, i.e., the number of facilities considered to be AFOs and the number of AFOs considered to be CAFOs, and therefore subject to regulatory requirements. These operations represent the universe to which model facility results are extrapolated.

The sections below discuss EPA's approach and the resulting characterization of the population of AFOs and CAFOs. More detailed information on the procedure used by EPA to estimate the number of operations that may be subject to the proposed regulations can be found in the TDD.

4.4.1 Approach

EPA estimates the number of operations that may be affected by the revised CAFO regulations using a two-step procedure. First, EPA determines the number of operations that raise animals under confinement by using available data on the total number of livestock and poultry facilities (see below). Next, the number of CAFOs is determined based on operations that are *defined* as CAFOs and smaller operations that are *designated* as CAFOs based on site-specific conditions, as determined by the permitting authority. For purposes of this discussion, the affected CAFO population includes those facilities that discharge or have the potential to discharge to U.S. waters. This definition does not include those smaller operations that are not defined or designated as CAFOs.

The USDA Census of Agriculture is a complete accounting of United States agricultural production and is the only source of uniform, comprehensive agricultural data for every county in the nation. The Census is conducted every five years by USDA's National Agricultural Statistics Service (NASS).[7] The Census is implemented through a mail questionnaire that is sent to a list of known U.S. agriculture operations from which $1,000 or more of agricultural products were produced and sold or normally would have been sold during the census year.

Aggregated 1997 Census data are readily available from USDA. In general, the published compendium provides summary inventory and sales data for the nation and for states. The Census database itself, however, contains respondent-level information that can be aggregated into more precise agriculture facility size groupings. The requested data summaries used for EPA's analysis were compiled with the assistance of staff at USDA's NASS, who performed special tabulations of the data to obtain information on the characteristics of facilities at specific size thresholds for each sector. All data provided to EPA were aggregated to ensure the confidentiality of an individual operation. EPA supplemented the available data with information from other sources, including other USDA data sets and industry publications. The following discussion briefly notes the nature of key gaps in the Census data and EPA's approach to addressing them.

- All USDA Census data are reported across all animal agriculture operations and do not distinguish between confinement and non-confinement production types (e.g., pasture or rangeland animals). However, only operations that raise animals under confinement (as defined under 40 CFR 122 Appendix B) are potentially subject to regulation as CAFOs. The facility counts for confined animal operations reported in USDA's "Profile of Farms with Livestock in the United States: A Statistical Summary" (Kellogg, 2002) are used in EPA's analysis.

- USDA data are not available on the number of poultry operations with wet manure management systems. EPA estimated these figures using available data from USDA and supplemental information from industry experts and agricultural extension agency personnel.

- Information on the number of animal facilities that raise more than a single animal type is also not available. To adjust for this consideration and reduce the likelihood of double-counting, EPA relied on a methodology used by USDA (Kellogg, 2002).

- Finally, USDA Census data report the number and size of livestock and poultry facilities as of year-end (December 31) and may not adequately reflect seasonal fluctuations in beef, dairy, and layer inventory, or the year-to-year fluctuations in number of animals sold. EPA algorithms reflect average herd

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[7] In prior years, the Census was conducted by the Department of Commerce's Bureau of the Census.

sizes at larger confinement facilities over the year. The outputs are based on both reported inventory and sales, adjusted by expected turnovers. This approach is consistent with that developed by USDA to estimate potential manure nutrient loadings from animal agriculture (Lander et al., 1998; Kellogg et al., 2000).

4.4.2 Estimated Number of AFOs and CAFOs

Based on the USDA data sources described above, there were 1.3 million livestock and poultry facilities in the United States in 1997. This number includes all operations in the beef, dairy, pork, broiler, layer, and turkey production sectors, and includes both confinement and non-confinement (grazing and range fed) production.

Of all these operations, EPA estimates that approximately 238 thousand AFOs raise or house animals in confinement, as defined by the existing regulations. Under the final rule, an estimated 15,198 AFOs will be defined or designated as CAFOs, and therefore required to obtain a permit.[8] Exhibit 4-6 summarizes the estimated number of CAFOs by production sector and facility size.

Exhibit 4-6

ESTIMATED NUMBER OF CAFOS SUBJECT TO REVISED REGULATIONS*

Production Sector	Currently Regulated	Regulated Under New Rule		
		Large CAFOs	Medium CAFOs	Total
Beef	1,940	1,766	174	1,940
Dairy	3,399	1,450	1,949	3,399
Heifers	0	242	230	472
Veal	0	12	7	19
Swine	5,409	3,924	1,485	5,409
Layers	433	1,112	50	1,162
Broilers	683	1,632	520	2,152
Turkeys	425	388	37	425
Horses	195	195	0	195
Ducks	21	21	4	25
Total	**12,505**	**10,742**	**4,456**	**15,198**

* AFOs that stable or confine animals in different sectors are counted more than once.

[8] This number is likely the upper bound estimate of the total number of operations that will be subject to the final rule.

4.4.3 Geographic Placement of Facilities

Finally, AFOs and CAFOs by region are placed into counties (and eventually watersheds) using the published county level Census data (see section 4.5.2 for more details). Where county level data was not presented, the facilities in the undisclosed counties were imputed from state- and region-level data.

4.5 SURFACE WATER MODELING

EPA develops estimates of changes in surface water quality by building on the analysis of edge-of-field pollutant loadings for model facilities and the analysis of the distribution of AFOs and CAFOs. These data are integrated into the National Water Pollution Control Assessment Model (NWPCAM), a national-scale model designed to translate pollutant loadings into water quality changes and associated economic benefits to support policy-level regulatory decision-making.

NWPCAM covers virtually all inland waters in the U.S., allowing EPA to examine how changes in loadings under various regulatory scenarios would influence key water quality parameters.[9] The model incorporates routines that simulate overland transport of pollutants, discharge of pollutants to nearby surface waters, discharges to surface water from other (non-AFO/CAFO) sources, and the fate and transport of pollutants in the interconnected network of surface waters. Specifically, the modeling involves the following steps:

- Developing the network of rivers and streams that serves as the geographic foundation for the modeling;
- Distributing AFO/CAFOs and associated facility-level edge-of-field loadings to agricultural lands within a defined watershed or county;
- Simulating transport of nutrients/pollutants and subsequent discharge to nearby waterbodies;
- Delivering nutrient/pollutant loadings from point sources (e.g., AFO/CAFO production area loads, municipal wastewater treatment plants, industrial facilities) and non-point sources (e.g., non-AFO/CAFO agricultural run-off, municipal run-off) to waterbodies; and
- Simulating dilution, transport, and kinetics of the nutrients/pollutants loaded to the waterbody as the nutrients/pollutants are transported along the waterbody.

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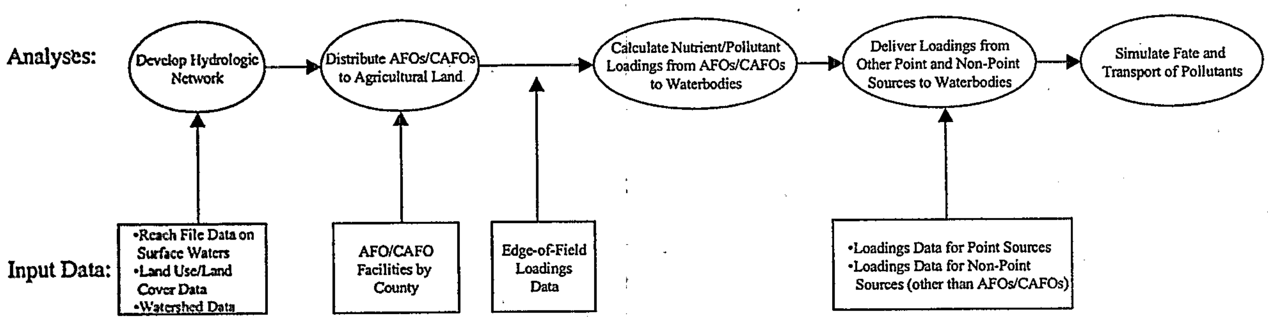
[9] NWPCAM does not address water quality benefits in bays, estuarine waters, or other coastal or marine waters.

Exhibit 4-7 summarizes these steps and the primary data used in the analysis. The sections below discuss the modeling in more detail and provide an overview of the estimated changes in pollutant loadings under the revised CAFO standards.[10]

Exhibit 4-7

WATER QUALITY MODELING ANALYSIS



4.5.1 Defining the Hydrologic Network

In the initial step of the analysis, EPA prepares the hydrological network of rivers and streams that serves as the geographic backdrop to the modeling. The hydrological network is developed from EPA's Reach Files, a series of hydrologic databases describing the inland surface waters of the U.S. Each "reach" in the database represents a segment of a river or stream; these segments are linked together to characterize complete systems of rivers and streams. EPA's Reach File 3 (RF3) forms the geographic foundation for NWPCAM, allowing the model to simulate the flow of water and pollutants from a point of origin to major rivers, and ultimately to ocean discharge.[11]

Once the hydrologic network is established, EPA uses a geographic information system (GIS) approach to overlay information on land-cover, characterizing land across the U.S. at a square-kilometer degree of resolution. From these data, EPA can identify areas classified as "agricultural"

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[10] Both the water quality modeling and the economic benefits analysis are presented in greater detail in *Estimation of National Economic Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations* (USEPA, 2002). This report is provided under separate cover.

[11] RF3 includes numerous tributaries and headwaters. EPA uses a subset of the RF3 network, referred to as RF3Lite, to develop its benefit estimates. This subset of RF3 represents larger streams (i.e., reaches on streams that are at least 10 miles in length and/or reaches that connect streams that are at least 10 miles in length).

land. Each land section, or "cell", is associated with the nearest RF3 river reach in the hydrologic network for subsequent drainage area, stream discharge, and hydrologic routing purposes.

4.5.2 Distributing AFOs and CAFOs to Agricultural Land

Once the hydrologic network is established, NWPCAM integrates data on the location of AFOs and CAFOs to spatially orient the facilities relative to surface waters. This analytic step links directly to the analyses discussed above wherein EPA determined the numbers of AFOs and CAFOs by county and, through analysis of model facilities, estimated the edge-of-field loadings associated with each facility and the acreage with which the loads are associated.[12] Here, AFOs/CAFOs and their associated edge-of-field loadings are randomly distributed to the appropriate amount of agricultural acreage in the appropriate county. In this manner, AFO/CAFO pollutant loads are geographically distributed over agricultural land in U.S. watersheds as accurately as possible given the available data.

4.5.3 Calculating AFO/CAFO-Related Loadings to Waterbodies

Once facility pollutant loadings are linked to a geographic area and river reach, these loadings are delivered from the agriculture cells to the river reaches using a routine to simulate an overland transport process. Overland travel times and associated nutrient decay are based on flow in a natural ditch or channel, as may typically be found on agricultural lands. A unit runoff ($ft^3/sec/km^2$) is derived for each watershed (i.e., hydrologic cataloging unit, the smallest element in a hierarchy of hydrologic units, as described at http://water.usgs.gov/GIS/huc.html) based on data compiled by the U.S. Geological Survey. The unit runoff therefore represents runoff from each agricultural cell within the watershed and can be used to derive time-of-travel estimates necessary to route pollutants from the land cover cell centroid to a river reach. NWPCAM also calculates nutrient/pollutant decay and transformation associated with overland transport. Total loadings to any given river reach are the total loadings discharged from all land-use cells draining to the reach (as well as discharges from upstream river reaches).

4.5.4 Loadings from Other Sources

In addition to loadings from AFOs/CAFOs, NWPCAM integrates data on loadings from other pollutant sources. This complete inventory of loadings is needed to assess the cumulative changes in water quality (i.e., the attainment of beneficial use levels) in surface waters. Specifically, the model integrates data on discharges from municipal and industrial point sources as well as loadings from (non-AFO) non-point sources, holding these loadings constant across regulatory scenarios. Point source loadings are based on several EPA databases, including the 1997 Permit Compliance System, Clean Water Needs Survey, and Industrial Facilities Database. Combined

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[12] EPA did not model facilities with fewer than 300 animals.

sewer overflows (CSOs) are integrated using loadings data on biochemical oxygen demand (BOD_5), total suspended solids (TSS), and fecal coliform, and default values for nitrogen and phosphorus content.

To model nutrient loads for non-point sources, EPA uses SPARROW (*SPA*tially *R*eferenced *R*egression *O*n *W*atershed attributes) (Smith et al., 1997), a statistical modeling approach for estimating major nutrient source loadings at a detailed geographic scale based on watershed characteristics. EPA developed export coefficients for nitrogen and phosphorus using an optimization process that provided the best match with SPARROW estimates. BOD_5 loadings were developed using a simple export coefficient term by land cover type. Export coefficients were developed for three major categories of land use or land cover (agriculture, forest, urban). TSS loadings for non-agricultural lands were estimated using an export coefficient for each land cover class. For agricultural lands, TSS loadings were estimated using a Revised Universal Soil Loss Equation (RUSLE). Background non-point source loadings are adjusted where necessary to remove contributions from land application of manure, which are accounted for separately in the AFO/CAFO pollutant loads described in Sections 4.3.1 and 4.5.6. These approaches allow estimation of total nitrogen, total phosphorus, total suspended solids, and BOD_5 loadings to the RF3 stream network.[13]

4.5.5 Fate and Transport Modeling

Once all loadings to surface waters have been estimated, NWPCAM routes pollutants through the hydrologic network from upstream to downstream reaches. The model simulates pollutant transport during this routing process, incorporating various hydrodynamic characteristics such as channel depth, channel width, and velocity. The model employs separate decay routines for BOD_5, nitrogen, phosphorus, TSS, fecal coliform, fecal streptococci, and DO to simulate changes in pollutant concentrations throughout the RF3 network. The resulting pollutant concentrations for the six water quality parameters (BOD_5, nitrogen, phosphorus, TSS, fecal coliform, and DO) used in the beneficial use value analysis below are then compared to beneficial use criteria to determine how potential recreational uses would change with improved water quality.

4.5.6 Estimated Changes in Loadings

Exhibit 4-8 summarizes the NWPCAM estimates of baseline loadings from AFOs and CAFOs and shows loadings associated with the phosphorus-based and nitrogen-based standards.[14] Similarly, Exhibit 4-9 presents the resulting removals associated with the standards. As shown, removal of all pollutants is greater under EPA's chosen phosphorus-based standard.

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[13] Non-point source data for fecal streptococci were not available at the national level and were not addressed in the analysis of non-AFO non-point sources.

[14] Loadings to the RF3 Lite network are the basis of the economic benefit estimates below. Therefore, we report RF3 Lite loadings and removals.

Exhibit 4-8

ESTIMATED ANNUAL AFO/CAFO NUTRIENT/POLLUTANT LOADINGS TO RF3 LITE NETWORK UNDER BASELINE CONDITIONS AND REVISED STANDARDS

Regulatory Standard	Nitrogen (lbs/yr)	Phosphorus (lbs/yr)	Sediments (lbs/yr)	BOD (lbs/yr)	Fecal Coliforms (MPN/yr)	Fecal Streptococci (MPN/yr)
Baseline	165,678,014	243,476,460	47,542,359,419	60,834,353	6.46E+21	1.11E+23
Phosphorus-Based	149,409,170	209,061,598	46,608,917,113	46,095,058	5.676E+21	8.956E+22
Nitrogen-Based	159,212,191	226,095,217	46,923,865,247	55,480,930	6.37E+21	1.07E+23

Source: *Estimation of National Economic Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations* (USEPA, 2002).

Exhibit 4-9

ESTIMATED ANNUAL REMOVALS UNDER REVISED STANDARDS

Regulatory Standard	Nitrogen (lbs/yr)	Phosphorus (lbs/yr)	Sediments (lbs/yr)	BOD (lbs/yr)	Fecal Coliforms (MPN/yr)	Fecal Streptococci (MPN/yr)
Phosphorus-Based	16,268,844	34,414,862	933,442,306	14,739,295	7.8E+20	2.1E+22
Nitrogen-Based	6,465,823	17,381,243	618,494,172	5,353,423	9E+19	4E+21

Source: *Estimation of National Economic Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations* (USEPA, 2002).

4.5.7 Modeling Quality Assurance Steps

A number of quality assurance steps have been taken to reduce potential sources of error or uncertainty in applying the NWPCAM model. These potential sources include model inputs (e.g., AFO/CAFO nutrient loadings, errors in hydrologic inputs from the RF3 file), model parameters (e.g., decay rates for BOD), benefits valuation methods, and data management or processing procedures. The measures taken to reduce these potential sources of error or uncertainty include (1) reviewing model inputs for reasonableness, (2) evaluating the robustness of the model's predictions with respect to changes in model parameters, (3) comparing baseline water quality predictions to observed water quality conditions, (4) evaluating the sensitivity of predicted monetary benefits to the benefits valuation methods selected, and (5) performing data processing quality assurance steps for each computational module of the NWPCAM system. These steps are discussed in USEPA 2002.

4.6 VALUATION OF WATER QUALITY CHANGES

To value predicted reductions in the pollution of rivers and streams by CAFOs, NWPCAM applies estimates of Americans' willingness to pay for improvements in water quality. The foundation of these estimates is a contingent valuation survey developed by Richard Carson and Robert Mitchell (Carson and Mitchell, 1993). This survey, which is national in scope, characterizes households' annual willingness to pay to improve freshwater resources from baseline conditions to conditions that better enable beneficial uses such as boating, fishing, and swimming. EPA uses the Carson and Mitchell research in two separate analyses:

- First, EPA develops benefits based on the public's willingness to pay for improvements in water quality that allow discrete movement to higher levels on a "ladder" of potential water uses.

- Second, EPA develops benefits based on a continuous water quality index.

Below, we discuss these two methods in greater detail. We then review the resulting economic benefit estimates.

4.6.1 Water Quality Ladder Approach

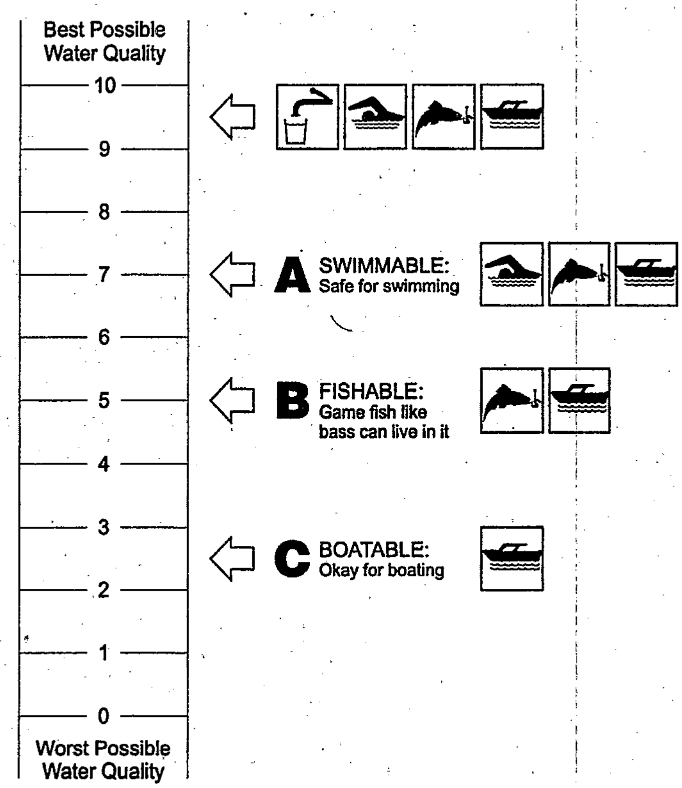
The water quality ladder approach entails relating changes in water quality parameters to the ability of a body of water to support activities such as boating, fishing, or swimming. Once the potential improvement in the ability of modeled rivers and streams to support these uses is determined, the analysis relies upon estimates of willingness to pay for such improvements. The following discussion explains the process by which EPA relates the results of the surface water modeling effort to the ability of a body of water to support a particular use. It then describes Carson and Mitchell's contingent valuation study and how the results are applied in NWPCAM.

4.6.1.1 Water Quality Ladder Concept

EPA's approach to relating surface water conditions to the ability of a body of water to support a particular designated use is based on a water quality ladder that Resources for the Future initially developed to support Carson and Mitchell's contingent valuation survey. As Exhibit 4-10 shows, the ladder uses a scale that ranges from 0 to 10, with 0 representing the worst possible water quality and 10 representing the best possible quality. The low end of the scale represents water quality so poor that it supports no plant or animal life, and human contact with it would be unsafe; the high end of the scale represents water safe enough to drink. Between these extremes, the ladder depicts levels of water quality sufficient to support boating, fishing, or swimming.

Exhibit 4-10

WATER QUALITY LADDER



The ability of a waterbody to support beneficial uses at each step of the water quality ladder is defined by measures of the following parameters:

- dissolved oxygen content;
- biological oxygen demand;
- suspended sediment concentrations; and
- pathogen counts.

In order for a body of water to be considered boatable, fishable or swimmable, it must satisfy the minimum numeric criteria consistent with that use for all modeled parameters.[15] These minimum conditions are the same for all geographic areas (see Appendix 4-C).

Based on the framework described above, NWPCAM classifies each segment of each modeled river or stream as swimmable, fishable, boatable, or non-supportive of any of these uses. The model calculates the total stream-miles that support each designated use under each set of loadings conditions (i.e. baseline conditions or conditions following implementation of the revised CAFO regulations).

4.6.1.2 Carson and Mitchell Study

The contingent valuation survey upon which this analysis relies examined households' willingness to pay to maintain or achieve specified levels of water quality in freshwater lakes, rivers and streams throughout the United States (Carson and Mitchell, 1993).[16] The survey was conducted in 1983 via in-person interviews at 61 sampling points nationwide, and employed a national probability sample based on the 1980 Census. Respondents were presented with the water quality ladder depicted in Exhibit 4-10 and asked to state how much they would be willing to pay to maintain or achieve various levels of water quality throughout the country. In eliciting responses, the survey used a payment card showing the amounts average households were currently paying in taxes or higher prices for certain publicly provided goods (e.g., national defense); respondents were then asked their willingness to pay for a given water quality change. The survey respondents were told that improvements in water quality would be paid for in higher product prices and higher taxes.

Exhibit 4-11 presents the results of the survey. These values represent "best estimates" of mean annual household willingness to pay (WTP) for the specified water quality improvement. Note that the values the exhibit reports are those originally obtained from the Carson and Mitchell survey, and are expressed in 1983 dollars. To provide benefit estimates appropriate for this analysis, EPA adjusts these values to account for inflation and changes in real income between 1983 and 2001.[17]

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[15] The criteria for each beneficial use category are based on criteria used by W.J. Vaughn to develop the original water quality ladder (see Carson and Mitchell (1993) for discussion of Vaughn's ladder). Vaughn's ladder included pH in addition to the four parameters adopted for this analysis.

[16] The scope of the survey excluded the Great Lakes.

[17] EPA employs the Consumer Price Index to adjust 1983 values to 2001 values. In addition, the adjustment to 2001 values takes into account the increase in real per capita disposable income over the period of interest. The adjustment for changes in real income is consistent with the survey's results, which found that respondents' willingness to pay for water quality improvements increased in almost direct proportion to household income.

Exhibit 4-11 INDIVIDUAL HOUSEHOLD WILLINGNESS TO PAY FOR WATER QUALITY IMPROVEMENTS (1983 $)		
Water Quality Improvement	**Total WTP**	**Incremental WTP**
Swimmable: WTP to raise all sub-swimmable water quality to swimmable	$241	$78
Fishable: WTP to raise all sub-fishable water quality to fishable	$163	$70
Boatable: WTP to maintain boatable water quality	$93	$93
Source: Carson and Mitchell, 1993.		

4.6.1.3 Additional Considerations When Using the Ladder

Applying the willingness to pay estimates obtained from the Carson and Mitchell study to analyze the benefits of revised CAFO regulations requires consideration of how households' willingness to pay for water quality improvements is likely to vary with the extent and location of the resources affected. All else equal, people are likely to value an action that improves water quality along a ten-mile stretch of river more highly than they would value an action that improves only a one-mile stretch. Similarly, people are likely to place greater value on improving the quality of water resources that are nearer to them. This is simply because less time and expense is typically required to reach nearer resources; as a result, these resources generally provide lower cost and more frequent opportunities for recreation and enjoyment. This assumption is supported by the results of the Carson and Mitchell survey, which asked respondents to apportion their willingness to pay values between improving the quality of local waters — where local waters were defined as those in each respondent's own state — and improving the quality of non-local waters (i.e., those located out-of-state). On average, respondents allocated two-thirds of their values to achieving water quality goals in-state, and one-third to achieving those goals in the remainder of the nation.

To reflect the considerations noted above, the analysis of the benefits of the revised CAFO regulations examines water quality improvements on a state-by-state basis and separately calculates the benefits of in-state and out-of-state improvements, assuming that households will allocate two-thirds of their willingness to pay values to the improvement of in-state waters. In addition, the analysis takes into account the extent of the final rule's estimated impacts (i.e., the number of stream-miles that improve from non-supportive to boatable; non-supportive or boatable to fishable; or non-supportive, boatable or fishable to swimmable) by scaling household willingness to pay for a given improvement in the quality of the nation's waters by the proportion of total stream-miles in-state or out-of-state that are projected to make the improvement. Appendix 4-A provides a detailed summary of the calculations employed.

The water quality ladder captures the benefits of categorical changes in the type of beneficial uses supported by water bodies (i.e., improvements from one use category to another). In doing so, it reflects the principles of water quality standards where determinants of beneficial use attainment are based on water quality criteria. However, it should be emphasized that the pollutant criteria in the discrete ladder include pollutants (such as TSS and BOD) that are not typically adopted by States as numerical criteria for determining boatable, fishable, and swimmable conditions. In addition, the ladder criteria are relatively stringent (e.g., 100 mg/l TSS for boatable). Inclusion of criteria for these pollutants therefore implies lower probability of beneficial use attainment under the ladder than might be indicated by other methods for determining use attainment in the nation's waters. For example, 71 percent of assessed streams and rivers in the nation are judged to be supporting swimmable uses (National Water Quality Inventory (NWQI): 2000 Report) (EPA 841-R-02-001), yet only five percent of RF3 Lite reach segments are meeting swimmable criteria at baseline (i.e., in the absence of the CAFO final rule) using the ladder.[18] Similar results are observed for the boatable amenity where the NWQI (2000) shows that 76 percent of the nation's assessed streams and rivers are supporting secondary contact recreation but only 14 percent of RF3 Lite reach segments are achieving boatable conditions under the ladder.

4.6.2 Water Quality Index Approach

A key limitation of the water quality ladder approach is that it only values changes in water quality to the extent that they lead to changes in beneficial-use attainment. As a result, the approach may overstate the benefits of relatively small changes that occur at the thresholds between beneficial use categories, while failing to capture the benefits of changes that occur within (i.e., without crossing) the thresholds. Furthermore, the use classification is determined by the worst individual water quality parameter. For example, if TSS changes to boatable but fecal coliform does not, the reach would still be classified as non-boatable. Finally, another limitation of the water quality ladder is that changes in nitrogen and phosphorus concentrations, both of which are CAFO parameters of interest with respect to eutrophication, are not directly included in use support determinations.

The water quality index approach is designed to address these concerns. Under this approach, NWPCAM calculates a score for each river reach based on six water quality parameters: BOD, DO, fecal coliform, total suspended solids, nitrate, and phosphate. Scores are assigned on a scale of 0 to 100, based on a weighting process that translates the six conventional water quality measures to a continuous, composite index. The weighting process reflects the judgments of a panel

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[18] Baseline results provided in *Estimation of National Economic Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations* - see docket.

of 142 water quality experts convened as part of a 1974 study by McClelland (McClelland, 1974).[19] The impact of the revised CAFO regulations for a given river reach is measured as the change in the water quality index for that reach (i.e., the difference between the reach's score under baseline conditions and its score under the post-regulatory scenario).

To value changes in the water quality index, EPA relies on a willingness to pay function derived by Carson and Mitchell using their survey results. This equation specifies household willingness to pay for improved water quality as a function of the level of water quality to be achieved (as represented by the water quality index value), household income, and other attributes (i.e., household participation in water-based recreation and respondents' attitudes toward environmental protection). EPA estimates changes in index values using NWPCAM, and applies the willingness to pay function to estimate benefits. Based on this approach, EPA is able to assess the value of improvements in water quality along the continuous 0 to 100 point scale. Appendix 4-B specifies the willingness to pay function and describes its derivation. As with the water quality ladder approach, the calculation of benefits is developed by State and takes into account differences in willingness to pay for local and non-local water quality improvements (i.e., it assumes households will allocate two-thirds of their willingness to pay to improvements in in-State waters).

4.6.3 Additional Considerations When Applying the Index

An issue in applying the results of the Carson and Mitchell survey in the context of the water quality index is the treatment of water quality changes occurring below the boatable range and above the swimmable range. There are concerns that the survey's description of non-boatable conditions was exaggerated, which implies that willingness-to-pay estimates for improving water to boatable conditions may be biased upwards. In addition, the survey did not ask respondents how much they would be willing to pay for improved water quality above the swimmable level.[20] These issues increase the uncertainty associated with valuing water quality changes outside the boatable to swimmable range (i.e., for water quality index values below 26 or above 70). In recognition of this uncertainty, value estimates for changes in water quality within each range are presented separately.

In contrast to the water quality ladder, the water quality index approach maintains greater consistency with baseline water quality conditions (i.e., NWQI results). For example, 90 to 95 percent of RF3 Lite reaches are estimated to have composite index values greater than 25 (the boatable threshold in the Carson and Mitchell survey) under baseline conditions (see memorandum summarizing distribution in record). This result is similar to the baseline conditions specified by Carson and Mitchell (approximately 99 percent of the nation's freshwater is boatable) and better

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[19] EPA modified the original McClelland index to eliminate three parameters not modeled in NWPCAM (temperature, turbidity, and pH).

[20] However, respondents were made aware of the potential for water quality to improve beyond swimmable in the ladder (e.g., drinkable).

represents NWQI results where 76 percent of assessed rivers and streams are identified as supporting beneficial uses associated with secondary contact. Note also that the WTP function used in the index approach assumes decreasing marginal benefits with respect to water quality index values; this is consistent with consumer demand theory and implies that willingness to pay for incremental changes in water quality decreases as index values increase. Other advantages of the index approach, as noted in earlier sections, include the ability to capture benefits of (1) marginal changes in water quality without triggering changes in beneficial use; and (2) changes in other parameters of interest (i.e., nitrate, phosphate) that are not included in the ladder.

4.6.4 Estimated Benefits

Exhibits 4-12 and 4-13 summarize NWPCAM's estimates of the annual economic benefits of the revised CAFO regulations. Using the water quality ladder methodology, the annual benefits attributable to the regulation of Large CAFOs under EPA's chosen phosphorus-based standard are estimated to be $166.2 million; in contrast, annual benefits under the nitrogen-based standard, which EPA considered but did not select, are estimated to be $102.4 million.[21] As Exhibit 4-12 shows, a large share of the benefits under both standards is realized in improving the condition of waters previously classified as non-boatable to boatable.

The estimates yielded by the water quality index approach are higher by roughly a factor of two. Applying this approach, the annual benefits attributable to the regulation of Large CAFOs under the phosphorus-based standard are estimated to be $298.6 million. Under the nitrogen-based standards, the analysis yields estimated annual benefits of $182.6 million.

The lower benefits estimated under the ladder approach are due, in part, to the likelihood that predicted changes in some parameters (e.g., TSS) are not sufficiently large to meet criteria necessary for changes in beneficial use, even in the case of boatable water. Under the index approach, benefits are not constrained by limiting parameters, and the benefits of all changes in water quality parameters are captured.

Apparent inconsistencies in the distribution of benefits between the two methods arise because many water bodies fail to meet boatable criteria under the ladder approach, yet estimated water quality index values for most of these same water bodies exceed the minimum threshold index of 25 for boatable waters. As a result, a majority of water quality changes under the ladder approach occur within the non-boatable category, while a majority of water quality changes under the continuous index approach create benefits in reaches that fall within the index range of 25 to 70. This occurs because the process for calculating the index provides opportunities for low concentrations of some pollutants to offset high concentrations of other pollutants, thereby driving

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[21] The results reported are limited to the impact of the revised standards on Large CAFOs. The change in standards will also affect pollutant loads from Medium CAFOs, but the analysis of these impacts was not available when this report was submitted for publication.

up the composite score. As a final note regarding the distribution of benefits, it is also possible that a regulation, such as the final CAFO rule, may affect specific geographic areas where non-boatable waters predominate, thus implying that a majority of benefits would be attributable to improvements from non-boatable to boatable conditions.

Exhibit 4-12

ANNUAL ECONOMIC BENEFIT OF ESTIMATED IMPROVEMENTS IN SURFACE WATER QUALITY: WATER QUALITY LADDER APPROACH*
(2001 $, millions)

Regulatory Standard	Waters Improved to Boatable**	Waters Improved to Fishable**	Waters Improved to Swimmable**	Total Benefits
Phosphorus-Based	$114.1	$38.8	$13.3	$166.2
Nitrogen-Based	$73.1	$23.2	$6.1	$102.4

Source: *Estimation of National Economic Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations* (USEPA, 2002).

* These figures account for changes in loadings from Large CAFOs only. The impact of revised standards on loadings from Medium CAFOs is not considered.

** Boatable benefits include only those benefits attributable to improvements from non-boatable to boatable. Benefits from improvements to other beneficial use categories appear in the other columns. For a reach that improved from non-boatable to fishable, for example, a portion of the benefits appear in the boatable column, while the remainder appears in the fishable column. Similarly, fishable and swimmable benefits include only those benefits attributable to improvements from boatable to fishable and from fishable to swimmable, respectively. Benefits from improvements to other use categories appear in the other columns as described above.

Exhibit 4-13

ANNUAL ECONOMIC BENEFIT OF ESTIMATED IMPROVEMENTS IN SURFACE WATER QUALITY: WATER QUALITY INDEX APPROACH*
(2001 $, millions)

Regulatory Standard	WQI < 26	26 < WQI < 70**	WQI > 70***	Total Benefits
Phosphorus-Based	$10.1	$241.5	$47.0	$298.6
Nitrogen-Based	$7.2	$135.3	$40.1	$182.6

Source: *Estimation of National Economic Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations* (USEPA, 2002).

* These figures account for changes in loadings from Large CAFOs only. The impact of revised standards on loadings from Medium CAFOs is not considered.

** This category includes only the benefits attributable to improvements between 26 and 70. For example, for a reach that improved from 24 to 30, the portion of benefits from the increase from 24 to 26 appears in the WQI<26 category; the remainder appears in the 26<WQI<70 category.

*** This category includes only the benefits attributable to improvements to a WQI >70. For a reach that improved from 24 to 80, for example, a portion of the benefits is allocated to each of the WQI<26, the 26<WQI<70, and the WQI>70 categories.

4.7 REFERENCES

Carson, Richard T. and Robert Cameron Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Water Quality." *Water Resources Research*, Vol. 29, No. 7.

Ham, J.M. and T.M. DeSutter. 1999. "Seepage Losses and Nitrogen Export from Swine-Waste Lagoons: A Water Balance Study." *Journal of Environmental Quality*. 28:1090-1099.

Kellogg, Robert L., Charles Lander, David Moffitt, and Noel Gollehon. 2000. *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the U.S.* Forthcoming. U.S. Department of Agriculture, National Resources Conservation Service. Washington, DC.

Kellogg, Robert L. 2002. *Profile of Farms with Livestock in the United States: A Statistical Summary.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington, D.C.

Lander, C.H., D. Moffitt, and K. Alt. 1998. *Nutrients Available from Livestock Manure Relative to Crop Growth Requirements.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington, DC. February.

McClelland, Nina I. 1974. Water Quality Index Application in the Kansas River Basin. Prepared for the U.S. Environmental Protection Agency, Region VII. EPA-907/9-74-001.

NPPC (National Pork Producers Council). 1998. Pork facts 1998/1999. Des Moines, IA: National Pork Producers Council. http://www.nppc.org/PorkFacts/pfindex.html.

Smith, Richard A., Gregory E. Schwarz, and Richard B. Alexander. 1997. "Regional Interpretation of Water-Quality Monitoring Data." *Water Resources Research*, Vol. 33, no. 12. December.

Sobecki, T.M., and M. Clipper. 1999. *Identification of Acreage of U.S. Agricultural Land with a Significant Potential for Siting of Animal Waste Facilities and Associated Limitations from Potential of Groundwater Contamination*, Draft. U.S. Environmental Protection Agency, Office of Water. December.

USDA/APHIS (Animal and Plant Health Inspection Service). 1995. Swine '95. Part III and Part I: Reference of 1995 Swine Management Practices. October.

USDA/NASS (U.S. Department of Agriculture, National Agricultural Statistics Service). 1999a. *1997 Census of Agriculture*. Volume I, Geographic Area Series Part 51. Washington, DC. March.

USDA/NASS (U.S. Department of Agriculture, National Agricultural Statistics Service). 1999b. *Cattle Final Estimates 1994-1998.* January.

USEPA (U.S. Environmental Protection Agency). 2000a. *Technical Development Document for Proposed Effluent Limitations Guidelines for Animal Feeding Operations*. Office of Water.

USEPA (U.S. Environmental Protection Agency). 2002. *Estimation of National Surface Water Quality Benefits Using the National Water Pollution Control Assessment Model to Evaluate Regulatory Options for Concentrated Animal Feeding Operations*. Prepared for the Office of Water by Research Triangle Institute. October.

Appendix 4-A

NWPCAM CALCULATION OF THE ECONOMIC BENEFITS OF IMPROVED SURFACE WATER QUALITY: WATER QUALITY LADDER APPROACH

Definitions

N = national benefits of estimated improvements in water quality
S_j = total benefits of estimated improvements in water quality for residents of state "j"
$B_{(l,j)}$ = benefits of in-state improvements in water quality for residents of state "j"
$B_{(n,j)}$ = benefits of out-of-state improvements in water quality for residents of state "j"
M_j = total stream-miles in state "j"
M_n = total stream-miles outside state "j"
$M_{(x,j)}$ = stream-miles in state "j" that achieve water quality improvement "x"
$M_{(x,n)}$ = stream-miles outside state "j" that achieve water quality improvement "x"
H_j = total households in state "j"
WTP_x = average household willingness to pay for water quality improvement "x"

Calculations

$$N = \sum_{j} S_j$$

$$S_j = B_{(l,j)} + B_{(n,j)}$$

$$B_{(l,j)} = \sum_{X} (M_{(x,j)} / M_j)(H_j)(WTP_x)(2/3)$$

$$B_{(n,j)} = \sum_{X} (M_{(x,n)} / M_n)(H_j)(WTP_x)(1/3)$$

Appendix 4-B

NWPCAM CALCULATION OF THE ECONOMIC BENEFITS OF IMPROVED SURFACE WATER QUALITY: WATER QUALITY INDEX APPROACH

The following willingness-to-pay function is used to derive economic benefits using the water quality index approach. This equation was estimated and reported by Carson and Mitchell using responses from their survey sample.

$$TOTWTP = \exp[0.413 + 0.819 \times \log(WQI/10) + 0.959 \times \log(Y) + 0.207 \times W + 0.46 \times A] \quad (1)$$

where

TOTWTP	=	each household's total WTP (in 1983 dollars) for increasing water quality up to each of the three water quality index (WQI) values
Y	=	household income (sample average = $33,170 in 1983 dollars)
W	=	dummy variable indicating whether the household engaged in water-based recreation in the previous year (sample average = 0.59)
A	=	dummy variable indicating whether the respondent regarded the national goal of protecting nature and controlling pollution as very important (sample average = 0.65).

To develop this equation, Carson and Mitchell used the water quality ladder to map each beneficial-use category to a corresponding index value (boatable = 25, fishable = 50, and swimmable = 70).

Equation 1 can also be used as a benefit-transfer function, to assess the value of increasing water quality along the continuous 100-point water quality index. Assuming that the sample averages for *W* and *A* are representative of the current population, the incremental value associated with increasing WQI from WQI_0 to WQI_1 can be calculated as

$$\Delta TOTWTP = \exp[0.8341 + 0.819 \times \log(WQI_1/10) + 0.959 \times \log(Y)] - \exp[0.8341 + 0.819 \times \log(WQI_0/10) + 0.959 \times \log(Y)] \quad (2)$$

Y, in this case, would be selected to correspond to average (or median) household income in the year of the water quality change (expressed in 1983 dollars). The resulting value estimates can be inflated to current dollars based on the growth rate in the consumer price index (CPI) since 1983.

Note that Equation 2 estimates average household willingness to pay to increase *all* impaired waters addressed in Carson and Mitchell's study by the increment WQI_0 to WQI_1. Additional adjustments, identical to those employed under the water quality ladder approach, are required to distinguish between values for local (i.e., in-state) and non-local water quality improvements.

Appendix 4-C

WATER QUALITY LADDER THRESHOLD CONCENTRATIONS

Beneficial Use	Biological Oxygen Demand (mg/L)	Total Suspended Solids (mg/L)	Dissolved Oxygen (% saturated)	Fecal Coliforms (MPN/100mL)
Swimmable	1.5	10	0.83	200
Fishable	3	50	0.64	1,000
Boatable	4	100	0.45	2,000

5.1 INTRODUCTION

Episodic fish kills resulting from manure runoff, spills, and other discharges from AFOs remain a serious problem in the United States. As described in Chapter 2, large releases of nutrients, pathogens, and solids from AFOs can cause sudden, extensive kill events.[1] In less dramatic cases, nutrients contained in runoff from AFOs can trigger increases in algae growth — often called algae blooms — that reduce concentrations of dissolved oxygen in water and can eventually cause fish to die.[2]

In addition to killing and harming fish directly, pollution from AFOs can affect other aquatic organisms that in turn harm fish. In particular, the Eastern Shore of the United States has been plagued with problems related to *Pfiesteria*, a dinoflagellate algae that, under certain circumstances, can transform into a toxin that attacks fish, breaking down their skin tissue and leaving lesions or large gaping holes that often result in death. The transformation of *Pfiesteria* to its toxic form is believed to be the result of high levels of nutrients in water (Morrison, 1997). Fish kills related to *Pfiesteria* in North Carolina's Neuse River have been blamed on waste spills and runoff from the state's booming hog industry (Leavenworth, 1996; Warrick, 1996).

This chapter examines the damages attributable to AFO-related fish kills and estimates the economic benefits that the revised CAFO standards would provide in reducing such incidents. As explained below, the analysis employs state data on historical fish kill events, combined with predicted reductions in the frequency of such events under the new regulations, to estimate the

[1] For example, in 1998, the release of manure into the West Branch of Wisconsin's Pecatonica River resulted in a complete kill of smallmouth bass, catfish, forage fish, and all but the hardiest insects in a 13-mile reach (Wisconsin DNR, 1992).

[2] For example, in 1996, the gradual runoff of manure into Atkins Lake, a shallow lake in Arkansas, resulted in a heavy algae bloom that depleted the lake of oxygen, killing many fish (Arkansas DEQ, 1997).

decrease that would occur in the number of fish killed annually in AFO-induced incidents. It then employs two alternate approaches to estimate the economic benefits associated with the predicted reduction in fish kill incidents. The first of these approaches values reduced fish mortality on the basis of average fish replacement costs; the second values reduced fish mortality on the basis of recreational anglers' willingness to pay for improved fishing opportunities.

5.2 ANALYTIC APPROACH

5.2.1 Data Sources and Limitations

EPA does not maintain a comprehensive database detailing the frequency or severity of fish kill events, and States are not required to report fish kills to EPA. As a result, the Agency lacks a uniform source of national information on which to rely in evaluating the potential impact of the revised CAFO standards on fish kill incidents.

Despite the lack of EPA reporting requirements, many states do record information on fish kills. For purposes of this analysis, EPA has compiled a database of fish kill events in 19 states. This database incorporates a range of information on each incident. Exhibit 5-1 lists the 19 states included in the database, and for each state indicates the years for which data were obtained, the total number of reported events, the average number of reported events annually, the estimated total number of fish killed in the events reported, and the average number of fish killed per event.[3]

As Exhibit 5-1 indicates, the data upon which this analysis relies are not comprehensive. The fish kill database excludes 31 states, including several, such as Oklahoma, that host a relatively large number of AFOs. The period of time for which data were obtained also varies from state to state; the information collected from some states, such as Missouri, covers nearly two decades, while that collected from others, such as West Virginia, covers only a few years. In addition, even in the states and years for which data were collected, it is likely that some fish kill events remain unreported, particularly if they occurred in remote areas.[4] These data gaps introduce considerable uncertainty into the analysis.

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[3] EPA's database incorporates records on fish kills obtained from the Natural Resources Defense Council and the Izaak Walton League (Frey, Hooper, and Fredregill, 2000).

[4] For instance, in 1995 the Raleigh *News & Observer* reported a 1991 manure spill incident in the North Carolina town of Magnolia that neither the town nor the responsible farm reported to state water quality officials (Warrick and Smith, 1995).

Exhibit 5-1 FISH KILL EVENT DATA OBTAINED BY EPA					
State	**Years**	**Recorded Events**	**Average Annual Events**	**Estimated Number of Fish Killed**	**Average Mortality per Event**
Arkansas	1995-1999	43	8.6	108,174	2,516
Illinois	1987-1999	182	14.0	629,118	3,457
Indiana	1994-1999	163	27.2	4,901,290	30,069
Iowa	1981-1998	473	26.3	2,342,296	4,952
Kansas	1990-1999	157	15.7	574,519	3,659
Kentucky	1995-1998	62	15.5	202,912	3,273
Minnesota	1981-1991	263	23.9	607,910	2,311
Mississippi	1990-1998	167	18.6	3,065,565	18,357
Missouri	1980-1999	2,505	125.3	701,821	280
Montana	1994-1998	9	1.8	11,212	1,246
Nebraska	1991-1998	177	22.1	167,628	947
New Mexico	1995-1998	19	4.8	3,356	177
New York	1984-1996	234	18.0	915,159	3,911
North Carolina	1994-1998	206	41.2	1,020,903	4,956
Ohio	1995-1998	81	20.3	30,923	382
South Carolina	1995-1998	22	5.5	77,760	3,535
Texas	1990-1998	1,032	114.7	141,910,079	137,510
West Virginia	1995-1997	18	6.0	64,676	3,593
Wisconsin	1988-1998	70	6.4	171,131	2,445
Total		**5,883**	**515.9**	**157,506,432**	**26,773**

In addition to the data gaps cited above, the analysis is limited by inconsistencies in the information collected in state fish kill reports. Some states appear to have established consistent guidelines for investigating a kill, which often include reporting the number of stream miles or lake acres affected, estimating the number of fish killed, describing the exact location of the kill, identifying the source of the pollutants suspected to have caused the kill, and obtaining water quality samples for testing. Other states appear to gather information on an ad hoc basis. In addition, the data present a number of anomalies or other limitations. For example, 25 percent of the records included in EPA's database give no estimate of the number of fish killed or provide only a qualitative description of the incident's magnitude. Another 13 percent of the records indicate that the number of fish killed in the event was zero.[5] In addition, most reports do not indicate the type(s) of fish killed.

Despite the apparent limitations of these data, they are useful for purposes of this analysis. EPA's database is the most comprehensive source of information on fish kill events currently available, and in most instances characterizes the source of the pollutants that caused individual fish kill events. Thus, EPA can apply these data to characterize a baseline of kill events potentially attributable to pollution from AFOs.

5.2.2 Predicted Change in Fish Kills Under the Revised CAFO Regulations

To estimate the potential benefits of the revised CAFO regulations in reducing fish kill incidents, EPA's analysis must first assess the current — or baseline — number of AFO-related fish kills. It must then determine the impact of the new regulations in reducing these incidents. EPA's approach to this analysis is described below.

5.2.2.1 Baseline Scenario

The EPA database records fish kill events attributable to a wide range of pollutants, sources, causes, and effects. The classification of this information varies from state to state. For purposes of identifying AFO-related fish kills, EPA applies the following criteria:

- If the source of the pollution that caused a fish kill was identified as "animal feeding/waste operations," the event was classified as AFO-related.
- If the source of the pollution that caused a fish kill was identified as "agriculture" and additional information indicated that a "lagoon break," "manure," or "ammonia toxicity" was a factor, the event was classified as AFO-related.

[5] This may be due to a variety of circumstances. In some cases, the report may accurately indicate an event in which contamination occurred (such as a manure spill or municipal waste release) but no fish were killed. In other cases, a record may indicate zero fish killed simply because investigators were unable to develop a count (e.g., because the number killed was too great to count, or because the investigation was conducted too late to determine the number killed).

On this basis, EPA has classified 482 of the fish kill events contained in its database as AFO-related. These incidents killed a reported total of approximately 4 million fish. Based on these data, EPA estimates that in the states evaluated, incidents attributable to pollution from AFOs kill an average of 351 thousand fish per year.[6]

5.2.2.2 Post-Regulatory Scenario

Due to time and resource constraints, EPA has not conducted a detailed analysis of the impact of the revised CAFO standards on the frequency or severity of fish kill events. It is likely, however, that the implementation of the new regulations will have a number of beneficial effects. For example, because more AFOs would be subject to regulation as CAFOs, the number of fish kill incidents caused by lagoon breaks and similar catastrophic events would likely diminish. In addition, the improvements in manure management practices required under the new regulations would likely reduce the chronic discharge of nutrients to the nation's waters, and thus reduce the number of fish killed as a result of severe eutrophication.

In lieu of more detailed modeling, EPA has attempted to develop a reasonable estimate of the impact of the revised CAFO standards on fish kills. The analysis begins with EPA's estimate of the number of fish killed annually by releases from AFOs. EPA multiplies this figure by the anticipated percentage reduction in nutrient loadings from the animal feeding operations modeled by NWPCAM (see Chapter 4).[7] The resulting value represents an estimate of the reduction in the number of fish killed annually by releases from AFOs.

Because the relationship between nutrient loadings and fish kill events is complex, this approach provides only a rough approximation of the beneficial impacts of the revised regulations. To reflect the underlying uncertainty, the analysis employs two different scaling factors:

- the percentage reduction in phosphorus loadings; and
- the percentage reduction in nitrogen loadings.

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[6] EPA estimates the average number of fish killed annually in the 19 states of record by dividing the total number of fish killed in each state by the number of years for which data from the state are reported. EPA then sums the state averages to obtain the annual average for all 19 states.

[7] The analysis of changes in loads is limited to the impact of the revised standards on Large CAFOs. The change in standards will also affect pollutant loads from medium CAFOs, but the analysis of these impacts was not available when the report was submitted for publication.

Exhibit 5-2 summarizes the estimated percentage reduction in nitrogen and phosphorus loadings under the revised CAFO standards. The exhibit presents results for both the phosphorus-based land application standard that EPA has incorporated into the final rule and the alternative nitrogen-based standard, which EPA considered but did not select. The values reported in each case are those estimated by NWPCAM for the full RF3 set of rivers and streams. The analysis uses these values, rather than those reported for the RF3 Lite subset, in order to reflect changes in loadings to small as well as large rivers and streams.[8]

Exhibit 5-2

SCALING FACTORS[1]

Regulatory Standard	Percent Nitrogen Reduction[2]	Percent Phosphorus Reduction[2]
Phosphorus-Based	9.7	14.0
Nitrogen-Based	3.9	7.0

[1] These figures account for changes in loadings from Large CAFOs only. The impact of revised standards on loadings from Medium CAFOs is not considered.
[2] The load reductions reported are NWPCAM estimates for the full RF3 set of rivers and streams.

Based on the methods described above, EPA estimates the anticipated reduction in fish kills under the revised standards. Exhibit 5-3 presents the results. As the exhibit shows, EPA estimates that under EPA's chosen phosphorus-based standard, the reduction in fish killed annually would range from 34 thousand to 49 thousand. Under the alternative nitrogen-based standard, the reduction in fish killed annually would range from 14 thousand to 26 thousand.

Exhibit 5-3

ESTIMATED REDUCTION IN THE NUMBER OF FISH KILLED ANNUALLY DUE TO RELEASE OF POLLUTANTS FROM AFOs[1]
(thousands)

Regulatory Standard	Nitrogen Reduction Scaling Factor	Phosphorus Reduction Scaling Factor
Phosphorus-Based	34	49
Nitrogen-Based	14	26

[1] These figures account for changes in loadings from Large CAFOs only. The impact of revised standards on loadings from Medium CAFOs is not considered.

[8] Chapter 4 provides additional detail on the RF3 and RF3 Lite datasets.

5.2.3 Valuation of Predicted Reduction in Fish Kills

The economic damages that stem from natural resource injuries like fish kills include the costs of restoring the resource to its prior state, any interim lost use values (e.g., the economic value of lost fishing days from the time the damage occurs until fish stocks are restored), and any interim lost non-use values. Estimating these values for a large number of heterogeneous fish kill events nationwide is infeasible without a significant investment of analytic resources. Determining full habitat restoration costs requires a case-by-case assessment of the nature of the injury and the restoration options available, while estimating interim lost non-use values requires the use of stated preference techniques to explore people's willingness to pay to avoid temporary depletions of fish stocks and associated damage to fish habitat. The economics literature does provide estimates of potential lost use values — e.g., willingness to pay for another day of fishing or willingness to pay for an additional fish caught — that could, theoretically, be applied to the analysis using a benefit transfer approach. Conducting such an assessment at a national level, however, requires general assumptions about a number of highly variable site-specific factors, such as the duration of the reduction in fish stocks, the effect of this reduction on recreational fishing activity in the affected areas, and the availability and characteristics of alternative fishing areas. Thus, an evaluation of interim lost use values is subject to considerable uncertainty.

In light of the difficulties cited above, this analysis employs two approaches to estimating the economic benefits of reducing the frequency of fish kills. The first of these approaches values reduced fish mortality based on one component of resource restoration costs: the replacement cost of the fish. The second approach is based on a review of case studies designed to assess the damages to recreational fishing values attributable to specific fish kill events. Additional information on each approach is provided below.

5.2.3.1 Replacement Cost Approach

EPA's first approach to valuing reduced fish mortality employs fish replacement cost estimates presented in a report developed by the American Fisheries Society (AFS, 1990). These replacement values incorporate the cost of raising fish at a hatchery, transporting them, and placing them in the water. As such, they provide a conservative estimate of the economic benefits of reducing the incidence of fish kills.[9]

The American Fisheries Society report provides replacement cost estimates for a variety of fish species and size categories. Unfortunately, the available data on fish kills do not always indicate

[9] The analysis employs fish replacement costs as a proxy measure for valuing anticipated reductions in fish kill incidents. The approach does not presume that all fish killed would necessarily be restocked.

the species of fish affected, and generally do not report mortality by size of fish. In light of these limitations, EPA applies a general fish replacement cost estimate, derived by selecting species known to have been killed in incidents related to AFOs and averaging reported replacement costs for these species across all size classes. The resulting average replacement cost employed in the analysis equals $1.37 per fish (2001 $).[10] To value the benefits of the revised regulations, the analysis simply multiplies this average replacement cost by the estimated reduction in the number of fish killed each year.

5.2.3.2 Recreational Use Value Approach

EPA's second approach to valuing reduced fish mortality relies on an analysis of recreational fishing studies conducted to assess the damages attributable to fish kill events (IEc, 2002). Although the scope of this analysis was limited, it identified two studies that provide useful insights into the valuation of fish kills.

- The first study, of an industrial spill to Indiana's White River, examined the impacts of the spill on populations of warmwater sportfish and characterized the likely reduction in recreational fishing effort until the fishery recovered. On this basis, the study estimated interim lost use damages that equate to approximately $1.60 per fish killed (1999 $).

- The second study evaluated the recreational fishing impacts associated with fish entrainment at two hydroelectric dams on the Potomac River. The study estimated the reduction in warmwater sportfish stocks caused by entrainment, and assumed a proportional impact on anglers' catch rates. The study then used available estimates of anglers' willingness to pay to catch an additional fish to translate the reduction in catch into economic losses. The results range from $2.69 to $3.69 per fish killed (1999 $).

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[10] To adjust replacement costs to 2001 dollars, EPA applies the Gross Domestic Product deflator.

On the basis of these findings the analysis estimates recreational fishing damages of approximately $2.50 per sportfish mortality (1999 $).[11] EPA's database, however, suggests that approximately 10 percent of fish kill events do not involve sportfish. Thus, the analysis recommends the use of a weighted-average figure of $2.25 per fish (1999 $) to value the recreational use benefits of reducing fish kills. EPA's analysis of the revised CAFO regulations adopts this recommendation, employing an inflation-adjusted value of $2.35 per fish (2001 $).[12]

5.3 RESULTS

Exhibit 5-4 presents estimates of the annual benefits attributable to the reduced incidence of fish kills under EPA's phosphorus-based standard and under the nitrogen-based standard that EPA considered but did not select. As the exhibit indicates, the estimated benefits range from $47 thousand to $115 thousand annually under the phosphorus-based standard and from $19 thousand to $61 thousand annually under the nitrogen-based standard, depending upon the valuation approach and scaling factor employed.

Exhibit 5-4

ESTIMATED ANNUAL BENEFITS ATTRIBUTED TO REDUCTION IN FISH KILLS[1] ($2001, thousands)

	Valuation Method			
	Replacement Cost		Recreational Use Value	
Regulatory Standard	Nitrogen Scaling	Phosphorus Scaling	Nitrogen Scaling	Phosphorus Scaling
Phosphorus-Based	$47	$67	$80	$115
Nitrogen-Based	$19	$36	$33	$61

[1] These figures account for changes in loadings from Large CAFOs only. The impact of revised standards on loadings from Medium CAFOs is not considered.

[11] The analysis notes that these figures reflect recreational fishing values for warmwater sportfish, primarily bass. Such values are higher than those for most other warmwater species (e.g., bullhead, catfish), but lower than those for coldwater species (e.g., trout).

[12] EPA applies the Gross Domestic Product deflator to adjust the base value to 2001 dollars.

5.4 LIMITATIONS AND CAVEATS

EPA's analysis of the benefits of the revised CAFO regulations in reducing fish kills is subject to numerous data gaps and uncertainties. In the face of these uncertainties, the analysis employs a number of simplifying assumptions and presents a range of results. The major limitations of the analysis are summarized below.

- The scope of the analysis is limited to 19 states. The data available from these states may not include all fish kill events, and the data on reported incidents often fail to include estimates of the number of fish killed. Therefore, EPA's baseline estimate is likely to understate the number of fish kill events and the total number of fish killed nationwide each year in incidents related to pollution from AFOs.

- EPA has not undertaken a detailed analysis of the impact of the revised regulations on the incidence of fish kills. In lieu of a detailed analysis, EPA assumes that fish kills attributable to releases of pollution from AFOs will be reduced in proportion to estimated reductions in loadings of nutrients from AFOs. The direction and magnitude of bias associated with these assumptions is unknown.

- To value estimated reductions in fish kill incidents, the analysis applies two approaches. The first, which employs an estimate of average fish replacement costs, ignores other aspects of the economic damages associated with fish kills (i.e., habitat restoration costs, interim lost use values, and interim lost non-use values). Thus, it likely understates the economic benefit of reducing fish kill incidents. The second, which is based on an estimate of recreational use values, rests on a limited number of studies that reflect highly variable case-specific factors, and thus is subject to considerable uncertainty.

In addition to these caveats, the analysis is limited to the impact of the revised CAFO standards on pollutant loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis is a source of downward (negative) bias in our estimate of the economic benefits of the new standards.

5.5 REFERENCES

AFS. 1993. American Fisheries Society Socioeconomics Section, *Sourcebook for Investigation and Valuation of Fish Kills*. Supplement to American Fisheries Society Special Publication 24. Bethesda, Maryland.

Arkansas DEQ (Department of Environmental Quality). 1997. *Report of Pollution Caused Fish Kills*. June 27.

Frey, Merritt, Rachel Hopper, and Amy Fredregill. 2000. "Spills and Kills: Manure Pollution and America's Livestock Feedlots." *Clean Water Network*, New York, NY. August.

Griffiths, Charles and Cynthia Morgan. 2002. "Benefits of Reduced Fish Kills from the NPDES and Effluent Guidelines Rule for CAFOs." National Center for Environmental Economics, U.S. Environmental Protection Agency. August 15.

IEc (Industrial Economics, Incorporated). 2002. Bob Black, Brian Morrison, and Dan Hudgens, IEc. "Alternatives for Evaluating Fish Kill Reduction Benefits." Memorandum to Charles Griffiths, U.S. Environmental Protection Agency. July 22.

Leavenworth, S. 1996. "Coastal Playground Turned Killing Ground." *The News & Observer*. March 7.

Mancl, K. and M. A. Veenhuizen. 1991. "Avoiding Stream Pollution from Animal Manure." Ohio State University Extension Fact Sheet.

Morrison, C. 1997. "The Cell from Hell and Poultry Farmers: Do They Have Anything in Common?" *The Shore Journal*. August 31.

Warrick, Joby. 1996. "A Bumper Crop of Waste." *The News & Observer*. March 5.

Warrick, Joby and Pat Smith. 1995. "New studies show that lagoons are leaking: Groundwater, rivers affected by waste." *The News & Observer*. February 19.

Wisconsin DNR (Department of Natural Resources). 1992. *Wisconsin Water Quality Assessment Report to Congress.*

U.S. Department of the Interior. 1996. "Natural Resource Damage Assessments — Type A Procedures." *Federal Register*. Vol. 61, No. 89 (May 7), pp. 20560-20614.

U.S. Fish and Wildlife Service. 2001. *The Economic Benefits of Improved Fish Passage at Potomac River Dams 4 and 5*. Draft Final Report. October.

U.S. Fish and Wildlife Service. 1998. *1996 Net Economic Values for Bass, Trout and Walleye Fishing, Deer, Elk and Moose Hunting, and Wildlife Watching: Addendum to the 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.* August.

6.1 INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) has identified pathogen contamination of U.S. coastal waters as a leading cause of government restrictions on commercial shellfish harvesting. Among the sources of pollution that contribute to such contamination are animal feeding operations (AFOs) and runoff from agricultural lands. This chapter estimates the impact of pollution from AFOs on commercial access to shellfish growing waters, the resulting impact on commercial shellfish harvests, and the potential increase in harvests that would result under the revised standards governing the discharge of pollutants from CAFOs. It then uses available estimates of consumer demand for shellfish to calculate the economic benefits associated with the predicted increase in commercial shellfish harvests under the new rule.

6.2 ANALYTIC APPROACH

6.2.1 Data on Shellfish Harvest Restrictions Attributed to AFOs

EPA's analysis of the impact of pollution from AFOs on shellfish harvests is based on information from *The 1995 National Shellfish Register of Classified Growing Waters* (NOAA, 1997) and related databases. NOAA produces the Register, which is published every five years, in cooperation with the nation's shellfish-producing states, federal agencies such as the U.S. Food and Drug Administration (FDA), and the Interstate Shellfish Sanitation Conference (ISSC). Its purpose is to summarize the status of shellfish-growing waters under the National Shellfish Sanitation Program (NSSP), which ISSC administers. The NSSP establishes comprehensive guidelines to regulate the commercial harvesting, processing, and shipment of shellfish. These guidelines include the measurement of fecal coliform concentrations as an indicator of pollution in shellfish-growing waters. Based in large part upon these measurements, shellfish-growing areas are designated as approved, conditionally approved, restricted, conditionally restricted, prohibited, or unclassified, and subjected to appropriate harvest and processing standards. Exhibit 6-1 describes these standards for each designation.

Exhibit 6-1

NSSP STANDARDS FOR CLASSIFIED SHELLFISH GROWING WATERS

Classification	Description	Standard[1]
Approved Waters	Growing waters from which shellfish may be harvested for direct marketing.	MPN may not exceed 14 per 100 ml, and not more than 10 percent of the samples may exceed an MPN of 43 per 100 ml for a 5-tube decimal dilution test.
Conditionally Approved Waters	Growing waters meeting the approved classification standards under predictable conditions. These waters are open to harvest when water quality standards are met. At all other times these waters are closed.	
Restricted Waters	Growing waters from which shellfish may be harvested only if they are relayed or depurated before direct marketing.[2]	MPN may not exceed 88 per 100 ml, and not more than 10 percent of the samples may exceed an MPN of 260 per 100 ml for a 5-tube decimal dilution test.
Conditionally Restricted Waters	Growing waters that do not meet the criteria for restricted waters if subjected to intermittent microbiological pollution, but may be harvested if shellfish are subjected to a suitable purification process.	
Prohibited Waters	Growing waters from which shellfish may not be harvested for marketing under any conditions.	NA
Unclassified Waters	Growing waters that are part of a state's shellfish program but are inactive (i.e., there is no harvesting) and unmonitored.	NA

Source: National Oceanic and Atmospheric Administration, *The 1995 National Shellfish Register of Classified Growing Waters*, obtained from: http://seaserver.nos.noaa.gov/projects/95register/, 11 June 2000.

Notes:

1 MPN = fecal coliform most probable number (median or geometric mean).

2 The process of relaying shellfish refers to the transfer of shellfish from restricted waters to approved waters for natural biological cleansing using the ambient environment as a treatment system, usually for a minimum of 14 days before harvest. Depuration is the process of removing impurities by placing the contaminated shellfish in clean water for a period of time.

The 1995 Shellfish Register provides information on 21.4 million acres of estuarine and non-estuarine commercial shellfish-growing waters as of January 1, 1995. A companion CD contains a GIS-based database of the location of all 4,320 shellfish growing areas in 21 coastal states, the acreage of each growing area, and the species harvested.[1] These species are classified into 13

[1] The Shellfish Register includes data for the following states: Alabama, California, Connecticut, Delaware, Florida, Georgia, Louisiana, Massachusetts, Maryland, Maine, Mississippi, North Carolina, New Hampshire, New Jersey, New York, Oregon, Rhode Island, South Carolina,

categories of clams, four categories of oysters, six categories of mussels, and two categories of scallops. In most cases, each category represents a unique species (e.g., Blue Mussel (*Mytilus edulis*)), but in some instances a category may include two or more species (e.g., Other Mussels (*Mytilus galloprovincialis* and *Mytilus edulis*)). The types of species harvested vary geographically, with large differences between the East and West Coasts.

In addition to the data described above, the shellfish database notes for each growing area any harvest limitations imposed and the known or possible source(s) of pollutants causing any impairment. The list of pollutant sources includes both "Animal Feedlots" and "Agriculture Runoff." Sources of impairment are further classified as actual or potential contributors. If a source is listed as an actual contributor, its significance as a cause of impairment is rated as high, medium, or low. Exhibit 6-2 shows the acreage of shellfish-growing waters that are potentially or known to be impaired by pollution from AFOs and/or agricultural runoff. As the exhibit indicates, AFOs and/or agricultural runoff are known or potential contributors to the impairment of more than 1.6 million acres of shellfish-growing waters.

Exhibit 6-2

SHELLFISH HARVEST LIMITATIONS BY REGION

Region	Approved Acres	Harvest-Limited Acres	Harvest-Limited Acres with Impacts from AFOs and/or Agricultural Runoff
North Atlantic (MA, ME, NH)	2,920,575	714,191	33,626
Middle Atlantic (CT, DE, MD, NJ, NY, RI, VA)	4,969,680	973,715	100,284
South Atlantic (FL, GA, NC, SC)	3,505,729	1,751,844	660,679
Gulf of Mexico (AL, LA, MS, TX)	3,238,431	3,067,730	718,828
Pacific (CA, OR, WA)	206,574	214,494	96,296
Total	14,840,989	6,721,975	1,609,713

Discrepancies between reported totals and sum of regional totals are due to rounding.
Source: U.S. National Oceanic and Atmospheric Administration, *The 1995 National Shellfish Register of Classified Growing Waters*, U.S. Department of Commerce, Silver Spring, MD, August 1997.

Texas, Virginia, and Washington.

6.2.2 Estimated Impact on Shellfish Harvests

As a causal factor in the imposition of government restrictions or prohibitions on shellfish harvesting, pollution from AFOs likely serves to reduce shellfish landings below levels that would otherwise be realized. To evaluate the potential beneficial effects of the new CAFO regulations, EPA's analysis begins by estimating the adverse impacts currently attributable to pollution from AFOs. The approach to this analysis involves the following steps.

- Step 1: characterize current, or baseline, annual shellfish landings.
- Step 2: estimate the area of shellfish-growing waters from which current landings are harvested.
- Step 3: calculate the average annual per-acre yield of shellfish from harvested waters.
- Step 4: estimate the area of shellfish-growing waters that are currently unharvested as a result of pollution from AFOs.
- Step 5: estimate the foregone harvest, i.e., the potential annual harvest of shellfish from waters that are currently unharvested as a result of pollution from AFOs.

Each of these steps is described in greater detail below.

6.2.2.1 Baseline Annual Shellfish Landings

To characterize the baseline quantity (Q_0) of shellfish harvested in each coastal state, the analysis relies on data collected by NOAA's National Marine Fisheries Service (NMFS), which reports commercial fishing harvests by state, year, and species (NMFS, 2000). NMFS maintains complete commercial harvest data on various species of clams, mussels, oysters and scallops for each state. The data consist of total pounds harvested and total ex-vessel revenues for harvested species. The data are provided as state-wide totals only and do not disaggregate harvest quantities between shellfish growing areas within each state. For the purpose of this analysis, EPA obtained shellfish harvest data by species and state for the five most recent years available: 1994 through 1998. The analysis employs the mean of the reported annual values for each species and state to characterize shellfish harvests under baseline conditions.[2]

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[2] The calculation of the mean ignores years for which harvest data for a particular species are unavailable. If landings in these years were actually zero, this approach will overstate average annual landings.

6.2.2.2 Estimated Acreage of Harvested Waters

The available data do not indicate the distribution of shellfish landings from waters that the 1995 Shellfish Register identifies as approved, conditionally approved, restricted, or conditionally restricted. For purposes of this analysis, EPA assumes that baseline landings are harvested primarily from approved or conditionally approved waters. Thus, in a given state (j), the area of shellfish growing waters assumed to be harvested is determined by the following calculation:

$$\text{Acres Harvested}_{(j)} = \text{Acres Approved}_{(j)} + \text{Acres Conditionally Approved}_{(j)}$$

6.2.2.3 Average Annual Yield of Harvested Waters

To calculate the average annual yield (Y) of harvested waters for a given species (n) in a given state (j), the analysis simply divides the annual baseline harvest (Q_0) for that species and state by the acres assumed to be harvested:

$$Y_{(n,j)} = Q_{0(n,j)}/\text{Acres Harvested}_{(j)}$$

This calculation provides an estimate of the pounds of shellfish landed per year from harvested waters.

6.2.2.4 Characterization of Waters that are Unharvested due to Pollution from AFOs

The next step in the analysis is to estimate the area of shellfish-growing waters that are currently unharvested due, at least in part, to pollution from AFOs. Consistent with the approach outlined thus far, EPA assumes that waters classified in the 1995 Shellfish Register as restricted, conditionally restricted, or prohibited are essentially unharvested. Thus, in a given state (j), the area of shellfish growing waters assumed to be unharvested is determined by the following calculation:

$$\text{Acres Unharvested}_{(j)} = \text{Acres Restricted}_{(j)} + \text{Acres Conditionally Restricted}_{(j)} + \text{Acres Prohibited}_{(j)}$$

This calculation, however, includes all impaired waters. To identify areas impaired, in whole or in part, by pollution from AFOs, EPA's analysis considers two cases. Under Case 1, EPA evaluates only those shellfish-growing waters for which AFOs are specifically identified as a contributing source of impairment. Under Case 2, EPA expands the analysis to include shellfish-growing waters that the Register identifies as impaired, in whole or in part, by AFOs and/or agricultural runoff. The inclusion of Case 2 is justified by the classification of shellfish-growing waters on the basis of fecal coliform levels. To the extent that agricultural runoff causes elevated fecal coliform counts, animal manure, potentially from AFOs, is the likely contributing factor.[3]

6.2.2.5 Estimated Impact of Pollution from AFOs on Commercial Shellfish Landings

To characterize the impact of pollution from AFOs on commercial shellfish landings, it is necessary to estimate the potential yield of impaired shellfish growing areas. For purposes of this analysis, EPA assumes that the average annual yield from harvested waters, as calculated above, is representative of the potential annual yield from impaired waters. Thus, the foregone harvest (Q_F) from an area of any size for a given species (n) in a given state (j) is calculated as follows:

$$Q_{F(n,j)} = Y_{(n,j)} \text{ x Acres Unharvested}_{(j)}$$

EPA calculates the foregone harvest for each of the two cases described above. Under Case 1, the calculation estimates the foregone harvest from shellfish-growing waters for which AFOs are specifically identified as a contributing source of impairment. Under Case 2, EPA expands the analysis to estimate the foregone harvest from shellfish-growing waters identified as impaired, in whole or in part, by AFOs and/or agricultural runoff.

6.2.3 Estimated Impact of the Revised Regulations on Commercial Shellfish Harvests

The next step in EPA's analysis is to estimate the impact of the new CAFO regulations on commercial shellfish harvests. To do so, EPA employs information obtained from the surface water quality modeling effort described in Chapter 4. The modeling exercise does not extend to estuaries or near-coastal waters, where most commercial shellfish-growing areas are located; however, it does consider the impact of the new regulations on fecal coliform counts in the terminal reaches of rivers and streams that flow into commercial shellfish growing areas. In lieu of more detailed modeling, this information provides a reasonable proxy for estimating the impact of the rule on water quality in shellfish growing areas.

EPA's approach to estimating the beneficial effects of the new CAFO regulations on commercial shellfish harvests assumes that the adverse impact of pollution from AFOs will be

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[3] In addition, NOAA staff who maintain the Register suggest that difficulty in pinpointing the source of pollution often results in classifying impacts from AFOs under the more general heading of "Agriculture Runoff." Personal communication with Jamison Higgins, NOAA, April 12, 1999.

reduced in proportion to modeled reductions in fecal coliform loadings to shellfish growing waters. The details of this approach are described below.

- First, EPA identifies all terminal reaches in each state that flow into waters supporting commercial shellfish beds. The total fecal coliform load from these waters is calculated under both baseline conditions and under the revised standards. The analysis examines fecal coliform loads under both the phosphorus-based land application standard incorporated into the final rule and the nitrogen-based alternative standard, which EPA considered but did not select.

- Next, for each state, EPA calculates the percentage reduction in fecal coliform loads predicted under the revised standards.[4]

- Third, EPA multiplies its estimates of the percentage reduction in fecal coliform counts by its previously developed estimates of the impact of pollution from AFOs and/or agricultural runoff on shellfish harvests (Q_F). This calculation was performed separately for each species and state. The result, Q_R, represents the incremental increase in harvest associated with the new CAFO standards.

Adding Q_R to baseline harvests (Q_0) yields an estimate of annual shellfish harvests following implementation of the revised CAFO regulations (Q_1). This calculation is performed for each state and species. Thus:

$$Q_{1(n,j)} = Q_{0(n,j)} + Q_{R(n,j)}$$

6.2.4 Valuation of Predicted Change in Shellfish Harvests

The appropriate measure of the economic benefits of an increase in commercial shellfish harvests is the welfare gain (i.e., the change in producer and consumer surplus) associated with the increased harvest. For purposes of this analysis, EPA focuses solely on changes in consumer surplus.[5] This focus is necessary because the information required to evaluate any changes in

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[4] The analysis of changes in loads is limited to the impact of the revised standards on Large CAFOs. The change in standards will also affect fecal coliform loads from Medium CAFOs, but an analysis of these impacts was not available when this report was submitted for publication.

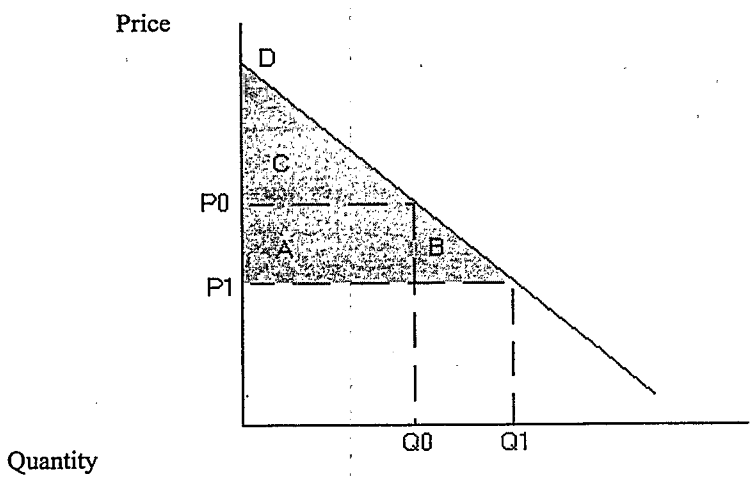
[5] As discussed in Chapter 3, the concept of consumer surplus is based on the principle that some consumers benefit at current prices because they are able to purchase a good at a price that is less than the amount they are willing to pay.

producer surplus that might result from an increase in shellfish harvests (i.e., a long-run supply curve for each species harvested) is difficult to obtain. In addition, the shellfish harvesting industry is to a significant extent characterized by regulated harvest levels and unregulated harvester effort (i.e., open access fisheries).[6] Generally accepted natural resource economics theory suggests that, in open access fisheries, overcapitalization leads to zero producer surplus. Thus, although shellfish harvesting is not entirely open access, any producer surplus in the industry is likely to be small, and any changes in producer surplus brought about by the new CAFO regulations is likely to be minor.

To calculate the change in consumer surplus associated with an increase in commercial shellfish harvests, the analysis makes use of information on consumer demand. Exhibit 6-3 illustrates a simple demand curve. The demand curve is the downward sloping solid line labeled D, and the initial quantity sold is the dashed, vertical line at Q_0. The intersection of these two lines gives the price at which quantity Q_0 is sold. This price is marked as P_0 and represented by the dashed horizontal line. The consumer surplus for quantity Q_0 is the area below the demand curve and above the horizontal line at P_0. That is, the consumer surplus for Q_0 is the area labeled "C" in Exhibit 6-3.

Exhibit 6-3

CONSUMER DEMAND AND CONSUMER SURPLUS



[6] Anecdotal evidence suggests that some shellfishing areas are leased by municipalities to individual enterprises with sole rights to harvest the area. In these cases, the limits on competition could lead to positive producer surplus. The extent of this practice, however, is unclear.

The measurement of the benefits of the revised CAFO regulations relies on the assumption that a decrease in the contamination of shellfish-growing waters would increase commercial access to shellfish beds, and thus increase the quantity of shellfish supplied to consumers (i.e., an increase from Q_0 to Q_1). This in turn would result in a lower market price for shellfish (i.e., P_1). The benefit to consumers can be determined based on the old and new prices and quantities. Before the change, the area labeled "C" in Exhibit 6-3 measures consumer surplus. After the change, consumer surplus is measured by the area of A+B+C. Thus, the difference in consumer surplus between these scenarios (i.e., Area A + Area B) is the additional consumer surplus attributable to the proposed rule and the appropriate economic measure of benefits to consumers.

6.2.4.1 Characterization of Consumer Demand for Shellfish

Analysis of the changes in consumer surplus that might result from an increase in shellfish harvests requires an understanding of the effect of an increased harvest on market prices. To gather the necessary information, EPA reviewed the economics literature. This review identified a number of relevant studies: Lipton and Strand (1992), which estimates a demand equation for surf clams and ocean quahogs on the East Coast; Wessells et al. (1995), which estimates a demand equation for U.S. harvested mussels in Montreal; Cheng and Capps, Jr. (1988), which estimates demand equations for oysters and total shellfish in the U.S.; and Capps, Jr. and Lambregts (1991), which estimates demand equations for scallops and oysters in Houston, Texas. Exhibit 6-4 lists the demand elasticities obtained from each of these studies.[7] These demand elasticities provide the means to determine the change in consumer surplus associated with changes in shellfish harvests.

Exhibit 6-4

SHELLFISH DEMAND ELASTICITIES

Citation	Species	Elasticity
Cheng and Capps	oysters	-1.132
Cheng and Capps	total shellfish	-0.885
Capps and Lambregts	oysters	not significant
Capps and Lambregts	scallops	-1.84
Wessells et al.	mussels	-1.98
Lipton and Strand	surf clams	-2
Lipton and Strand	ocean quahogs	-0.87

6.2.4.2 Determining the Change in Consumer Surplus Associated with Increased Harvests

[7] The price elasticity of demand represents the percentage change in demand for a good brought about by a one percent change in its price; thus, a price elasticity of -2 implies that a one percent increase in price will result in a two percent decrease in demand.

EPA's analysis of the benefits of an increase in shellfish harvests begins by estimating prices and quantities (i.e., P_0 and Q_0) under baseline conditions, as well as the quantity of shellfish that would be harvested following the implementation of the new CAFO regulations (Q_1). Consistent with the analysis of shellfish harvests described above, Q_0 for each state and species is based on NMFS data, and specified as the mean annual harvest for the years 1994 through 1998. P_0 is calculated by dividing the total reported revenues from 1994 through 1998 for each species and state, adjusted to 2001 dollars, by the total quantity harvested.[8] Q_1 is determined as described above, adding to Q_0 the increase in shellfish harvests estimated to occur under the new regulations (Q_R). EPA determined the value of these factors for each broad category of shellfish for which NMFS data are available: scallops, oysters, mussels, and clams. When the data allow, EPA developed separate values for quahogs, surf clams, and other clams. This approach enables the analysis to take advantage, whenever possible, of the demand equations identified for the quahog and surf clam subcategories.[9]

Once P_0, Q_0, and Q_1 are estimated, the appropriate price elasticities of demand are applied to determine the new price (P_1) associated with an increase in shellfish harvests. For purposes of this analysis, the percentage change in price is determined by dividing the percentage increase in the quantity of shellfish supplied in each case by the appropriate price elasticity. This percentage change is then applied to the initial price (P_0) to calculate the new price (P_1) for each species harvested.[10]

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[8] EPA adjusts reported revenues to 2001 dollars using the Consumer Price Index. In calculating P_0, EPA considers only those years for which harvest and revenue data are available.

[9] The analysis employs the Wessells et al. demand elasticity for mussels and the Capps and Lambregts demand elasticity for scallops for all states in which these species are harvested. When disaggregated data on surf clam or quahog harvests are available, the analysis relies on the demand elasticities for these species developed by Lipton and Strand; in all other instances, demand for clams is analyzed using the total shellfish price elasticity estimated by Cheng and Capps. For oysters, the analysis relies upon the demand elasticity estimated by Cheng and Capps; this value was selected because it was based on evaluation of a broader market than that considered by Capps and Lambregts.

[10] Mathematically, the price elasticity of demand ($\in$) is calculated as:

$$\in = \partial Q / \partial P$$

where:

$$\partial Q = (Q_1 - Q_0)/Q_0$$
$$\partial P = (P_1 - P_0)/P_0$$

therefore:

$$\partial P = \partial Q / \in$$
$$P_1 = (Q_1 - Q_0)(P_0)/[(\in)(Q_0)] + P_0$$

EPA employs the estimated values for P_0, P_1, Q_0 and Q_1 to measure the increase in consumer surplus associated with the projected increase in shellfish harvested and resulting reduction in market price under the new regulations. This calculation is conducted for every state and species category. The estimated annual benefit of the revised CAFO standards is simply the sum of the estimated increase in consumer surplus across states and species.[11]

6.3 RESULTS

Exhibit 6-5 summarizes the estimated economic benefits associated with increased shellfish harvests under the new CAFO standards. Results are provided for both the phosphorus-based land application standard incorporated into the final rule and the nitrogen-based alternative standard, which EPA considered but did not select. The exhibit also presents two cases: Case 1, which considers beneficial impacts on shellfish growing waters that the Shellfish Register specifically identifies as impaired by pollution from AFOs; and Case 2, which expands the analysis to consider beneficial impacts on shellfish growing waters identified as impaired by pollution from AFOs and/or agricultural runoff. As the exhibit indicates, EPA's estimates of annual benefits in Case 2 are more than an order of magnitude greater than in Case 1; this range reflects the significant increase in the number and area of shellfish growing waters considered to be impaired by AFOs when runoff from agricultural land, as opposed to pollution specifically attributed to AFOs, is included in the analysis. Under EPA's chosen phosphorus-based standard, the estimate of annual benefits ranges from approximately $0.3 million in Case 1 to $3.4 million in Case 2. Under the alternative nitrogen-based standard, the estimates of annual benefits are lower, ranging from $0.1 million in Case 1 to $1.9 million in Case 2.

Exhibit 6-5

ESTIMATED ANNUAL BENEFITS OF INCREASED COMMERCIAL SHELLFISH HARVESTS[1] (2001 $, millions)

Regulatory Standard	Case 1: AFOs	Case 2: AFOs and Agricultural Runoff
Phosphorus-Based	$0.3	$3.4
Nitrogen-Based	$0.1	$2.0

[1] The analysis accounts for changes in the regulation of Large CAFOs only. The impact of revised standards for Medium CAFOs is not considered.

[11] The calculation of increased consumer surplus is based on a simple geometric approximation of the change in areas under the demand curve, rather than formal integration using calculus. As a result, the estimated increase in consumer surplus may be slightly overstated.

6.4 LIMITATIONS AND CAVEATS

The analysis set forth above is subject to a number of uncertainties and relies upon several simplifying assumptions. These factors may lead to a potential under- or over-estimation of the benefits of decreasing AFO-related contamination of commercial shellfish growing waters. The most significant of these limitations are described below.

- The analysis assumes that a reduction in pollution from AFOs will result in an increase in commercial shellfish harvests. While this assumption appears reasonable in light of the extent to which AFOs contribute to current restrictions or prohibitions on shellfish harvesting, the actual impact of these restrictions or prohibitions on annual shellfish landings is unknown.

- To estimate the potential impact of pollution on annual shellfish landings, the analysis calculates an average annual yield (pounds per acre) for shellfish growing waters. The calculation of this figure assumes that current harvests are obtained from waters classified as approved or conditionally approved. To the extent that this approach over- or understates the increase in annual yields that might be realized from waters currently subject to harvest restrictions or prohibitions, the analysis may either over- or understate the impact of pollution on annual shellfish landings.

- The actual contribution of AFOs to the impairment of shellfish growing waters is unclear. In light of ambiguities in the data and uncertainties associated with the impact of pollution from other sources, the analysis considers two cases to characterize the impact of pollution from AFOs on shellfish harvests. The broad range of results across the cases analyzed suggests considerable uncertainty concerning the impact of pollution from AFOs.

- Similarly, in characterizing the impact of the revised regulations, the analysis assumes that the adverse impact of pollution from AFOs (i.e., the foregone harvest) will be reduced in proportion to modeled reductions in fecal coliform loadings from rivers and streams that flow into shellfish-growing areas. While this approach may provide a reasonable approximation of the impacts of the new CAFO standards, it is less reliable than detailed modeling of pathogen concentrations in waters that support commercial shellfish beds. The direction and magnitude of any bias introduced by reliance on this approach is unclear.

- The analysis relies on estimates of the price elasticity of demand for shellfish that are not necessarily representative of current conditions or of conditions nationwide. The direction and magnitude of any bias introduced by reliance on these estimates, however, is unclear.

Finally, the analysis is limited to the impact of the revised CAFO standards on pollutant loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis is a source of downward (negative) bias in the estimated economic benefits of the final rule.

6.5 REFERENCES

Capps, Oral Jr. and Johannes Adrianus Lambregts. 1991. "Assessing Effects of Prices and Advertising on Purchases of Finfish and Shellfish in a Local Market in Texas," *Southern Journal of Agricultural Economics*, Vol. 23, July, pp. 181-194.

Cheng, Hsiang-tai and Oral Capps, Jr. 1998. "Demand Analysis of Fresh and Frozen Finfish and Shellfish in the United States," *American Journal of Agricultural Economics*, Vol. 70, August, pp. 533-542.

Griffiths, Charles and Sabrina Lovell. 2002. "Benefits of CAFO Regulations to Shellfish Beds," Office of Economy and Environment, U.S. Environmental Protection Agency, December 12.

Lipton, D.W. and I. Strand. 1992. "Effect of Stock Size and Regulations on Fishing Industry Cost and Structure: The Surf Clam Industry," *American Journal of Agricultural Economics*, Vol. 64, February, pp. 197-208.

U.S. National Oceanic and Atmospheric Administration. 1997. *The 1995 National Shellfish Register of Classified Growing Waters*, Office of Ocean Resources Conservation and Assessment, Silver Spring, MD. Available from: http://seaserver.nos.noaa.gov/projects/95register/.

U.S. National Oceanic and Atmospheric Administration, Fisheries Statistics and Economics Division, "Commercial Fisheries," U.S. Department of Commerce, obtained from http://www.st.nmfs.gov/st1/commercial/index.html.

Wessells, Cathy R., Christopher J. Miller and Priscilla M. Brooks. 1995. "Toxic Algae Contamination and Demand for Shellfish: A Case Study of Demand for Mussels in Montreal," *Marine Resource Economics*, Vol. 10, pp. 143-159.

7.1 INTRODUCTION

CAFOs can contaminate aquifers and thus impose health risks and welfare losses on those who rely on groundwater for drinking water or other uses. Of particular concern are nitrogen and other animal waste-related contaminants (which come from manure and liquid wastes) that leach through soils and ultimately reach groundwater. Nitrogen loadings convert to elevated nitrate concentrations at household and community system wells, and elevated nitrate levels in turn pose a risk to human health.

The federal health-based National Primary Drinking Water Standard for nitrate is 10 mg/L. This Maximum Contaminant Level (MCL) applies to all Community Water Supply systems, but not to households that rely on private wells. As a result, households served by private wells are at risk of exposure to nitrate concentrations above 10 mg/L, which EPA considers unsafe for sensitive subpopulations (e.g., infants). Nitrate above concentrations of 10 mg/L can cause methemoglobinemia ("blue baby syndrome") in bottle-fed infants (National Research Council, 1997), which causes a blue-gray skin color, irritability or lethargy, and potentially long-term developmental or neurological effects. Generally, once nitrate intake levels are reduced, symptoms abate. If the condition is untreated, however, methemoglobinemia can be fatal.[1]

U.S. Census data for 1990, the most recent available for this analysis, show that approximately 13.9 million households located in counties with AFOs are served by domestic wells. A number of sources provide information on the percentage of such wells with nitrate concentrations in excess of 10 mg/L. As indicated in Exhibit 7-1, the values reported vary widely, depending on the location studied, local hydrology, and other factors. According to the nationwide USGS (1996) Retrospective Database, however, the concentration of nitrate exceeds the 10 mg/L threshold in 9.45

[1] No other health impacts are consistently attributed to elevated nitrate concentrations in drinking water. As discussed in Chapter 2, however, other health effects are suspected.

percent of domestic wells in the United States. Thus, EPA estimates that approximately 1.3 million households in counties with AFOs are served by domestic wells with nitrate concentrations above 10 mg/L.[2]

Exhibit 7-1

PERCENTAGE OF DOMESTIC WELLS EXCEEDING THE MCL FOR NITRATE

Study	Location	Type of Well	Percent Exceeding 10 mg/L
CDC, 1998	Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Wisconsin	Domestic	13.4%
Agriculture Canada, 1991 (as cited by Giraldez and Fox, 1995)	Ontario	Domestic farm	13%
Kross et al., 1993	Iowa	Rural	18%
Retrospective Database; USGS, 1996	National	Domestic	9.5%
Richards et al., 1996	Indiana, Kentucky, Ohio, West Virginia	Rural	3.4%
Spalding and Exner, 1993	Iowa, Kansas, Nebraska, North Carolina, Ohio, Texas	Rural	20%, 20%, 20%, 3.2%, 2.7%, 8.2%, respectively
Swistock et al., 1993	Pennsylvania	Private	9%
U.S. EPA, 1990	National	Rural domestic	2.4%
USGS, 1985	Upper Conestoga River Basin	Rural	40+%
USGS, 1998	Nemaha Natural Resources District, Nebraska	Rural	10%
Vitosh, 1985 (cited in Walker and Hoehn, 1990)	Southern Michigan	Rural	34%

[2] Based on analysis of the 1990 Census data, 13,871,413 households served by private wells are located in counties with AFOs. The USGS database indicates that nitrate concentrations exceed 10 mg/L in 9.45 percent of domestic wells nationwide. Applying this percentage to the figure above (13,871,413 x .0945) yields an estimate of 1,310,849 domestic wells that (1) are located in counties with AFOs and (2) exceed the MCL for nitrate.

EPA's revisions to the NPDES regulation and effluent guidelines affect the number and type of facilities subject to regulation as CAFOs, and also introduce new requirements governing the land application of manure. As a result, EPA anticipates that the revised regulations will reduce nitrate levels in household wells. In light of clear empirical evidence from the economics literature that households are willing to pay to reduce nitrate concentrations in their water supplies — especially to reduce concentrations below the MCL — the anticipated improvement in the quality of water drawn from private domestic wells represents a clear economic benefit. This chapter estimates these benefits for the final effluent guideline and final NPDES regulation.

7.2 ANALYTIC APPROACH

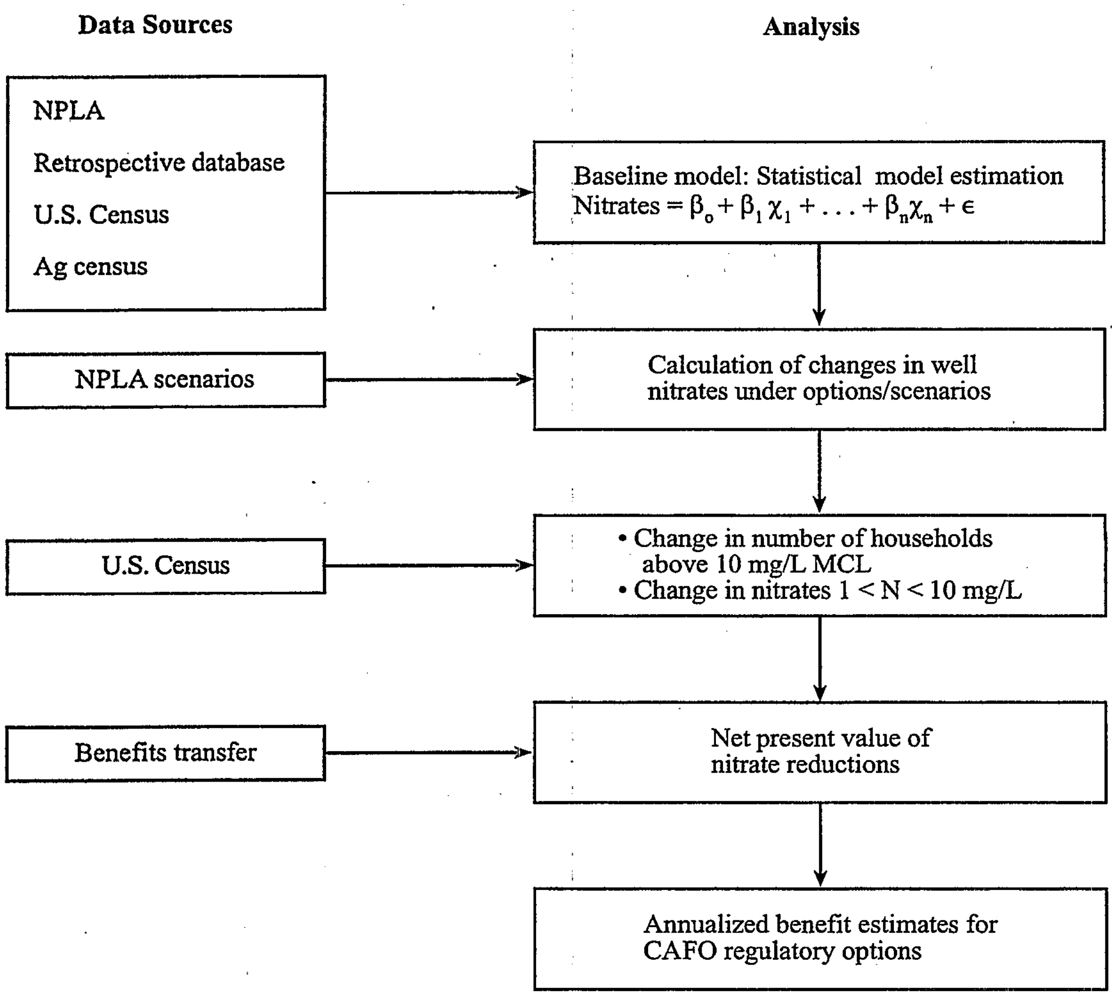
Exhibit 7-2 provides an overview of EPA's approach to estimating the benefits of well nitrate reductions. As the exhibit indicates, the analysis begins by developing a statistical model of the relationship between nitrate concentrations in private domestic wells and a number of variables found to affect nitrate levels, including nitrogen loadings from AFOs. It then applies this model, in combination with the projected change in nitrogen loadings from CAFOs, to characterize the distribution of expected changes in well nitrate concentrations. Next, the analysis applies this distribution to the number of households served by private domestic wells to calculate (1) the increase in the number of households served by wells with nitrate concentrations that are below the MCL and (2) the marginal change in nitrate concentrations for households currently served by wells with nitrate concentrations below the MCL. Finally, the analysis employs estimates of households' values for reducing well nitrate concentrations to develop a profile of the economic benefits of anticipated improvements in well water quality. Additional detail on EPA's analytic approach is provided below.

7.2.1 Relationship Between Well Nitrate Concentrations and Nitrogen Loadings

EPA's approach begins with the use of regression analysis to develop a model characterizing the empirical relationship between well nitrate concentrations and a number of variables that may affect nitrate levels, including nitrogen loadings from AFOs. The variables included in the model are based on a review of hydrogeological studies that have observed statistical relationships between groundwater nitrate concentrations and various other hydrogeological and land use factors. The following discussion describes the variables included in EPA's model and the sources of data for each variable. It also notes potentially significant variables that the model does not include. Appendix 7-A and Appendix 7-B provide additional detail on the model's development.

Exhibit 7-2

OVERVIEW OF ANALYTIC APPROACH



7.2.1.1 Included Variables and Data Sources

Although the groundwater monitoring and modeling studies that EPA reviewed covered different geographic areas and focused on varying nitrate sources (e.g., septic systems, agricultural fertilizers, animal feedlots), they often found similar significant variables. In particular, nitrogen application or loadings rates, whether from animal wastes, private septic systems, or agricultural fertilizers, were the most consistent and significant factor affecting well nitrate levels (e.g., Burrow, 1998; CDC, 1998). EPA's model includes variables characterizing nitrogen loadings from each of these sources:

- *AFOs* — Studies that addressed the effect of animal manure production on groundwater nitrate concentrations found a positive correlation between these variables (e.g., Ritter and Chirnside, 1990; Division of Water Quality, Groundwater Section, 1998). EPA's model therefore includes a variable that characterizes nitrogen loadings from AFOs. EPA obtained data on these loadings, aggregated at the county level, from the National Pollutants Loadings Analysis (NPLA; TetraTech, 2002).

- *Septic Systems* — Several studies found that the proximity of septic systems to wells is a small, but significant, contributing factor to elevated nitrate concentrations (e.g., Carleton, 1996; Richards et al., 1996). As a proxy measure for loadings from septic systems, EPA's model includes a variable characterizing the use of private septic systems in each county. Information on septic system use was drawn from the 1990 U.S. Census.

- *Other Sources* — Several studies found that the type of crop cultivated in the vicinity of wells significantly influences well nitrate levels, reflecting variation in the crops' nutrient and water needs and suggesting that agricultural fertilizers are a significant source of nitrogen to groundwater (e.g., Swistock et al., 1993; Lichtenberg and Shapiro, 1997). EPA obtained data on nitrogen loadings associated with agricultural fertilizers from the NPLA. EPA obtained data on atmospheric deposition of nitrogen from the USGS Retrospective Database (1996).

In addition to variables characterizing nitrogen loadings, EPA's model includes the following variables describing well, soil, and land use characteristics found to significantly influence well nitrate concentrations:

- *Well Depth:* Several studies found well depth to be a significant variable, inversely correlated with well nitrate concentrations, regardless of nitrate source (e.g., Detroy, 1988; Ham et al., 1998).

- *Soil Group:* A number of studies identified at least one hydrogeological characteristic, such as aquifer composition and soil type, as a significant factor affecting well nitrate concentrations (e.g., Lichtenberg and Shapiro, 1997; Lindsey, 1997).

- *Land Use:* Agricultural land use in the vicinity of wells was found to be associated with higher groundwater nitrate in several studies (e.g., Mueller et al., 1995; Carleton, 1996).

For purposes of model development, EPA obtained data on these variables from the USGS Retrospective Database (1996).

EPA's model also includes variables that describe each well's location with respect to the five regions identified in the NPLA: Central, Mid-Atlantic, Midwest, Pacific, or South. The use of these variables helps to account for potential regional differences (e.g., differences in climate) that may affect the transfer of leached nitrogen into nitrates in groundwater, as well as geological differences that may relate to background (natural) levels of nitrate in groundwater. The states that each region encompasses are as follows:

- *Central* — AZ, CO, ID, MT, NV, NM, OK, TX, UT, WY;
- *Mid-Atlantic* — CT, DE, KY, ME, MD, MA, NH, NJ, NY, NC, OH, PA, RI, TN, VT, VA, WV;
- *Midwest* — IA, IL, IN, KS, MI, MN, MO, NE, ND, SD, WI;
- *Pacific* — AK, CA, HI, OR, WA;
- *South* — AL, AR, FL, GA, LA, MS, SC.

7.2.1.2 Omitted Variables

Because of incomplete or unreliable national data, EPA's model does not include all of the potentially significant variables identified in the literature. For example, several studies cite well construction and age as significant variables with respect to well nitrate concentrations (e.g., Spalding and Exner, 1993; Swistock et al., 1993). In general, older wells are more vulnerable to nitrate contamination because their casings are more likely to be cracked, allowing surface contaminants to enter the well. Different construction materials and methods also affect how easily nitrate or other pollutants can reach groundwater via direct contamination at the wellhead. Data on this variable, however, are often unreliable because they are generally obtained by surveying well owners and relying on their subjective assessment of when and how a well was constructed; no reliable, nationally comprehensive data on well construction are available.

Several studies also found the distance from a pollutant source to the well to be significantly correlated with well nitrate concentrations (e.g., Swistock et al., 1993; Division of Water Quality, Groundwater Section, 1998). Although spatial data for well locations are available, data on the location of animal feedlots, cropland, and septic systems are not; therefore, the model excludes this variable.

7.2.2 Modeling of Well Nitrate Concentrations

To estimate the impact of selected variables on well nitrate concentrations, EPA compiled a database of 2,985 records. Each record provides information characterizing a different well, including the observed well nitrate concentration; well location, depth, soil, and land use information; data on baseline nitrogen loadings from AFOs; and data characterizing nitrogen loadings from septic systems, agricultural fertilizer, and atmospheric deposition. EPA developed its regression model on the basis of this database.

After estimating the regression model using baseline loading information, EPA estimated expected values for well nitrate concentrations under baseline conditions and following implementation of the new CAFO regulations. Two regulatory options were analyzed: the phosphorus-based land application standard incorporated into the final rule, and a nitrogen-based application standard, which EPA considered but did not select. In each case, the calculation of expected values employed data on AFO nitrogen loadings obtained from the NPLA (Tetra Tech, 2002).[3] Exhibit 7-3 summarizes the expected percentage changes in well nitrate concentrations under each regulatory standard.[4]

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[3] Chapter 4 provides additional information on the development of pollutant loadings estimates for both the baseline and post-regulatory scenarios. For purposes of this analysis, the characterization of post-regulatory conditions is limited to the impact of the revised standards on Large CAFOs. The impact of the revised standards on Medium CAFOs is not addressed.

[4] Testing of EPA's model indicates that it underestimates well nitrate concentrations. As a result, comparing predicted values to observed baseline values would bias the analysis. To avoid this bias, EPA compares the well nitrate concentrations the model predicts to the values it predicts under baseline conditions. The benefits assessment is based on the resulting projected percentage changes in expected well nitrate concentrations.

Exhibit 7-3 PERCENT REDUCTION IN PROJECTED NITRATE CONCENTRATIONS[1]		
	Projected Nitrate Concentration (mg/L)	
Regulatory Standard	Mean Percent Reduction	Median Percent Reduction
Nitrogen-based	1.8%	0.2%
Phosphorus-based	2.0%	0.2%
[1] The results reported reflect the impact of the revised standards on Large CAFOs. Impacts on Medium CAFOs are not addressed.		

7.2.3 Discrete Changes from above the MCL to below the MCL

As noted above, the most recent U.S. Census data show that approximately 13.5 million households located in counties with AFOs are served by domestic wells. The USGS Retrospective Database indicates that the concentration of nitrate in 9.45 percent of U.S. domestic wells exceeds 10 mg/L. Thus, under the baseline, EPA estimates that approximately 1.3 million households in counties with AFOs are served by domestic wells with nitrate concentrations above 10 mg/L.

To estimate the impact of the new CAFO regulations on the number of wells that would exceed the nitrate MCL, EPA applied the mean percentage reduction in nitrate concentrations predicted above to the nitrate concentration values that the USGS Retrospective Database reports. Based on the resulting values, EPA calculated the percentage reduction in the number of wells with nitrate concentrations exceeding 10 mg/L. As shown in Exhibit 7-4, it then applied these values to EPA's baseline estimate of the number of households in counties with AFOs that are served by domestic wells with nitrate concentrations above 10 mg/L. Based on this analysis, EPA estimates that the phosphorus-based regulatory standard would bring approximately 111 thousand households under the 10 mg/L nitrate threshold, while the nitrogen-based standard would have a similar effect on approximately 121 thousand households.

Exhibit 7-4 EXPECTED REDUCTIONS IN NUMBER OF HOUSEHOLDS WITH WELL NITRATE CONCENTRATIONS ABOVE 10 mg/L[1]		
Regulatory Standard	Percentage of Wells above MCL at Baseline Expected to Achieve MCL	Reduction in Number of Households above the MCL
Nitrogen-based	9.2%	120,823
Phosphorus-based	8.5%	111,529
[1] The results reported reflect the impact of the revised standards on Large CAFOs. Impacts on Medium CAFOs are not addressed.		

7.2.4 Incremental Changes below the MCL

Households currently served by wells with nitrate concentrations below the 10 mg/L level may also benefit from marginal reductions in nitrate concentrations. For purposes of this analysis, EPA assumes that such incremental benefits would be realized only for wells with baseline nitrate concentrations between 1 and 10 mg/L; presumably, an individual would not benefit if nitrate concentrations were reduced to below background levels, which for purposes of this analysis are assumed to be 1 mg/L.[5] Exhibit 7-5 shows EPA's estimate of the new CAFO regulations' impact on mean and median nitrate concentrations in wells with baseline values between 1 and 10 mg/L. The exhibit also indicates in each case the total expected reduction in nitrate levels, expressed in mg/L.[6] EPA estimates that approximately 5.6. million households would benefit from these marginal reductions.

Exhibit 7-5

MEAN AND MEDIAN REDUCTIONS IN NITRATE CONCENTRATIONS FOR WELLS WITH CONCENTRATIONS BETWEEN 1 AND 10 mg/L AT BASELINE[1]

Regulatory Standard	Mean Nitrate Reduction (mg/L)	Median Nitrate Reduction (mg/L)	Total Expected National Nitrate Reduction (mg/L)
Nitrogen-based	0.114	0.015	695,662
Phosphorus-based	0.126	0.016	768,221

[1] The results reported reflect the impact of the revised standards on Large CAFOs. Impacts on Medium CAFOs are not addressed.

7.2.5 Valuation of Predicted Reductions in Well Nitrate Concentrations

EPA's analysis relies on a benefits transfer approach to value predicted reductions in well nitrate concentrations. EPA used three general steps to identify and apply values for benefits transfer:

[5] EPA's analysis also ignores marginal reductions in nitrate concentrations for wells that would remain above the MCL. The Agency's review of the economics literature failed to identify studies that would provide an adequate basis for valuing such changes.

[6] The information reported in Exhibit 7-5 pertains only to wells with baseline nitrate concentrations below the MCL. Information for wells with baseline nitrate concentrations above the MCL is not included, since the benefits associated with reducing nitrate concentrations in these wells to below the MCL are potentially captured in valuing the achievement of safe nitrate concentrations.

(1) A literature search to identify potentially applicable primary studies.

(2) Evaluation of the validity and reliability of the studies identified. Primary evaluation criteria included:

- the relevance (applicability) of the commodity being valued in the original studies to the policy options being considered for CAFOs; and

- the robustness (quality) of the original study, evaluated on multiple criteria such as sample size, response rates, significance of findings in statistical analysis, etc.

(3) Selection and adjustment of values for application to CAFO impacts.

Appendix 7-C provides detailed information on EPA's literature search and the criteria applied to evaluate and select the studies employed in the benefits assessment.

Through its review and evaluation of the relevant literature, EPA selected three studies to provide the primary values used for the benefit transfer:

- A study by Poe and Bishop (1992), which EPA employs to value changes in well nitrate concentrations from above the MCL to below the MCL.

- A study by Crutchfield et al. (1997), which EPA employs to value marginal changes in nitrate concentrations below the MCL.

- A study by De Zoysa (1995), which EPA employs to value marginal changes in nitrate concentrations below the MCL.

The Crutchfield et al. and De Zoysa studies were rated as having similar overall quality. From each of these studies EPA identified a per milligram value for marginal changes in well nitrate concentrations; the analysis employs the average of these two values for the benefits transfer.

The discussion below briefly summarizes these studies. Additional information is provided in Exhibit 7-6.

7.2.5.1 Poe and Bishop (1992)

Poe and Bishop (1992, 1999) and Poe (1993) report on the results of a contingent valuation study conducted in rural Portage County, Wisconsin, to estimate the conditional incremental benefits of reducing nitrate levels in household wells. The area had experienced extensive nitrate problems, and previous research suggested that 18 percent of private wells in the area exceeded the MCL. The survey comprised two stages. In the first stage, individuals were asked to submit water samples from their tap and to complete an initial questionnaire. In the second stage, individuals were provided with their nitrate test results, general information about nitrates, and a graphical depiction of their exposure levels relative to both natural levels and the MCL; they then were asked to respond to contingent valuation questions (*ex post*).

Exhibit 7-6

SUMMARY INFORMATION ON STUDIES USED FOR BENEFITS TRANSFER

Study Reference	Poe and Bishop	Crutchfield et al.	De Zoysa
Year of Analysis	1991	1994	1994
Place	Portage County, WI	IN, Central NE, PA, WA	Maumee River Basin, northwest Ohio
Household Water Supply/ Groundwater Use	100% on private wells	IN 73%; NE 31%; PA 47%; WA 26% nonmunicipal	Not specified
Groundwater Baseline Scenarios	An increase in the number of wells in Portage County with nitrate contamination	None given	Typical N concentrations range from 0.5 to 3 mg/L, although some are much higher
Change in Groundwater Scenario	Groundwater protection program to keep nitrate levels below EPA standards	If tap water has 50% greater N levels than EPA's MCL, how much to reduce to min. safety standards; how much to eliminate	Reduce levels to 0.5-1 mg/L
Source of Contaminants	Agricultural activities	Not specified	Agricultural fertilizer
Types of Values Estimated	Option price (use value)	Total value	Total value
Duration of Payment Vehicle	Annually, for as long as respondent lives in the county	Monthly, in perpetuity	One time
Mean Annual HH WTP in 2001 Dollars	$536 (25% reduction in nitrates to safe level) $629 (households with 100% probability of future contamination) — Average $583	$2.29 per mg/L	$1.89 per mg/L (using 3% discount rate)

The respondents' willingness-to-pay values varied, as expected, in accordance with the results of their wells' nitrate tests and other information provided to them. Poe (1993) reports that households whose wells were considered certain at some point in the future to exceed the nitrate

MCL would be willing to pay, on average, $629 (2001 dollars) per year for a program to keep all wells in Portage County at or below the MCL. Poe and Bishop (1999) expand on the results of the survey by developing a nonlinear valuation function that characterizes how household willingness to pay for a 25 percent reduction in well nitrate concentrations varies with the initial extent of nitrate contamination. Their analysis shows that household willingness to pay for such a program increases as baseline well nitrate concentrations increase from 2 mg/L to 14.5 mg/L, then declines to zero at a baseline concentration of approximately 22.5 mg/L. Based on their valuation function, Poe and Bishop estimate that households would be willing to pay an average of $536 (2001 dollars) per year for a 25 percent reduction from a baseline nitrate contamination level of 14.5 mg/L. Since such a change would reduce nitrate concentrations to very near the MCL, EPA considers it representative of household willingness to pay to reduce such concentrations to safe levels. Taking the midpoint of the $629 and $536 values reported by Poe (1993) and Poe and Bishop (1999), respectively, EPA estimates that households whose wells exceed the nitrate MCL would be willing to pay $583 (2001 dollars) per year to reduce nitrate concentrations to safe levels.

The reliability of these results appears to be reasonably high because the contingent valuation (CV) instrument was developed and implemented with careful attention to detail and established CV research protocol. A potential limitation is that the study is based on a relatively small sample size (480 households); however, good response rates were obtained from this sample (approximately 80 percent for the first stage and 64 percent for the *ex post* stage). The Poe and Bishop study is the only study EPA reviewed that elicited such informed *ex post* values. These value statements may be considered more reliable than others because respondents knew more about the condition of their own water supply and thus were able to make better informed decisions. Moreover, in comparison to the other studies evaluated, the value estimates from this study seemed to represent a conservative lower bound on households' values for reducing nitrates to the MCL.

7.2.5.2 Crutchfield et al. (1997)

Crutchfield et al. (1997) evaluated the potential benefits of reducing or eliminating nitrates in drinking water by estimating average willingness to pay for safer drinking water. They surveyed 800 people in rural and nonrural areas in four regions of the United States (Indiana, Nebraska, Pennsylvania, Washington) using the contingent valuation method (CVM) and posing questions in a dichotomous choice format. Respondents were specifically asked what they would be willing to pay to have the nitrate levels in their drinking water (a) reduced to "safe levels" and (b) completely eliminated. Respondents were told that this would be accomplished using a filter installed at their tap, and the cost would be included in their monthly water bill. Respondents were also asked questions regarding sociodemographic characteristics such as income, age, education, and whether they currently use treated or bottled water. Across all regions, the resulting household willingness to pay to reduce nitrates to safe levels ranged from $45.42 per month to $60.76 per month, with a mean of $52.89 (1994 dollars). The willingness to pay to completely remove nitrates from drinking water ranged from $48.26 per month to $65.11 per month, with a mean of $54.50 (1994 dollars). The study found two variables to be significantly related to a respondent's willingness to pay: "years lived in ZIP code," which was positively correlated with willingness to pay, and "age of respondent," which was negatively correlated.

7.2.5.3 De Zoysa (1995)

De Zoysa (1995) applied the contingent valuation method to evaluate the benefits of a number of programs to enhance environmental quality in Ohio's Maumee River basin, including a program to stabilize and reduce groundwater nitrate levels. The study solicited willingness-to-pay values from residents of both rural and urban areas in the river basin, as well as residents of one out-of-basin urban area. A portion of respondents were asked whether they would pay different amounts, via a one-time special tax, to reduce nitrate contamination from fertilizer applied to fields. Under the hypothetical scenarios, nitrate concentrations would be reduced from the current range of 0.5-3.0 mg/L to a range of 0.5-1.0 mg/L. Individuals were also asked questions regarding sociodemographic characteristics, preferences for priorities for public spending, and how they used the resource in question. Based on the lower bound of the mean values reported, the study found an average one-time household willingness to pay of $52.78 (1994 dollars) for a 1 mg/L reduction in groundwater nitrate concentrations. The study also found that income, the level of priority placed on groundwater protection, and interest in increasing government spending on education, healthcare, and vocational training all were positively and significantly correlated with willingness to pay to improve groundwater quality.

7.2.5.4 Adjustments to the Values

EPA employs the results of the Crutchfield et al. and De Zoysa reports to estimate annual household willingness to pay to reduce well nitrate concentrations when those concentrations are already below the nitrate MCL. EPA derives the appropriate value from Crutchfield by comparing the reported monthly willingness-to-pay values for reducing nitrate concentrations from above the MCL to the MCL and from above the MCL to zero. The difference between these values is $1.61 per month. For a change between the MCL of 10 mg/L and 0 mg/L, this represents a per mg/L monthly willingness to pay of $0.16, or $1.92 annually (1994 dollars). To derive a comparable annual value from De Zoysa, EPA annualizes the willingness to pay value obtained from that study – an average one-time household willingness to pay of $52.78 (1994 dollars) for a 1 mg/L reduction in groundwater nitrate concentrations – using an annual discount rate of 3 percent. This calculation yields an estimated annual household willingness to pay for a 1 mg/L reduction in nitrate concentrations of $1.58 (1994 dollars). EPA applied the Consumer Price Index (CPI) to convert these values to 2001 dollars.[7] The Agency then applied the midpoint of the two values, $2.09 per mg/L per household per year, to value changes in well nitrate concentrations between 10 mg/L and 1 mg/L. Reductions in well nitrate concentrations below 1 mg/L are not valued, since EPA assumes a natural nitrate background level of 1 mg/L.

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[7] CPI-U Series ID CUUR0000SA0, not seasonally adjusted, U.S. city average, all items.

As noted above, EPA relies on the findings of Poe and Bishop to estimate that households whose wells exceed the nitrate MCL would be willing to pay $583 (2001 dollars) per year to reduce nitrate concentrations to safe levels. These values are expressed as willingness to pay per year as long as the individual lives in the county, and thus can be directly translated to value the benefits of the new regulations.

Exhibit 7-7 summarizes the point value estimates used for benefits transfer.

Exhibit 7-7

WILLINGNESS-TO-PAY VALUES APPLIED TO BENEFITS TRANSFER

Study	Value	2001$
Poe and Bishop	Annual WTP to reduce nitrate to below 10 mg/L	$583.00
Average of Crutchfield et al. and De Zoysa	Annual WTP per mg/L between 10 mg/L and 1 mg/L	$2.09

7.2.5.5 Timing of Benefits

It is unlikely that changes in CAFO regulations would immediately result in the changes in well nitrate concentrations that EPA's statistical model predicts. While hydrogeological conditions and other factors may vary significantly from case to case, considerable time may pass before most wells reach the steady state nitrate concentrations the model forecasts. Therefore, it is necessary to develop a time profile of the anticipated benefits of revised CAFO standards.

EPA estimates that approximately 75 percent of affected wells would realize the full benefits of reduced nitrogen loadings within 20 years (Hall, 1996). Assuming that the number of wells achieving new steady state conditions increases linearly over time, this translates to approximately 3.7 percent of wells achieving new steady state conditions each year. At this rate, all affected wells would achieve new steady state conditions in approximately 27 years. For purposes of characterizing the benefits of reduced contamination of private wells, EPA's analysis adopts these assumptions.

7.3 RESULTS

7.3.1 Annual Benefits over Time

Exhibit 7-8 illustrates the time profile of benefits for EPA's revisions to the CAFO rule. For the phosphorus-based application standard that EPA selected, the annual benefits attributable to the new regulations on Large CAFOs increase from approximately $2.3 million in the first year following implementation to $66.6 million in the twenty-seventh and subsequent years. For the nitrogen-based application standard, which EPA considered but did not select, the annual benefits attributable to the new regulations on Large CAFOs increase from approximately $2.5 million in the first year following implementation to $71.9 million in the twenty-seventh and subsequent years. Exhibit 7-9 summarizes the estimated annual benefits once steady state conditions are achieved under both regulatory standards. As the exhibit indicates, these benefits are estimated to be $72 million under the nitrogen-based standard and $67 million under the phosphorus-based standard.

Exhibit 7-8

ANNUAL BENEFITS OF REDUCING PRIVATE WELL CONTAMINATION

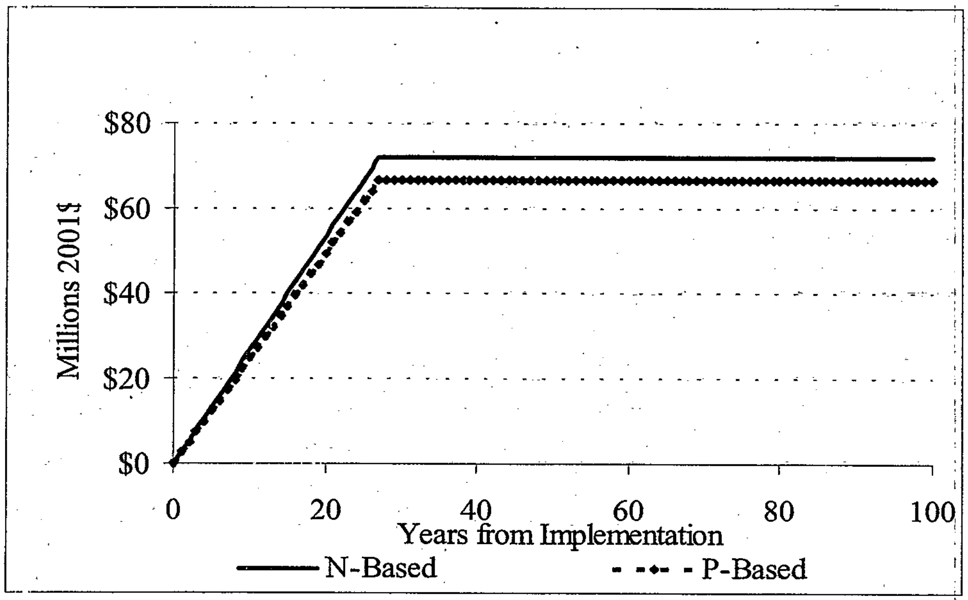

Exhibit 7-9 ESTIMATED ANNUAL BENEFITS OF REDUCED CONTAMINATION OF PRIVATE WELLS UNDER STEADY STATE CONDITIONS[1] (2001 $, millions)	
Regulatory Standard	**Annual Benefits**
Nitrogen-based	$71.89
Phosphorus-based	$66.63

[1] The results reported reflect the impact of the revised standards on Large CAFOs. Impacts on Medium CAFOs are not addressed.

7.3.2 Annualized Benefits

As discussed above, the benefits associated with reduced contamination of private wells are likely to increase for a number of years, until steady state conditions are reached. This is in contrast to the estimates of benefits developed in previous chapters, which EPA assumes will be constant over time. To report all benefits on a comparable basis, it is necessary to calculate the constant stream of benefits — the "annualized" benefits — that would yield the same present value as the uneven stream of benefits described above.

Exhibit 7-10 presents EPA's estimate of the annualized benefits associated with the reduction of nitrate concentrations in private wells under both the proposed phosphorus-based standard and the alternate nitrogen-based standard. As the exhibit indicates, the calculation of annualized benefits depends on the discount rate employed — 3, 5, or 7 percent — with lower rates yielding higher benefits.[8] Under the phosphorus-based standard, the annualized benefits attributable to the new regulations for Large CAFOs range from approximately $30.9 million to $45.7 million per year. The benefits under the nitrogen-based standard range from $33.3 million to $49.3 million per year.

Exhibit 7-10

ESTIMATED ANNUALIZED BENEFITS OF REDUCED PRIVATE WELL CONTAMINATION (2001 $, millions)

	Nitrogen-Based Standard			Phosphorus-Based Standard		
	Discount Rate			Discount Rate		
Regulated Entities	3 Percent	5 Percent	7 Percent	3 Percent	5 Percent	7 Percent
Large CAFOs	$49.29	$39.98	$33.34	$45.68	$37.05	$30.90

Under both regulatory standards, the benefits are achieved largely as a result of reducing the concentration of nitrate in private wells from above to below the 10 mg/L MCL. As discussed above, EPA estimates the value of these reductions, based on willingness-to-pay studies, to be $583 annually (2001$) per household. Under the nitrogen-based standard, for Large CAFOs, the total annualized value of these reductions is estimated to be $32.7 million to $48.3 million. Under EPA's chosen phosphorous-based standard, for Large CAFOs, the total annualized value of these reductions is estimated to be $30.2 million to $44.6 million. Another 5.6 million households that currently have nitrate levels in their private wells below the MCL are predicted to experience further reductions in nitrate levels because of this rule. EPA estimates a willingness-to-pay value of $2.09 per mg/L for such reductions. For Large CAFOs, these additional reductions provide estimated annualized

[8] Chapter 8 provides additional information on the selection of discount rates, the calculation of present values, and the calculation of annualized benefits.

benefits of $0.7 million to $1.0 million under the nitrogen-based standard and $0.7 million to $1.1 million under EPA's chosen phosphorous-based rule.

7.4 LIMITATIONS AND CAVEATS

Omissions, biases, and uncertainties are inherent in any analysis relying on several different data sources, particularly those that were not developed specifically for that analysis. Exhibit 7-11 summarizes key omissions, uncertainties, and potential biases for this analysis.

Exhibit 7-11

OMISSIONS, BIASES, AND UNCERTAINTIES IN THE NITRATE LOADINGS ANALYSIS

Variable	Likely Impact on Net Benefit	Comment
Well, Land, and Nitrate Data		
Geographic coverage	Unknown	Data availability limited the well samples used in the statistical modeling to those from 374 counties nationwide.
Well location selection	Unknown	Wells sampled in the USGS Retrospective database may not be random. Samples appear to be focused on areas with problems with high levels of agricultural activities and possibly higher nitrate levels.
Year of sample	Unknown	Samples taken over 23 years. Land use and other factors influencing nitrate concentrations in the vicinity of the well may have changed over time.
Nitrate loadings from AFOs with 0-300 AU	Positive	Data for the smallest AFOs were not included in this analysis because they will not be affected by the revised regulations. This may subsequently underestimate total loadings, resulting in an overestimate of the impact of nitrogen loadings on well nitrate concentrations.
Percent of wells above 10 mg/L	Unknown	Based on the USGS Retrospective Database, EPA assumes that 9.45 percent of wells currently exceed the MCL. If the true national percent is lower (higher), EPA's analysis overstates (understates) benefits.
Sampling methods	Unknown	Data set compiled from data collected by independent state programs, whose individual methods for measuring nitrate may differ.
Model Variables		
Well construction and age	Unknown	No reliable data available nationally.
Spatial data	Unknown	No national data available on the distance from well to pollutant source.
Benefit Calculations		
Per household value for reducing well nitrates to the MCL	Negative	The Poe and Bishop values generally appear to be a lower bound estimate of households' WTP for reducing nitrates to the MCL.
Years until wells achieve steady state.	Negative	The analysis assumes a linear path over 27 years until reduced nitrogen loadings would result in most wells achieving reduced nitrate concentrations. A large portion of wells (especially shallower wells) may achieve this much faster.
Values for marginal reductions below the MCL	Positive	If most of the benefits from reductions in nitrate concentrations below the MCL are related to a threshold effect or removing all human induced nitrates, then the assumption that benefits increase linearly with reductions in nitrate concentrations from 10 mg/L to 1 mg/L will overstate the benefits of marginal reductions.

Exhibit 7-11

OMISSIONS, BIASES, AND UNCERTAINTIES IN THE NITRATE LOADINGS ANALYSIS

Variable	Likely Impact on Net Benefit	Comment
Baseline characterization	Negative	Baseline well concentrations are based on observed levels that are in some cases more than 20 years old. These reflect AFO loadings from past decades that most likely understate current loadings and, hence, underestimate anticipated well concentrations absent regulations.
Exclusion of values for reduced nitrate concentrations in wells that would remain above the MCL after the implementation of new regulations	Negative	Reductions in nitrate concentrations in wells that would remain above the MCL after the implementation of new regulations are not valued. The Agency's review of the economics literature failed to identify studies that would provide an adequate basis for valuing such changes.
Exclusion of values for marginal reductions in nitrate concentrations below the MCL, for wells with nitrate concentrations above the MCL at baseline and below the MCL after implementation of new regulations	Negative	The benefits of marginal changes in nitrate concentrations between 10 mg/L to 1 mg/L for wells with nitrate levels above the MCL at baseline and below the MCL after implementation of new regulations are not calculated. These benefits are potentially captured in valuing the achievement of safe nitrate concentrations.
Percent change in well nitrate levels.	Positive	Poe and Bishop values are based on a 25% reduction from current levels. Modeled changes in nitrate levels for wells crossing from above to below the MCL are considerably less than 25% on average. To the extent that the value from moving from above to below the MCL is for the absolute change in nitrate levels rather than from the threshold effect, the WTP estimates used from Poe and Bishop will overstate values.

7.5 REFERENCES

Agriculture Canada. 1991. Ontario Farm Groundwater Quality Survey. Agriculture Canada, Ottawa.

Burrow, K.R. 1998. Occurrence of Nitrate and Pesticides in Groundwater beneath Three Agricultural Land-Use Settings in the Eastern San Joaquin Valley, California. USGS, Denver, CO.

Carleton, G.B. 1996. Nitrate in Groundwater and Surface Water in a Residential Subdivision, West Mercer Township, New Jersey. USGS, Denver, CO.

CDC. 1998. A Survey of the Quality of Water Drawn from Domestic Wells in Nine Midwest States. NCEH 97-0265. Centers for Disease Control and Analysis. National Center for Environmental Health.

Crutchfield, S.R., J.C. Cooper, and D. Hellerstein. 1997. Benefits of Safer Drinking Water: The Value of Nitrate Reduction. Agricultural Economic Report 752. U.S. Department of Agriculture, Economic Research Service, Food and Consumer Economics Division.

De Zoysa, A.D.N. 1995. A Benefit Evaluation of Programs to Enhance Groundwater Quality, Surface Water Quality and Wetland Habitat in Northwest Ohio. Dissertation, The Ohio State University, Columbus.

Desvousges, W.H., M.C. Naughton, and G.P. Parsons. 1992. "Benefit Transfer: Conceptual Problems in Estimating Water Quality Benefits Using Existing Studies." *Water Resources Research* 28(3):675-683.

Detroy, M.G. 1988. Groundwater Quality Monitoring Program in Iowa: Nitrate and Pesticides in Shallow Aquifers. USGS, Denver, CO.

Division of Water Quality, Groundwater Section. 1998. Impact of Animal Waste Lagoons on Ground Water Quality. Draft Report. Department of Environment and Natural Resources, Raleigh, NC.

Giraldez, C. and G. Fox. 1995. "An Economic Analysis of Groundwater Contamination from Agricultural Nitrate Emissions in Southern Ontario." *Canadian Journal of Agricultural Economics* 43:387-402.

Hall, M.D. 1996. Simulation of Nitrates in a Regional Subsurface System: Linking Surface Management with Ground Water Quality. Ph.D. Thesis. Colorado State University, Fort Collins.

Ham, J.M., L.N. Reddi, C.W. Rice and J.P. Murphy. 1998. Evaluation of Lagoons for Containment of Animal Waste. Department of Agronomy, Kansas State University, Manhattan.

Kross, B.C., G.R. Hallberg, and D.R. Bruner. 1993. "The Nitrate Contamination of Private Well Water in Iowa." *American Journal of Public Health* 83:270.

Lichtenberg, E. and L.K. Shapiro. 1997. "Agriculture and Nitrate Concentrations in Maryland Community Water System Wells." *Journal of Environmental Quality* 26:145-153.

Lindsey, B.D. 1997. Nitrate in Groundwater and Streambase Flow in the Lower Susquehanna River Basin, Pennsylvania and Maryland. USGS, Denver, CO.

Mueller, D.K., P.A. Hamilton, D.R. Helsel, K.J. Hitt, and B.C. Ruddy. 1995. Nutrients in Ground Water and Surface Water of the United States — An Analysis of Data through 1992. U.S. Geological Survey Water Resources Investigations Report 95-4031.

National Research Council. 1997. *Valuing Ground Water: Economic Concepts and Approaches*. National Academy Press, Washington, DC.

Poe, G.L. 1993. Information, Risk Perceptions, and Contingent Value: The Case of Nitrates in Groundwater. Ph.D. Dissertation, University of Wisconsin-Madison.

Poe, G.L. and R.C. Bishop. 1992. Measuring the Benefits of Groundwater Protection from Agricultural Contamination: Results from a Two-Stage Contingent Valuation Study. Staff Paper Series, University of Wisconsin-Madison.

Poe, G.L. and R.C. Bishop. 1999. "Valuing the Incremental Benefits of Groundwater Protection When Exposure Levels Are Known." *Environmental and Resource Economics* 13:341-367.

Richards, R.P. et al. 1996. "Well Water Quality, Well Vulnerability, and Agricultural Contamination in the Midwestern United States." *Journal of Environmental Quality* 25:389-402.

Ritter, W.F. and A.E.M. Chirnside. 1990. "Impact of Animal and Waste Lagoons on Groundwater Quality." *Biological Wastes* 34:39-54.

Spalding, R.F. and M.E. Exner. 1993. "Occurrence of Nitrate in Groundwater — A Review." *Journal of Environmental Quality* 22:392-402.

Swistock, B.R., W.E. Sharpe, and P.D. Robillard. 1993. "A Survey of Lead, Nitrate, and Radon Contamination of Individual Water Systems in Pennsylvania." *Journal of Environmental Health* 55:6.

Tetra Tech. 2002. "Development of Pollutant Loading Reductions from Revised Effluent Limitation Guidelines for Concentrated Animal Feeding Operations." Draft report prepared for U.S. Environmental Protection Agency, Office of Science and Technology.

U.S. EPA. 1990. National Survey of Pesticides in Drinking Water Wells. U.S. Environmental Protection Agency, Washington, DC.

USGS. 1985. Occurrence of Nitrate and Herbicides in Groundwater in the Upper Conestoga River Basin, Pennsylvania. Water Resources Investigations Report 85-4202.

USGS. 1996. Retrospective Database for Nutrients in Groundwater and Surface Water. USGS. http://water.usgs.gov/nawqa/nutrients/datasets/retrodata.html. Accessed 6/1/00.

USGS. 1998. Nitrate Concentrations in Ground Water in the Paleovalley Alluvial Aquifiers of the Nemaha Natural Resources District, Nebraska, 1989 and 1994-96. USGS Water Resources Investigations Report 98-4106. USGS, Lincoln, NE.

Vitosh, M.L. 1985. "Nitrogen Management Strategies for Corn Producers." Extension Bulletin WQ06. Cooperative Extension Service, Michigan State University. August.

Walker, D.R. and J.P. Hoehn. 1990. "The Economic Damages of Groundwater Contamination in Small Rural Communities: An Application to Nitrates." *Northcentral Journal of Agricultural Economics* 12:47-56.

Appendix 7-A

MODEL VARIABLES

EPA's statistical analysis of the relationship between nitrogen loadings and well nitrate concentrations is based on the following linear model:

$$\text{Nitrate (mg/L)} = \beta_0 + \beta_1 \text{ Ag Dummy} + \beta_2 \text{ Soil Group} + \beta_3 \text{ Well Depth} + \beta_4 \text{ Septic Ratio} + \beta_5 \text{ Atmospheric Nitrogen} + \beta_6 \text{ Loadings Ratio} + \beta_7 \text{ Regional Dummies} + \varepsilon_i ,$$

where nitrate concentration (mg/L) is the dependent variable.

The variables used to explain nitrate concentrations in well water (i.e., the model's independent variables) can be classified into two groups: well and land characteristics, and nitrogen inputs. Definitions of these variables are provided below. Unless otherwise noted, EPA obtained the data used in developing the model from the USGS Retrospective Database.

Well and Land Characteristics

Ag Dummy: This variable describes the predominant land use at the well's location (1 for agricultural land; 0 otherwise). Other land uses identified in the database include woods, range, urban, and other.

Soil Group: The soil group variable is an index that integrates several factors — including runoff potential, permeability, depth to water table, depth to an impervious layer, water capacity, and shrink-swell potential — to characterize hydrological conditions in the vicinity of the well. Values range from a minimum of 1 to a maximum of 4.

Well Depth: The well depths reported in the USGS database range from 1 foot to 5,310 feet. For observations used in the regression analysis, the maximum well depth is 1,996 feet.

Nitrogen Inputs

Loadings Ratios and Analysis of New Regulations: The loadings ratio is the sum of three variables measuring pounds of leached nitrogen per acre in each county from three different sources: CAFOs, the application of manure from CAFOs, and commercial fertilizers (because of the correlation between these nitrogen input measures, EPA was not able to estimate their parameters separately). The loadings ratio is a unique value for each county. It is calculated by dividing estimated leached nitrate loadings for the county (pounds per year) by the county's total area (acres). The analysis employs baseline loadings data to estimate the coefficients for the independent variables. It applies these coefficients, combined with loadings data representative of post-regulatory conditions, to estimate changes in well nitrate concentrations under the new regulations.

Septic Ratio: The septic ratio is a proxy measure of potential nitrogen loadings from septic systems. The analysis develops a unique value for each county. This value is calculated by dividing the number of housing units in the county that use septic systems by the county's total area (acres). EPA obtained data on septic system use from the 1990 U.S. Census.

Atmospheric Nitrogen: The atmospheric nitrogen variable accounts for nitrogen loadings from atmospheric deposition. Values for this variable are reported in pounds per acre per year.

Regional Dummies: The regional dummy variables describe the well's location with respect to the five regions identified in the NPLA: Central, Mid-Atlantic, Midwest, Pacific, or South. The variable is assigned a value of 1 for the region in which the well is located, and a value of zero for all other regions. The use of these variables helps to account for potential regional differences (e.g., differences in climate) that may affect the transfer of leached nitrogen into nitrates in groundwater, as well as geological differences that may relate to background (natural) levels of nitrate in groundwater.

Summary Statistics

Exhibit 7A-1 reports summary statistics on the variables used in the analysis.

Exhibit 7A-1

SUMMARY STATISTICS

Variable	N	Mean	Standard Deviation	Minimum	Maximum
Nitrate Concentrations	2985	3.569668	6.514109	0.05	84.3
Loadings Ratio	2985	2.023526	4.156983	0.001196	18.950392
Atmospheric Nitrogen	2985	5.071787	1.865252	0.5375	8.921875
Well Depth	2985	170.0693	136.1121	1	1996
Soil Group	2985	2.422781	0.655885	1	4
Septic Ratio	2985	0.028794	0.027698	0.000217	0.151336
Ag Dummy	2985	0.776214	0.41685	0	1
Central Region Dummy	2985	0.064657	0.24596	0	1
Mid-Atlantic Region Dummy	2985	0.3933	0.488564	0	1
Pacific Region Dummy	2985	0.123953	0.329583	0	1
South Region Dummy	2985	0.070687	0.256344	0	1

Appendix 7-B

THE GAMMA MODEL

The analysis uses a gamma model to fit the right skew of observed values for well nitrate concentrations as well as the nonnegative constraint on the dependent variable. Visual inspection of the nitrate concentration distribution suggests a gamma distribution with density function:

$$f(y) = \frac{\theta^{\alpha}}{\Gamma(\alpha)} \exp(-\theta y) y^{\alpha-1}$$

For this distribution, the expected value of y_i is:

$$E(y_i) = \alpha/\theta_i = \alpha \exp(\beta\chi_i)$$

The use of the gamma distribution instead of the more commonly employed exponential distribution is appropriate because α is assumed to equal 1 in the exponential distribution, but was estimated to be significantly different than 1 in EPA's empirical work. The gamma distribution also offers the advantages of making the density function more flexible and giving more curvature to the distribution. The likelihood function is:

$$\log L(y_i|x_i;\alpha,\beta) = \sum_i [\alpha \log \theta_i - \log \Gamma(\alpha) - \theta_i y_i + (\alpha - 1)\log(y_i)]$$

Exhibit 7B-1 provides statistical results from the gamma model. All coefficients are of the expected sign. The coefficient for the loadings ratio variable is significant and positive, indicating that an increase in nitrogen loadings leads to increased well nitrate concentrations.

Exhibit 7B-1

GAMMA REGRESSION RESULTS

Variable	Parameter Estimate	Standard Error	Asymptotic T-Statistic	Significance
Intercept	2.2013	0.1939	11.352	0.000
Loadings Ratio	0.0456	0.0070	6.543	0.000
Atmospheric Nitrogen	0.0315	0.0275	1.144	0.2527
Well Depth*	-0.1705	0.0124	-13.782	0.000
Soil Group	-0.3844	0.0444	-8.660	0.000
Septic Ratio	1.6179	1.7278	0.936	0.3491
Ag Dummy	0.6856	0.0643	10.663	0.000
Central Region Dummy	-0.0757	0.1596	-0.475	0.6350
Mid-Atlantic Region Dummy	-0.1654	0.0978	-1.691	0.0908
Pacific Region Dummy	0.8117	0.1173	6.918	0.000
South Region Dummy	-0.9073	0.1265	-7.170	0.000
Alpha	0.4967	0.0098	50.639	0.000
Mean log-likelihood = -1.85646				
N = 2,985				
*In the model, well depth is scaled to units of hundreds of feet.				

Appendix 7-C

LITERATURE SEARCH AND EVALUATION

Literature Search

The objective of EPA's literature search was to identify prior studies that had developed or elicited values for changes in groundwater quality, focusing in particular on values for reduced nitrates. The search drew in part on two databases: the Colorado Association of Research Libraries (CARL), which includes the holdings of several university libraries in Colorado and the West; and the Environmental Valuation Resource Inventory (EVRI), a database compiled by Environment Canada that includes empirical studies on the economic value of environmental benefits and human health effects. In addition, EPA solicited suggestions for studies pertaining to groundwater valuation and nitrate contamination through the ResEcon listserver, which reaches a network of approximately 700 academics, professionals, and other individuals with interests in natural resource and environmental economics. Through this extensive search and additional review of selected bibliographies, EPA identified 11 potentially relevant studies. Since most households' values for reducing nitrates in private domestic wells are primarily nonmarket values, most of the identified studies involve stated preference value elicitation (e.g., contingent valuation).

Evaluating Studies for Benefits Transfer

The economics literature suggests several criteria in evaluating primary studies for undertaking benefits transfer. Desvousges et al. (1992) develop five criteria to guide the selection of studies for application to a surface water quality issue: that the studies to be transferred (1) be based on adequate data, sound economic method, and correct empirical technique (i.e., "pass scientific muster"); (2) evaluate a change in water quality similar to that expected at the policy site; (3) contain regression results that describe willingness to pay as a function of socioeconomic characteristics; (4) have a study site that is similar to the policy site (in terms of site characteristics and populations); and (5) have a study site with a similar market as the policy site. NOAA condenses the five Desvousges criteria into three considerations: (1) comparability of the users and of the resources and/or services being valued and the changes resulting from the discharge of concern; (2) comparability of the change in quality or quantity of resources and/or services; and (3) the quality of the studies being used for transfer [59 FR 1183]. In a general sense, items (2), (4), and (5) of Desvousges et al. and items (1) and (2) of NOAA are concerned with the *applicability* of an original study to a policy site. Items (1) and (3) of Desvousges et al. and item (3) of NOAA are concerned with the *quality* of the original study.

To assess original studies for use in valuing estimated changes in well nitrate levels under revised CAFO regulations, EPA evaluated the *applicability* and the *quality* of the original studies on several criteria. To the extent feasible, EPA obtained or derived information from each of the reports or papers for 28 categories of information used to characterize the studies. Because applicability to CAFOs and quality of the value estimates are distinct concepts, EPA evaluated these characteristics of the studies separately. Overall, the goal of the rating process was to identify studies that elicited high-quality value estimates (reliable and valid) and which were most applicable to the benefits assessment. There were three steps in the rating process:

(1) identify study characteristics upon which to judge applicability and quality;

(2) assign scores to the studies based on these characteristics;

(3) assign weights to these scores for aggregating scores into unidimensional measures of applicability and quality.

Criteria for Ranking based on Applicability

Applicability refers to the relationship between values elicited in the primary groundwater valuation studies and benefit estimates necessary for application to the analysis of revised CAFO regulations. EPA's criteria for evaluation of applicability included comparison of the following characteristics of studies with likely CAFO situations:

- location (urban, rural, etc.);
- water supply/groundwater use (percentage on wells);
- type of contaminants (scenario involved nitrate contamination of groundwater);
- source of contaminants (scenario involved conditions similar to those relevant for CAFOs);
- value estimates are for the correct theoretical construct (e.g., total willingness to pay for reducing groundwater contamination from nitrates).

Criteria for Ranking based on Quality

Analysis of study quality was based on evaluation of the validity and reliability of the value estimates derived in the primary groundwater valuation research. Most of the 11 identified studies involved stated preference elicitation using survey methods. Based on professional experience as to what constitutes a valid and reliable stated preference valuation study, EPA identified characteristics of these studies that indicate reliability and validity. Criteria for evaluation of study quality included:

- whether the study was published or peer reviewed;
- whether the survey implementation met professional standards;
- how many respondents there were and what the response rate was;
- whether and how the groundwater baseline was characterized and what change was presented in the groundwater scenario;
- whether the credibility of scenario change was assessed;
- what valuation method was used and whether it was appropriate for eliciting the intended value measures;
- the type and duration of payment vehicle;
- whether appropriate empirical estimation was undertaken;
- whether expected explanatory variables were found to be significant.

8.1 INTRODUCTION

A safe water supply is essential to the production of healthy livestock and poultry. Water supplies contaminated with pollutants such as nitrates, pathogens, organic materials, and suspended solids can adversely affect livestock health and productivity. According to the U.S. Department of Agriculture's (USDA) Agricultural Research Service, livestock disease costs society over $17.5 billion dollars each year (U.S. Department of Agriculture, 2002).

Nitrate poisoning and pathogen-related illness are among the most common livestock diseases. In high concentrations, nitrate can be a health hazard to livestock. Nitrate poisoning is most common in ruminants (e.g., cows and sheep). Affected animals experience insufficient oxygen in the blood stream, which can lead to decreased growth and, in some cases, death.[1] A number of enteric (i.e., intestinal) pathogens may also be present in manure and can cause disease in livestock, including *Coccidiosis, Cryptosporidium, Giardia, E. coli, Salmonella, Campylobacter,* and *Listeria.*[2] Pathogen-related effects can include diarrhea, lowered milk production, decreased growth rates, and death (Xiao et al., 1993; Pell, 1994).[3]

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[1] State agricultural extension publications indicate that levels in excess of 100 mg/l nitrate-nitrogen may be harmful to cattle, particularly in combination with high nitrate feed (Hutchinson; Grant, 1993; Cassel, 1989).

[2] According to a University of Nebraska-Lincoln study, fecal coliform concentrations should be kept under 1 colony forming unit (CFU) per 100 ml of water to protect calves, and under 10 CFU per 100 ml to protect mature cattle. Similarly, fecal streptococcus should be kept under 3 CFU per 100 ml of water to protect calves, and under 30 CFU per 100 ml to protect mature cattle (Grant, 1993).

[3] Public and animal health agencies are also becoming increasingly concerned about the occurrence of *Salmonella typhimurium* (definitive type [DT] or phage type) 104, which is resistant to at least five antimicrobics: ampicillin, chloramphenicol, streptomycin, sulfonamides, and tetracycline.

The most common route of disease transmission is through fecal contact. For instance, large herds or flocks of animals are almost certain to produce known pathogens in their manure (Kuczynska and Shelton, 1999). AFOs that apply manure to on-site land may thus increase the incidence of disease by contaminating livestock watering sources.[4] Other CAFOs close to these source operations may also receive contaminated water and experience livestock illness and mortality.[5]

This chapter examines the impact of changes in manure management practices on animal health. Specifically, the analysis quantifies potential reductions in beef and dairy cattle nitrate poisoning and pathogen-related mortality resulting from the improved on-site manure application practices required by the revised CAFO rule.[6]

8.2 ANALYTIC APPROACH

To evaluate the impact of on-site manure application on animal health, EPA estimates beef and dairy cattle mortality attributable to nitrates and enteric pathogens present in groundwater livestock watering sources.[7] This analysis estimates the number of animals at risk from waterborne diseases and determines their baseline and anticipated change in mortality. EPA then monetizes the change in mortality by calculating the cost to replace the cattle. The sections below describe the approach in more detail.

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[4] The survival and transport of pathogens in groundwater is dependent on a number of factors related to the characteristics of the water and soil. Pathogens generally survive longer in waters where organic matter is readily available because the organic matter provides both substrate and nutrients for the organisms (Fallon and Perri, 1996). These conditions are generally present when manure is applied to agricultural lands.

[5] See Pumphrey and Haines, 2002 for a discussion of nitrate poisoning and pathogen-related disease exposure and incidences via groundwater contamination.

[6] In this analysis, EPA does not quantify impacts on other livestock sectors (e.g., swine). Based on a review of available literature on these sectors, EPA found limited on-site land application of manure and nominal projected benefits or insufficient data to estimate monetary benefits.

[7] For this analysis, EPA includes heifers and veal calves in the beef cattle sector.

8.2.1 Number of Cattle Affected

In this analysis, EPA examines the number of cattle at Large CAFOs that are covered under the effluent guideline and NPDES permit portions of the final rule.[8] EPA employs data on the number of animal units at these operations reported by the U.S. Department of Agriculture (Kellogg, 2002). EPA then multiplies these estimates by the number of cattle per animal unit (1.0 for beef cattle and 0.7 for dairy cattle) to estimate the average number of cattle at the large CAFOs. This approach generates estimates of over 11,873,000 beef cattle and over 2,352,000 dairy cattle at Large CAFOs.

Because not all CAFOs use groundwater for livestock watering and not all livestock watering sources are considered to be contaminated by pathogens or nitrates, EPA must scale the above number of cattle by estimates of the contamination risk. Exhibit 8-1 summarizes these scaling factors. Based on a USDA survey of water sources at farms with more than 1,000 cattle, 82.9 percent of livestock watering sources are wells, and approximately 13 percent of those wells exceed recommended nitrate levels of 100 ppm (U.S. Department of Agriculture, 2000). In addition, because other sources of nitrate can contaminate well water, EPA assumes that only 50 percent of nitrate contamination results from land application of manure.

In a 1984 report, EPA found that 19.8 percent of individual rural water supplies contained fecal coliform in excess of 1 colony forming unit (CFU) per 100 ml of water (Francis et al., 1984). Because these supplies often also serve as the source of water for livestock, the analysis uses this rate as a proxy for the rate at which water supplies for livestock are contaminated. For purposes of this analysis, EPA assumes that 100 percent of pathogen contamination results from land application of manure.

Exhibit 8-1

EXPOSURE SCALING FACTORS

	Nitrate	Pathogens
Percent of CAFOs using groundwater wells	82.9%[1]	82.9%[1]
Percent of wells contaminated	13.0%[2]	19.8%[3]
Percent attributable to manure management	50%	100%

Notes:
1 Based on U.S. Department of Agriculture, 2000.
2 EPA assumes wells with nitrate concentrations greater than 100 ppm to be contaminated.
3 EPA assumes wells with greater than 1 CFU per 100 ml of water to be contaminated.

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[8] The change in standards will also affect nitrogen and pathogen loads from Medium CAFOs, but an analysis of these impacts was not available when this report was submitted for publication.

Based on these scaling factors, EPA estimates that contaminated groundwater exposes almost 640,000 beef cattle and 127,000 dairy cattle to nitrate poisoning, and approximately 1,949,000 beef cattle and 386,000 dairy cattle to enteric pathogens. Based on a five-year herd replacement cycle, EPA estimates that 20 percent of the exposed cattle are calves.

8.2.2 Baseline Cattle Mortality

Exhibit 8-2 summarizes the nitrate poisoning and pathogen-related mortality rates for beef and dairy cattle. EPA applies these mortality rates to the number of exposed cattle to estimate the number of cattle expected to die absent the regulations. Exhibit 8-3 provides these baseline mortality estimates.

Exhibit 8-2

NITRATE POISONING AND PATHOGEN-RELATED MORTALITY RATES BY LIVESTOCK SECTOR

Health Impact	Sector	Mature Cattle	Calves
Nitrate Poisoning	Beef	0.00075	0.00036
	Dairy	0.00035	0.00015
Pathogens	Beef	0.00243	0.0078
	Dairy	0.00593	0.0321

Source: U.S. Department of Agriculture, 1997a.

Exhibit 8-3

BASELINE ESTIMATED CATTLE LOSSES PER YEAR AT LARGE CAFOs BY CONTAMINANT AND LIVESTOCK SECTOR

	Beef		Dairy	
Health Impact	**Mature Cattle**	**Calves**	**Mature Cattle**	**Calves**
Nitrate Poisoning	384	46	35	4
Pathogens	3,789	3,040	1,832	2,479
Total	4,173	3,086	1,867	2,483

Note: Totals may not sum due to rounding.

8.2.3 Predicated Change in Cattle Mortality

The benefits of improved animal health resulting from this rule are based solely on changes in on-site manure application practices and the resulting impact on the quality of on-site groundwater livestock watering sources. As such, this analysis employs two regulatory scenarios based upon anticipated nitrate and pathogen loading reductions that would result from:

- on-site manure application at a nitrogen-based limiting nutrient rate; and
- on-site manure application at a phosphorus-based limiting nutrient rate.

Using USDA GLEAMS model data, Exhibit 8-4 summarizes the expected change in edge-of-field subsurface nitrate and pathogen loadings.

To estimate the reduction in animal mortality that would result from this rule, EPA scales the baseline mortality estimates by the percentage change in nitrate and pathogen loadings. Due to the lack of appropriate dose-response curves, the analysis assumes that the relationship between reductions in pollutant loadings and associated mortality is linear. For example, an 87 percent reduction in edge-of-field subsurface pathogen loadings is assumed to result in an 87 percent reduction in pathogen-related mortality for the cattle currently at risk.

Exhibit 8-4

ESTIMATED CHANGES IN NITRATE AND PATHOGEN LOADINGS BY SECTOR AND LAND APPLICATION SCENARIO

Land Application Scenario	Sector	Nitrates	Pathogens (Fecal Coliform and Fecal Streptococcus)
Nitrogen-based	Beef	87.4%	57.5%
	Dairy	77.3%	69.3%
Phosphorus-based	Beef	90.6%	67.4%
	Dairy	82.7%	72.5%

Source: USDA GLEAMS model.

As shown in Exhibit 8-5, EPA estimates that nitrogen-based application rates would reduce annual beef and dairy cattle and calf mortality from nitrate poisoning and pathogens by 7,315 animals. Phosphorus-based application rates would reduce annual beef and dairy cattle and calf mortality from nitrate poisoning and pathogens by an estimated 8,154 animals.

Exhibit 8-5

ANNUAL REDUCTION IN CATTLE MORTALITY AT LARGE CAFOs BY LAND APPLICATION SCENARIO AND SECTOR

Land Application Scenario	Beef		Dairy		TOTAL	
	Mature Cattle	Calves	Mature Cattle	Calves	Mature Cattle	Calves
Nitrogen-based	2,512	1,787	1,296	1,720	3,808	3,507
Phosphorous-based	2,903	2,092	1,358	1,801	4,261	3,893

Note: Totals may not sum due to rounding.

8.2.4 Valuation

To determine the monetary benefit of reduced animal mortality that would result from changes in manure land application rates, EPA values the respective reductions in animal mortality based upon estimated animal replacement costs.[9] The available literature suggests that the replacement cost for the average beef or dairy cow is approximately $1,100 (1997 $), while the replacement cost for a day-old calf is approximately $50 (U.S. Department of Agriculture, 1997b). This analysis uses inflation-adjusted replacement cost values of approximately $1,185 and $54 for mature cattle and calves, respectively (2001 $).[10]

[9] Review of available literature reported by USDA revealed little information on the total cost of livestock mortality, such as pre-death animal healthcare costs and mortality management. The anticipated mortality reductions are also not expected to have market-level impacts. As a result, benefit estimates are limited to reduced animal replacement costs.

[10] EPA applies the Gross Domestic Product deflator to adjust the replacement cost values to 2001 dollars.

8.3 RESULTS

Exhibit 8-6 summarizes the results of the above analysis. Phosphorus-based application rates, which represent the proposed standard, would reduce annual cattle mortality from nitrate poisoning and pathogens at large CAFOs by 4,261 mature cattle and 3,893 calves. Using a replacement value of $1,185 for mature cattle and $54 for day-old calves, the annual monetary benefit would equal approximately $5.3 million. Similarly, the alternative nitrogen-based standard would reduce annual cattle mortalities at large CAFOs by 3,808 mature cattle and 3,507 calves. Based on the same replacement values, the annual monetary benefit of reduced beef and dairy cattle mortality under this standard would be approximately $4.7 million.

Exhibit 8-6

ANNUAL MONETARY BENEFIT OF REDUCED CATTLE MORTALITY AT LARGE CAFOs BY LAND APPLICATION SCENARIO AND SECTOR (2001 $, thousands)

Land Application Scenario	Beef	Dairy	TOTAL
Nitrogen-based	$3,073	$1,629	$4,702
Phosphorus-based	$3,553	$1,706	$5,259

Note: Totals may not sum due to rounding.

8.4 LIMITATIONS AND CAVEATS

EPA's analysis of reduced cattle mortality benefits from the revised CAFO regulations is subject to several significant uncertainties. These limitations include the following.

- This analysis does not examine potential reduced animal mortality at medium-sized CAFOs regulated under the effluent guideline and NPDES permit portions of this rule. Additionally, insufficient information exists to estimate potential reduced nitrate poisoning and pathogen-related mortality in other livestock sectors. Consequently, the analysis fails to consider potential benefits at these additional operations and sectors.

- This analysis examines the benefits of avoided mortality only and does not consider the benefits of avoided livestock and poultry morbidity from waterborne pathogens or excessive nitrate consumption. As a result, EPA considers neither slower animal growth rates nor the costs associated with disease prevention (e.g. antibiotics) or treatment.

- The lack of pathogen dose-response functions for cattle requires EPA to assume that percent reductions in pathogen loadings result in similar reductions in beef and dairy cattle mortality. This assumption may be inaccurate. For instance, it would predict the elimination of all mortality due to gastrointestinal illness at farms with contaminated groundwater contamination if all manure land applications were eliminated. The direction and magnitude of the bias related to this assumption, however, is unclear.

8.5 REFERENCES

Cassel, E. Kirm. 1989. Water Quality for Dairy Cattle. University of Maryland College of Agriculture and Natural Resources.

Fallon A. and K. Perri. 1996. Pathogen Survival and Transport in Groundwater; Groundwater Pollution Primer. Civil Engineering Department, Virginia Polytechnic Institute.

Francis, J.D. et al. 1984. National Statistical Assessment of Rural Water Conditions: Technical Summary, prepared for the Office of Drinking Water, U.S. Environmental Protection Agency. EPA 570/09-84-004.

Grant, R. 1993. Water Quality Requirements for Dairy Cattle. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska - Lincoln.

Hutchinson, D., Ph.D. Undated. Water Quality Guidelines. Montana State University, Bozeman: MSU Beef Update.

Kellogg, R. 2002. "Profile of Farms with Livestock in the United States: A Statistical Summary." USDA, NRCS.

Kuczynska, E. and D.R. Shelton. 1999. "Method for detection and enumeration of *Cryptosporidium parvum* oocysts in feces, manures, and soils." *Appl. Environ. Microbiol.* 65: 2820-2826.

Pell, A. 1997. "Manure and Microbes: Public and Animal Health Problems?" *J. Dairy Science.* 80: 2673-2681.

Pumphrey, B. and J. Haines, 2002. Estimated Reductions in Beef and Dairy Mortality from Nitrate Poisoning and Gastrointestinal Illness Resulting from Improved Manure Land Application Practices at Large and Medium CAFOs. U.S. Environmental Protection Agency.

U.S. Department of Agriculture. March 1997a. Cattle and Calves Death Loss 1995. APHIS/NASS. Washington, DC.

United States Department of Agriculture. 1997b. Johne's disease on U.S. dairy operations. NAHMS dairy '96/APHIS. Washington, DC.

U.S. Department of Agriculture. 2002. Agriculture Research Service Animal Health National Program(103). Available at http://www.nps.ars.usda.gov/programs/programs.htm?npnumber=103&docid=820.

Xiao, L.H., R.P. Herd, and D.M. Rings. 1993. Concurrent infection of *Giardia* and *Cryptosporidium* on two farms with calf diarrhea. *Vet. Parasitol.* 51:41-48.

POTENTIAL BENEFITS OF REDUCED EUTROPHICATION OF U.S. ESTUARIES — CHAPTER 9

9.1 INTRODUCTION

In its 1999 *National Estuarine Eutrophication Assessment*, the National Oceanic and Atmospheric Administration (NOAA) identified more than half of the 138 U.S. estuaries studied as either moderately or highly eutrophic. Eutrophication occurs when the addition of nitrogen, phosphorus, and other nutrients to a body of water stimulates the growth of algae. While this is a natural process, it is accelerated when human activity elevates loadings of nutrients above naturally occurring levels. Significant sources of excess nutrients include point source discharges (e.g., municipal wastewater treatment facilities), agricultural and urban runoff, and the deposition of atmospheric pollutants. CAFOs are a potential contributing factor.

Eutrophication degrades water quality in a variety of ways, including:

- reducing the amount of light that penetrates the water's surface, with subsequent loss of submerged aquatic vegetation;
- increasing the incidence of nuisance or toxic algae blooms; and
- increasing the quantity of decaying organic matter in the aquatic environment, which in turn draws down the concentration of oxygen dissolved in the water.

These water quality impacts result in loss of habitat, fish kills, and offensive odors, and thus adversely affect social welfare. According to NOAA:

> The implications are serious and affect not only the natural resources but also the economy and human health. The resource uses most frequently reported as being impaired were commercial fishing and shellfish harvesting. Recreational fishing, swimming, and boating, all of which contribute to tourism in coastal areas, were also reported as impaired to some degree. The reported risks to human health include the

consumption of tainted shellfish as well as direct skin contact or the inhalation/ingestion of water during an active bloom of toxic algae.

The revised CAFO regulations will reduce nutrient loadings to estuaries nationwide, thus reducing eutrophication and producing economic benefits. While the models and economic studies necessary to adequately measure these benefits are largely unavailable, this chapter presents, for nine selected estuaries, estimates of the impact of the final rule on nutrient loadings.[1] In addition, the chapter presents a case study of the economic benefits associated with reduced nutrient loadings to an estuary. The example focuses on improved recreational fishing opportunities in North Carolina's Albemarle and Pamlico Sounds. While the information presented is not comprehensive, it is indicative of the potential benefits of the final rule in reducing the eutrophication of U.S. estuaries.

9.2 ANALYSIS OF CHANGES IN NUTRIENT LOADINGS TO SELECTED ESTUARIES

9.2.1 Estuaries Analyzed

EPA's estimate of the impact of the final rule on nutrient loadings focuses on the following estuaries: Albermarle Sound; Cape Fear River; Delaware Inland Bays; Lower Laguna Madre; Matagorda Bay; New River; Pamlico Sound; Suwannee River; and Upper Laguna Madre. EPA selected these estuaries based on information in the NOAA report that identified each of them as adversely influenced by pollution from animal feeding operations.

9.2.2 Analytic Approach

EPA employs NWPCAM to characterize pollutant loadings to each estuary, both under baseline conditions and following implementation of the final rule (Bondelid, 2002).[2] The analysis involves three steps:

- *Step 1: Identify RF3Lite "terminal" reaches that end at coastlines* - Based on information provided in the RF3Lite data table, EPA identifies the reach of each stream network that is furthest downstream.

[1] These benefits are not captured in Chapter 4's analysis of surface water quality benefits because (1) the National Water Pollution Control Assessment Model (NWPCAM) is primarily an inland river and stream model, and (2) the benefit transfer values based on the Carson and Mitchell (1993) willingness to pay (WTP) estimates only apply to changes in freshwater quality.

[2] For a more detailed discussion of NWPCAM, see Chapter 4.

- *Step 2: Overlay the RF3Lite terminal reaches from Step 1 onto NOAA's Coastal Assessment Framework (CAF)* - The CAF contains polygons in GIS format that identify each major estuarine system in the U.S. The estuaries identified for analysis by EPA are a subset of CAF's master list. CAF's coverage is at a less detailed scale than the RF3 GIS coverages, so the RF3Lite endpoints do not precisely align with the CAF polygons. The downstream endpoints of the terminal reaches identified in Step 1 are linked to the specific estuaries by "buffering" the CAF polygon boundaries, which in effect connects terminal reaches that are reasonably close to the CAF polygons. RF3Lite terminal reaches that are within the buffered boundary or fall within the polygon itself are then associated with the respective estuarine CAF polygon. This process generates a list of the RF3Lite terminal reaches that discharge into each of the estuaries analyzed.

- *Step 3: Produce pollutant loadings estimates for AFO/CAFO Baseline and Final Rule Scenarios* - Once the list of RF3Lite reaches associated with each estuary is developed, EPA relies on NWPCAM to estimate pollutant loadings to the estuaries from each terminal reach.

It is important to note that the analysis is limited to the impact of revised standards on Large CAFOs. The revised standards will also affect loadings of nutrients from Medium CAFOs, but the analysis of these impacts was not available when this report was submitted for publication.

9.2.3 <u>Results</u>

Exhibit 9-1 presents EPA's findings, including results of the analysis for both the phosphorus-based land application standard incorporated into the final rule and the nitrogen-based alternative standard, which EPA considered but did not select. As the exhibit shows, total loadings of phosphorus under the phosphorus-based standard are estimated to fall by 4.3 percent, while total loadings of nitrogen are estimated to fall by 0.4 percent. Under the nitrogen-based standard, the estimated reductions in phosphorus and nitrogen loadings are 2.1 percent and 0.1 percent, respectively. Under both standards, the estimated change in loadings varies from estuary to estuary, with the greatest reduction in loadings predicted for the Suwannee River estuary.

9.2.4 <u>Limitations and Caveats</u>

For the reasons discussed below, EPA's approach tends to under-estimate the total loadings of nutrients to estuaries and the reduction in loadings likely to result under the final rule.

- The analysis ignores loadings (and reductions in loadings) from non-RF3Lite terminal reaches that empty into the estuaries of interest.

Exhibit 9-1

EFFECT OF REVISED CAFO STANDARDS ON NUTRIENT LOADINGS TO SELECTED ESTUARIES[1]

Estuary	Baseline Conditions		Phosphorus-Based Standard				Nitrogen-Based Standard			
	Nitrogen Load (tons)	Phosphorus Load (tons)	Nitrogen Load		Phosphorus Load		Nitrogen Load		Phosphorus Load	
			Tons	Percent Change	Tons	Percent Change	Tons	Percent Change	Tons	Percent Change
Albemarle Sound	4,684.31	330.66	4,668.20	-0.3%	317.71	-3.9%	4,680.13	-0.1%	325.94	-1.4%
Cape Fear River	1.48	0.13	1.48	0.0%	0.13	0.0%	1.48	0.0%	0.13	0.0%
Delaware Inland Bays	374.59	72.05	374.48	0.0%	69.59	-3.4%	374.68	0.0%	70.80	-1.7%
Lower Laguna Madre	597.81	82.41	597.11	-0.1%	79.01	-4.1%	597.22	-0.1%	80.03	-2.9%
Matagorda Bay	3,616.90	424.94	3,606.47	-0.3%	421.62	-0.8%	3,615.70	0.0%	423.89	-0.2%
New River	470.93	146.40	467.24	-0.8%	142.21	-2.9%	470.67	-0.1%	145.34	-0.7%
Pamlico Sound	2,636.61	250.05	2,619.79	-0.6%	240.06	-4.0%	2,633.03	-0.1%	246.32	-1.5%
Suwannee River	2,504.38	388.78	2,481.48	-0.9%	349.17	-10.2%	2,498.09	-0.3%	365.60	-6.0%
Upper Laguna Madre	1,654.10	174.52	1,653.08	-0.1%	170.82	-2.1%	1,653.26	-0.1%	171.94	-1.5%
Total	16,541.11	1,869.94	16,469.34	-0.4%	1,790.32	-4.3%	16,524.25	-0.1%	1,829.99	-2.1%

[1] The analysis accounts for changes in the regulations governing Large CAFOs only. The impact of revised standards for Medium CAFOs is not considered.

- Some portions of the estuaries of interest are part of the RF3Lite network. Because EPA's estimates of loadings to each estuary are based on loadings at the terminus of the RF3Lite network, they incorporate a degree of pollutant decay ("loss") that does not actually occur until after pollutants have entered the estuary.

- The analysis is likely to underestimate loadings associated with the atmospheric deposition of nutrients (especially nitrogen) from AFOs/CAFOs. While atmospheric deposition is an implicit component of NWPCAM's estimates of nonpoint source loadings, these estimates are based on observations from the 1980's, when atmospheric loadings from AFOs/CAFOs were likely much lower than they are today.

These caveats clearly affect EPA's estimates of total pollutant loadings, but their effect on EPA's estimate of the change in loadings following implementation of the final rule is less obvious. EPA's estimates of marginal changes in pollutant loadings are dependent upon the percentage of total loadings that are related to AFOs/CAFOs. As a hypothetical example, suppose that the baseline scenario reflects 100 pounds of total loadings, 30 pounds of which are from AFOs/CAFOs. If the reduction in AFO/CAFO loadings attributable to the final rule is 20 percent, the loadings change is 0.2 times 30, or 6 pounds. This 6 pounds represents an overall reduction in loadings of 6 percent, as opposed to the 20 percent reduction from AFOs/CAFOs. Therefore, systematic underestimation of the proportion of total loadings from AFOs/CAFOs – as is suggested by the third caveat above – will lead to an underestimate of the final rule's impact on total loadings.

In addition to the caveats listed above, we note again that the analysis is limited to the impact of the revised CAFO standards on loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis further contributes to underestimation of the final rule's impacts on total nutrient loadings.

9.3 CASE STUDY: ALBEMARLE AND PAMLICO SOUNDS

9.3.1 <u>Introduction and Summary of Analytic Approach</u>

To illustrate the potential economic benefits of the anticipated reduction in nutrient loadings to estuaries, EPA has evaluated the impact of the revised CAFO regulations on recreational fishing opportunities in North Carolina's Albemarle and Pamlico Sounds (Van Houtven and Sommer, 2002). The case study uses the approach described above to estimate annual nitrogen and phosphorus loadings (tons/year) from 17 "terminal" reaches to the Albemarle-Pamlico Sounds (APS) Estuary; the analysis relies on NWPCAM to characterize pollutant loadings both under baseline conditions and following implementation of the final rule. To evaluate the economic benefits associated with reduced nutrient loads to the APS Estuary, the case study employs a benefit transfer approach. This approach adapts value estimates from three previously conducted recreation-based studies, applying the adapted values to estimate recreational fishing benefits. Although the results of the analysis cannot be easily extrapolated to the rest of the country or to other benefit categories, they highlight the potential importance of improved water quality in U.S. estuaries.

The discussion that follows summarizes the studies employed in the benefit transfer analysis, highlighting key differences and similarities in their methods and findings. It then describes the selection of appropriate value estimates from these studies and the adaptation of these values to estimate the benefits of the CAFO rule.

9.3.2 Summary of Relevant Studies

The Albemarle-Pamlico case study relies on economic value estimates obtained from three studies conducted by researchers at North Carolina State University:

- Kaoru, Yoshiaki. 1995. "Measuring Marine Recreation Benefits of Water Quality Improvements by the Nested Random Utility Model." *Resource and Energy Economics* 17(2): 119-36.

- Kaoru, Y., V. Kerry Smith and Jin Long Liu. 1995. "Using Random Utility Models to Estimate the Recreational Value of Estuarine Resources." *Amer. J. Agric. Econ.* 77: 141-151.

- Smith, V. Kerry and Raymond B. Palmquist. 1988. "The Value of Recreational Fishing on the Albemarle and Pamlico Estuaries." U.S. Environmental Protection Agency. January.

These studies are based on common data sets. Specifically, they use recreation data obtained from a 1981-82 intercept survey of recreational fishermen that was conducted at 35 boat ramps or marinas within the APS Estuary (Kaoru, 1995; Kaoru, et al., 1995; Smith and Palmquist, 1988). The studies also employ common estimates of upstream point and nonpoint source nutrient loads to the APS Estuary. These data, which reflect conditions at approximately the same time the recreational activity survey was conducted, were acquired from NOAA's National Coastal Pollutant Discharge Inventory (NCPDI).

Exhibit 9-2 summarizes the key characteristics and findings of the three studies. As the exhibit indicates, the Smith and Palmquist study provides estimates of the benefits of a reduction in phosphorus loads; the studies by Kaoru and Kaoru et al. provide estimates of the benefits of reducing nitrogen loads to the APS Estuary. The studies are described in more detail below.

Exhibit 9-2

SUMMARY DESCRIPTION AND COMPARISON OF SELECTED VALUE ESTIMATES

	Smith and Palmquist (1988)			Kaoru, Smith and Liu (1995)						Kaoru (1995)	
	Value 1.1	**Value 1.2**	**Value 1.3**	**Value 2.1**	**Value 2.2**	**Value 2.3**	**Value 2.4**	**Value 2.5**	**Value 2.6**	**Value 3.1**	**Value 3.2**
Value Estimate											
mean value	$60.06	$20.61	$2.46	$6.52	$3.95	$3.38	$1.51	$1.27	$0.76	$4.70	$2.45
$ year	1981	1981	1981	1982	1982	1982	1982	1982	1982	1982	1982
per trip	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
per person	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water Pollutant											
nitrogen				✓	✓	✓	✓	✓	✓	✓	✓
phosphorus	✓	✓	✓								✓
change in loading	–25%	–25%	–25%	–36%	–36%	–36%	–36%	–36%	–36%	–25%	–25%
Value Concept											
WTP (compensating variation)				✓	✓	✓	✓	✓	✓	✓	✓
consumer surplus	✓	✓	✓								
Travel Cost Model											
random utility model (RUM)				✓	✓	✓	✓	✓	✓	✓	✓
nested site choice										✓	✓
varying parameter model	✓	✓	✓								
number of sites	11	11	8	35	35	23	23	11	11	35	35
Travel Cost Calculation											
per mile cost ($)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
percent of income/wage	100	100	100	100	33	100	33	100	33	100	100
avg speed (mph)	40	40	40	40	40	40	40	40	40	40	40
multi- and 1-day trips included	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Study Sample/Population											
sample size	1012	1012	1012	1012	1012	1012	1012	1012	1012	1012	1012
total number of observations	252	150	108	612	612	612	612	612	612	547	547
average number of trips/yr	29.7	29.7	33.3	29.7	29.7	29.7	29.7	33.3	33.3	32.04	32.04
mean household income	$32,174	$32,174	$31,759	$32,174	$32,174	$32,174	$32,174	$31,759	$31,759		

9.3.2.1 Smith and Palmquist (1988)

The primary objective of the Smith and Palmquist study was to investigate recreational fishing activity within the APS Estuary. The study employed two separate single-site travel cost models to estimate the demand for two major regional destinations ("composite sites"): the Pamlico Sound and Outer Banks areas. The Pamlico Sound region consisted of eight primary boat launching sites, while the Outer Banks region contained 11 sites.

Both regional demand estimates used the same explanatory variables, including reported catch rates. For the Pamlico Sound region, a single demand function was estimated, based on a sample of 108 survey respondents (i.e., n = 108) visiting one of the eight launch sites. The Outer Banks analysis estimated two separate demand functions. The first included the full sample of survey respondents visiting one of the 11 launch sites (n = 252). The second focused on a subset of this sample, defined as individuals residing within 200 miles of a site (n = 150).

Smith and Palmquist first estimated the demand and value of trips under the nutrient loading conditions that existed at the time of the survey. A separate regression model was used to estimate the relationship between phosphorus loadings and catch rates at the sites. Based on this relationship, the study predicted changes in catch rates and the resulting shift in trip demand due to changes in loadings. The changes in consumer surplus resulting from the estimated demand shifts were used to estimate the value of improved environmental conditions. The main improvement of interest with respect to the AFO/CAFO final rule is a 25 percent reduction in average phosphorus loadings to the APS Estuary. For the full sample and the sub-sample model, the Outer Banks analysis yielded benefit estimates of $60.06 and $20.61 (1981 dollars) per person-trip, respectively. The Pamlico Sound model estimated a value of $2.46 for the same reduction in phosphorus loads.

9.3.2.2 Kaoru et al. (1995)

Kaoru et al. used a random utility model (RUM) to investigate the demand for recreational fishing in the APS Estuary and estimate the value of improving water quality. Like the Smith and Palmquist study, Kaoru et al. used estimates of the impact of different pollutant loadings on catch rates to link water quality changes to total demand for recreational fishing trips. This linkage involved a two-step modeling procedure. First, a household production function (HPF) was estimated to predict expected catch rates for individuals based on variables such as equipment used, effort exerted, and the physical characteristics of the fishing site, including pollutant loadings. Kaoru et al. then used the HPF model to predict the impact of a 36 percent reduction in nitrogen loadings on expected catch rates. The changes in predicted catch rates were then incorporated into a site choice model using information from 612 boat fishing parties at 35 boat launching sites throughout the APS region. RUM models were estimated at three distinct levels of site aggregation. Aggregated site alternatives were created by grouping launch sites together based on location and other characteristics. This aggregation allowed the RUM to be estimated for a 35-site scenario, a 23-site scenario, and an 11-site scenario.

As Exhibit 9-2 shows, Kaoru et al. estimated separate values for each level of site aggregation (35, 23, 11) and for two specifications of the opportunity cost of time (OCT): the full wage rate and one-third the wage rate. This modeling approach produced six estimates of the economic benefit of a 36 percent reduction in nitrogen loadings. The estimated values range from $0.76 to$6.52 (1982 dollars) per person-trip.

9.3.2.3 Kaoru (1995)

The Kaoru study used a three-level nested RUM to estimate the value of water quality improvements in the APS Estuary. The 35 boat launching sites located in the APS Estuary were grouped into five subregions, based on location and other characteristics. The study investigated recreational fishing demand within these subregions using a nested model. The nested model approach breaks the recreational fishing decision into three stages: a decision on the duration of the trip (1, 2, 3, or more than 3 days), a decision on which of the five regions to visit, and a decision on which of the individual sites within the region to visit. The model estimation process was based on 547 observations from the fishing database. The study investigated the impact that different pollutant loadings and catch rates had on visitors' trip decisions, and the value that individuals placed on these differences. The impact of nitrogen and phosphorus loadings was specifically investigated in the second stage of the decision process (Regional Choice).

The regression analysis yielded coefficients with unanticipated signs for some parameters. For example, the analysis produced a positive coefficient for phosphorus loadings, suggesting that increases in phosphorus levels would increase the number of trips to a region. To address this unexpected outcome, the author reported values for pollutant reductions in two ways. First, the values associated with loading reductions that have the anticipated signs are reported, followed by the estimated values including both anticipated and unanticipated coefficient estimates. A 25 percent reduction in nitrogen loadings for the entire APS Estuary resulted in a benefit estimate of $4.70 (1982 dollars) per person- trip. When the positive coefficient estimates on phosphorus are included in the benefit measures, a 25 percent reduction in both nitrogen and phosphorus resulted in a benefit estimate of $2.45 per person-trip.

In contrast to the other two studies, the values cited above were estimated assuming no relationship between pollutant loadings and catch rates. When a 25 percent increase in catch rates was assumed to occur in conjunction with 25 percent loadings reductions, the benefit estimates increased slightly (to $4.88 and $2.63, respectively).

9.3.3 <u>Evaluation and Selection of Value Estimates</u>

As the summaries above indicate, the studies examined calculate the value of a reduction in pollutant loadings using similar estimation procedures; nevertheless, there are important differences in both methods and results. These differences warrant careful consideration in selecting the most appropriate values to be used in a benefit transfer procedure. Below we discuss these differences, many of which are also highlighted in Exhibit 9-2.

9.3.3.1 Reductions in Phosphorus Loadings

The study conducted by Smith and Palmquist estimated, per person-trip, the economic welfare gains associated with a 25 percent reduction in phosphorus loadings to the APS Estuary. The values listed in Exhibit 9-2 represent those generated from the Outer Banks full sample, the Outer Banks sub-sample (those residing within 200 miles of a site), and the Pamlico Region sample (Values 1.1, 1.2, and 1.3 respectively). These values span a wide range – from $60.06 per person-trip for the full Outer Banks model to $2.46 for the Pamlico model.

The second study that estimated values for reductions in phosphorus loadings is Kaoru (1995). Unfortunately, this study estimated the effects of (1) reducing both nitrogen and phosphorus loadings (Value 3.2) and (2) only reducing nitrogen loadings (Value 3.1); therefore, it is difficult to isolate the effect of changes in phosphorus loadings alone. More importantly, the regression analysis in this study produced unexpected (positive) signs on the coefficients for phosphorus loadings. This suggests that reductions in phosphorus loadings decreased recreational benefits, which is implausible. For this reason in particular, the Kaoru (1995) estimates for changes in phosphorus loadings are excluded from consideration for this benefit transfer.

9.3.3.2 Reductions in Nitrogen Loadings

Both Kaoru et al. (1995) and Kaoru (1995) used RUMs to estimate, per person-trip, the economic welfare gains associated with reductions in phosphorus loadings to the APS Estuary. Nonetheless, the studies differ significantly on the following points.

- **Magnitude of pollutant reduction** – Both studies estimate the benefits of a uniform percentage reduction in nitrogen loadings from all coastal counties adjacent to the APS Estuary. Kaoru et al. (1995) value a 36 percent reduction in loadings (through its effect on predicted catch rates and site choice), while Kaoru (1995) values a 25 percent reduction (through its effect on regional site choice).

- **Site definition** – The Kaoru et al. (1995) study presents six different values for a 36 percent reduction in nitrogen loadings – two for each of three models that vary with respect to the level of site aggregation. Based on a formal specification test, the authors conclude that their 35-site model is the most defensible; Exhibit 9-2 presents the results for this model as Values 2.1 and 2.2. The Kaoru (1995) study presents a single value for a 25 percent reduction in nitrogen loadings. This value is also based on a 35-site model. Exhibit 9-2 presents the results for this model as Value 3.1.

- **Calculation of travel costs** – As Exhibit 9-2 shows, travel costs are calculated in the same way for both studies, with one exception. Kaoru et al. (1995) specify two alternatives for the opportunity cost of time. One calculation uses the full wage rate, the other one-third of this rate. In contrast, the Kaoru study is based exclusively on an analysis that sets the opportunity cost of time equal to the full wage rate.

- **Number of observations** – Both studies rely on the same basic data set; however, the Kaoru et al. (1995) study employs a total of 612 observations, while the analysis presented in Kaoru (1995) is based on 547 observations.

9.3.3.3 Selection of Value Estimates

Based on the information above, the analysis retains the following values for the benefit transfer process:

- For reductions in phosphorus loadings, Value 1.1 and Value 1.3 from Smith and Palmquist (1988). Each value is for a distinct subregion of the APS Estuary, and both values are derived from models that were based on the full sample of intercept survey respondents. The distinctly higher benefit suggested by Value 1.1 ($60.06 per person-trip for the Outer Banks Site) raises some doubts about its validity, but not enough at this stage to exclude it from consideration.

- For reductions in nitrogen loadings, Value 2.1 and Value 2.2 from Kaoru et al. (1995), and Value 3.1 from Kaoru (1995). Each of these values is based on a 35-site model, which Kaoru et al. found superior to other specifications.

9.3.4 <u>Value Conversion for Benefit Transfer</u>

For benefit transfer purposes, it is necessary to express the values selected above on a consistent basis. This entails:

- applying the Consumer Price Index (CPI) to update all values to 2001 dollars; and

- deriving benefits values for unit changes in pollutant loads (i.e., a value for each one percent reduction in the quantity of nitrogen or phosphorus entering the estuary).

The latter adjustment is accomplished by dividing the value obtained from the literature by the percentage reduction in pollutant loads associated with that value. Thus, for example, a benefit of $2.50 per person-trip for a 25 percent reduction in nitrogen loads would equate to a benefit of $0.10 per person-trip for each percentage reduction.

A further adjustment is necessary to convert the values obtained from the literature to units that are compatible with NWPCAM's estimates of the changes in nutrient loads attributable to the final CAFO rule. NWPCAM estimates pollutant loads and changes in such loads in tons per year. According to Kaoru (1995), the average nitrogen load to the APS Estuary at the time the study was conducted was 1,741 tons per bordering county per year; for phosphorus, the average load was 260 tons per county per year. With 13 North Carolina counties bordering the APS Estuary, these values translate to a total of 22,633 tons of nitrogen and 3,380 tons of phosphorus loadings per year.

With these conversions, the values become:

- Value 1.1 – $0.147 per trip per Outer Banks fisher per ton reduction in phosphorus load per year;
- Value 1.3 – $0.0060 per trip per Pamlico fisher per ton reduction in phosphorus load per year;
- Value 2.1 – $0.0015 per trip per APS Estuary boat fisher per ton reduction in nitrogen load per year;
- Value 2.2 – $0.0009 per trip/per APS Estuary boat fisher/per ton reduction in nitrogen load per year; and
- Value 3.1 – $0.0015 per trip per APS Estuary boat fisher per ton reduction in nitrogen load per year.

9.3.5 Benefit Transfer Calculation

To estimate the total annual recreational fishing benefits of the final CAFO rule for the APS Estuary, it is necessary to combine the per-unit value estimates described above and the estimates of changes in pollutant loadings generated by NWPCAM with information on historic visitation rates to the APS Estuary. Specifically, total benefits can be calculated by the following formula:

$$TB_i = V_i \times \Delta L_i \times T$$

where

TB_i	=	the total annual recreational fishing benefits of reducing pollutant i under the final rule (dollars)
V_i	=	the annual per trip value per unit reduction of pollutant i (dollars per person-trip per ton per year)
ΔL_i	=	the change in loadings for pollutant i under the final rule (tons per year)
T	=	the total number of annual fishing trips to the APS Estuary (person-trips per year)

The calculation relies on 2001 visitation rates for recreational fishers in the APS Estuary, as provided by the Marine Fisheries Statistics Survey (MRFSS). This database contains information on the number, type and destination of recreational fishers for several coastal regions across the United States. The analysis disaggregated the MRFSS data from the regional and state level to include only trips to the APS Estuary, yielding an estimate of nearly 940,000 person-trips per year; boating fishers account for over seventy percent of these trips.

In calculating benefits, the analysis employed several additional assumptions regarding appropriate unit value estimates (V_i). Specifically:

- For nitrogen reductions, the unit value estimates obtained from the literature are based on a survey of boat fishers. The analysis assumes that these unit value estimates also apply to non-boat fishers.

- For phosphorus reductions, separate unit value estimates are available for Outer Banks and Pamlico Sound fishers (boat and non-boat fishers combined); however, MRFSS does not provide visitation rates for the Outer Banks. In addition, the Outer Banks analysis represents a very specific population and produces surprisingly high values. In light of these limitations, the analysis of the benefits of phosphorus reductions is based solely on the unit value estimate developed for Pamlico fishers (Value 1.3). This approach assumes that this value applies to all recreational fishers in the APS Estuary.

9.3.6 Results

Exhibit 9-3 reports the results of the benefit transfer calculations, presenting estimates of the total annual recreational fishing benefits for anticipated reductions in nitrogen and phosphorus loadings under both the phosphorus-based land application standard incorporated into the final

CAFO rule and the alternative nitrogen-based application standard, which EPA considered but did not select.[3] Based on the NWPCAM analysis, annual nitrogen loadings to the APS Estuary under the phosphorus-based standard are estimated to decrease 32.9 (short) tons per year, while annual phosphorus loadings are estimated to decrease 22.9 tons per year. The annual benefits attributable to the anticipated reduction in nitrogen loadings range from $28 thousand to $47 thousand, depending upon the unit value estimate employed. The benefits associated with the anticipated reduction in phosphorus loadings are estimated at approximately $129 thousand per year. In total, the annual recreational fishing benefits for the anticipated reductions in nitrogen and phosphorus loadings range from $158 thousand to $177 thousand.

Exhibit 9-3

ESTIMATED ANNUAL RECREATIONAL FISHING BENEFITS IN THE APS ESTUARY DUE TO NUTRIENT LOADING REDUCTIONS[1]
(2001 dollars)

Pollutant	Annual Trips	Baseline Loadings (tons/year)	Value of Reduction ($/ton/trip)	Phosphorus-Based Standard		Nitrogen-Based Standard	
				Loading Reduction (tons/year)	Economic Benefit ($/year)	Loading Reduction (tons/year)	Economic Benefit ($/year)
Nitrogen	939,020	7,320.9	0.0009 to 0.0015	32.9	$28,487 to $47,478	7.8	$6,715 to $11,192
Phosphorus	939,020	580.7	0.0060	22.9	$129,142	8.5	$47,594
Total Benefit				$157,629 to $176,621		$54,309 to $58,786	

[1] The analysis accounts for changes in the regulations governing Large CAFOs only. The impact of revised standards for Medium CAFOs is not considered.

Under the nitrogen-based standard, the estimated benefits are lower. Annual nitrogen loadings to the APS Estuary under this standard are estimated to decrease 7.8 tons per year, while annual phosphorus loadings are estimated to decrease 8.5 tons per year. The annual benefits attributable to the anticipated reduction in nitrogen loadings range from $7 thousand to $11 thousand, depending upon the unit value estimate employed. The benefits associated with the anticipated reduction in phosphorus loadings are estimated at approximately $48 thousand per year.

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[3] As noted previously, the analysis of changes in nutrient loadings is limited to the impact of the revised standards on Large CAFOs. The revised standards will also affect loadings of nutrients from Medium CAFOs, but the analysis of these impacts was not available when this report was submitted for publication.

In total, the annual recreational fishing benefits for the anticipated reductions in nitrogen and phosphorus loadings range from $54 thousand to $59 thousand.

9.3.7 Limitations and Caveats

Although the annual benefit estimates presented in Exhibit 9-3 are not large, it is important to emphasize that these values only apply to recreational fishing in the APS Estuary. They do not capture benefits for other recreational and non-recreational uses of the estuary, nor do they capture potential non-use values.

In addition, the analysis described above is subject to uncertainties and has required a number of simplifying assumptions, each of which may lead to over- or under-estimation of benefits. In particular:

- The value estimates are based on fishing activity data that are over two decades old. The analysis assumes that the benefits of water quality changes have remained constant (in real terms) over this period.

- The original value estimates were based on pollutant loadings data from NOAA for the late 1970s and were estimated for rather large changes (25–36 percent reductions) in these loadings. The analysis assumes that similar percent reductions in the NOAA and NWPCAM estimates produce similar total loadings reduction estimates (in tons per year), and that per-trip benefits vary linearly with respect to loading reductions.

- The value estimates obtained from the literature were based on percentage reductions in nutrients that were uniform across the APS Estuary, whereas the reductions associated with the CAFO regulations are likely to be non-uniform. The analysis assumes that average per trip benefits do not vary with respect to the spatial distribution of the loadings reductions.

- The analysis assumes that unit value estimates for reductions in nitrogen loadings are the same for both boat and non-boat fishers, and that unit value estimates for reductions in phosphorus loadings are the same for fishers in Pamlico Sound and other parts of the APS Estuary.

Finally, the analysis is limited to the impact of the revised CAFO standards on loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis is a source of downward (negative) bias in the estimated economic benefits of the final rule.

9.4 REFERENCES

Bondelid, Tim. 2002. "Methodology for Estimating NWPCAM Loadings and Changes in Loadings to Estuaries." Draft. RTI International. September 11.

Carson, Richard, and Robert Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, Swimmable Water Quality." *Water Resources Research* 29(7):2445-2454.

Kaoru, Yoshiaki. 1995. "Measuring Marine Recreation Benefits of Water Quality Improvements by the Nested Random Utility Model." *Resource and Energy Economics* 17(2): 119-36.

Kaoru, Y., V. Kerry Smith and Jin Long Liu. 1995. "Using Random Utility Models to Estimate the Recreational Value of Estuarine Resources." *Amer. J. Agric. Econ.* 77: 141-151.

Smith, V. Kerry and Raymond B. Palmquist. 1988. "The Value of Recreational Fishing on the Albemarle and Pamlico Estuaries." U.S. Environmental Protection Agency. January.

Van Houtven, George and Allan Sommer. 2002. *Recreational Fishing Benefits: A Case Study of Reductions in Nutrient Loads to the Albemarle-Pamlico Sounds Estuary.* Final Report. Prepared for Linda Chappell, U.S. Environmental Protection Agency, Office of Water by Research Triangle Institute, Center for Economics Research. December 11.

IMPROVEMENTS IN WATER QUALITY AND REDUCED DRINKING WATER TREATMENT COSTS **CHAPTER 10**

10.1 INTRODUCTION

Total suspended solids (TSS) entering surface waters from AFOs can cause many problems for stream health and aquatic life. High sediment concentrations can also hinder effective drinking water treatment by interfering with coagulation, filtration, and disinfection processes. Treatment costs can rise as a result. Since more than 11,000 public drinking water systems throughout the United States rely on surface waters as a primary source, these costs can be substantial.

In this analysis, EPA utilizes the National Water Pollution Control Assessment Model (NWPCAM) to predict the impact of revisions to the CAFO standards on the ambient concentration of TSS in the source waters of public water supply systems. To measure the value of reductions in TSS concentrations, EPA estimates the extent to which lower TSS concentrations reduce the operation and maintenance (O&M) costs associated with the conventional treatment technique of gravity filtration. The following sections present the analytic approach, results of the analysis, and associated limitations and caveats.

10.2 ANALYTIC APPROACH

EPA's approach to this analysis comprises three steps:

- Identification of public drinking water systems and associated source waters that are potentially affected by discharges from AFOs/CAFOs;
- Linkage of source waters to TSS watershed concentrations projected by NWPCAM under baseline conditions and under the revised CAFO standards; and
- Estimation of reductions in drinking water treatment costs.

This three-step approach is explained in more detail below.

10.2.1 Identification of Public Drinking Water Systems

There are approximately 170,000 public water systems (relying on surface water and groundwater as a source) in the United States, as reported to EPA by the States for the fiscal year ending September 30, 2000 (U.S. EPA, 2000a). Of these systems, 11,403 are Community Water Systems (CWSs) that rely on surface water to serve 178.1 million people.[1] The water supplies of many of these CWSs may be adversely affected by discharges from AFOs/CAFOs. For this analysis, EPA employs two Agency databases to identify CWSs, the streams that serve as their water supplies, the populations they serve, and the operating status of each CWS: (1) the Water Supply Database (WSDB) (U.S. EPA, 2000b) and (2) the Safe Drinking Water Information System (SDWIS) (U.S. EPA, 2000a).

WSDB, also known as the Drinking Water Supply File, was developed by EPA in 1980 to identify the locations of public water utilities (i.e., CWSs), their intakes, and sources of water supplies (surface water or groundwater) across the United States. It contains information on approximately 7,500 public water utilities. Of these, 5,783 are dependent upon surface waters to serve the public and are linked to specific watersheds and geographic areas in EPA's Reach File.[2,3] While no longer an EPA maintained database and limited in the number of water utilities

[1] CWSs supply water to the same population year-round.

[2] The Reach File is a series of national hydrologic databases that uniquely identify and interconnect the stream segments or "reaches" that comprise the nation's surface water drainage system. First created in 1982, four versions of the Reach File currently exist (RFI, RF2, RF3, and NHD), each with increasing resolution of digital hydrography data. Each stream segment is identified by a unique reach code. RF1 forms the geographic foundation for the Water Supply Database (WSDB); RF3 for NWPCAM.

[3] Watersheds are identified based on an 8-digit hydrologic unit code (cataloging unit), a national standard watershed identifier defined by the United States Geological Survey (USGS). The Reach File uses these codes as part of every reach number, which permits the NWPCAM results to be analyzed on a watershed basis.

it reports, WSDB is currently the only hydrologically linked database of drinking water utilities.[4] This link is essential to integrating the rest of the data with TSS stream concentrations projected by NWPCAM.

Since some of the information in WSDB is out-of-date, EPA obtains information on each water system's service population and operating status from SDWIS. SDWIS was first developed in 1997 and now serves as OW's major database for storing and tracking compliance and monitoring information on the nation's drinking water systems. The database was not designed to serve as a primary source of locational data and water utilities are not currently hydrologically linked to a geographic area or stream reach. Updating the locational information obtained from WSDB with available information from SDWIS ensures inclusion of the most current and readily available information in the analysis. For this analysis, production capacities for each water utility are estimated based on the population each water utility serves and a 1995 per capita water usage of 192 gallons per day (U.S. Bureau of the Census, 2001).[5]

10.2.2 Application of TSS Concentrations and Water System Data

EPA estimates reduced drinking water treatment costs based on projected reductions in TSS stream concentrations.[6] EPA links the site-specific water system data from WSDB and SDWIS with watershed-specific TSS concentrations projected by NWPCAM, under baseline conditions and under the revised CAFO standards. The analysis considers both the phosphorus-based manure application standard incorporated into the final rule and the alternative nitrogen-based standard, which the Agency considered but did not select. EPA calculates a median TSS concentration at the baseline and under the revised standards for each of the 2,003 watersheds (comprised of a total of 577,068 reach segments) covered by NWPCAM. The median concentrations are applied to each of the public water utilities located within the watershed. TSS watershed concentrations and complete water utility information (i.e., population served) are available for 5,509 of the 5,783 previously identified public water utilities that rely on surface waters to supply the public with water.

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[4] USGS and EPA have completed the development of the National Hydrography Dataset (NHD), a database that will provide a common framework for interrelating data contained in many EPA environmental water systems, including domestic water supplies. EPA is currently working on improving and verifying the geographic coordinates of drinking water intakes. Once this process is completed, identification of water systems and their water sources will be more comprehensive and readily available for modeling applications.

[5] This number includes commercial use of water.

[6] The analysis of changes in TSS concentrations is limited to the impact of the revised standards on Large CAFOs. The change in standards will also affect TSS loads from Medium CAFOs, but an analysis of these impacts was not available when this report was submitted for publication.

10.2.3 Estimation of Drinking Water Treatment Costs

EPA utilizes the Water Treatment Estimation Routine (WaTER), developed in a cooperative effort between the U.S. Department of the Interior, Bureau of Reclamation, and the National Institute of Standards and Technology, to estimate reduced drinking water treatment costs based on projected reductions in TSS stream concentrations (U.S. Bureau of Reclamation, 1999).

WaTER was developed by the Bureau of Reclamation to assist small communities in addressing their water quality problems and subsequently improving their drinking water quality. Using production capacity and raw water composition (e.g., TSS stream concentrations), WaTER calculates dose rates and cost estimates (construction and annual O&M) for 15 standard water treatment processes. Cost estimates are derived independently for each selected process. The program employs cost indices as established by the *Engineering News Record*, Bureau of Labor Statistics, and the Producer Price Index, and derives cost data from *Estimating Water Treatment Costs* (U.S. EPA, 1979) and *Estimating Costs for Treatment Plant Construction* (Qasim et al., 1992).

EPA assumes the conventional treatment technique of gravity filtration in estimating the reduced O&M costs for TSS removal. There are two components to gravity filtration: the backwashing system and the gravity filter structure. O&M costs are based on the area of the filter bed (applicable range 13-2600m^2) as determined by the system flow rate (production capacity) and TSS concentration. Default design values are as follows:

- wash cycle - 24 hours;
- TSS density - 35 grams per liter;
- media depth - 1 meter; and
- maximum media capacity - 110 L-TSS/m^3 (Degrémont, 1991).

Major O&M costs include materials, energy, and labor. The unit cost estimates and cost index values (March 2001) used for updating the 1979 EPA process costs are:

- Electricity Cost ($/kWhr) - 0.0796;
- ENR Labor Rate for Skilled Labor ($/hr) - 32.60; and
- ENR Materials Index - 2115.65.

These values were obtained from the *Engineering News Record* (ENR, 2001) and the U.S. Department of Energy (U.S. DOE, 2001). Off-site disposal costs and pretreatment costs, as well as construction costs, are not included in EPA's estimates. Cost saving estimates are based on the difference in O&M costs predicted between baseline conditions and conditions under the final rule.

10.3 RESULTS

Exhibit 10-1 summarizes the estimated annual benefits associated with improvements in surface water quality (i.e., TSS concentrations) and reduced drinking water treatment costs. The exhibit presents results for both the phosphorus-based manure application standard incorporated into the final rule and for the alternative nitrogen-based standard, which the Agency considered but did not select. The results are based on the analysis of 5,509 public drinking water systems located throughout the contiguous United States (i.e., 48 states and the District of Columbia are represented). The average production capacity for the water systems is 3.5 million gallons per day (MGD), with capacities ranging from 0.001 MGD to 614 MGD.[7]

Exhibit 10-1

ESTIMATED ANNUAL BENEFITS OF REDUCED DRINKING WATER TREATMENT COSTS[1,2] (2001 $)

Regulatory Option	Average Production Capacity	Average TSS Reduction (mg/L)	Average Water System Benefit (per intake)	Total National Benefit (millions)
Phosphorus-Based Standard	3.5 MGD (0.001 to 614)	0.181	$111	$1.1 to $1.7
Nitrogen-Based Standard	3.5 MGD (0.001 to 614)	0.132	$69	$0.7 to $1.0

[1] The analysis accounts for changes in the regulation of Large CAFOs only. The impact of revised standards for Medium CAFOs is not considered.
[2] Based on analysis of 5,509 public drinking water systems extrapolated to 11,403 public CWSs on a national level.

TSS concentration data for the watersheds, as simulated by NWPCAM under baseline conditions and the revised CAFO standards, were provided by EPA in December, 2002 (U.S. EPA, 2002). Under the phosphorus-based standard, reductions in TSS stream concentrations averaged

[7] The average production capacity for the 11,403 CWSs is estimated to be 3 MGD, based on a total service population of 178.1 million (U.S. EPA, 2000a) and per capita water usage in 1995 of 192 gallons per day (U.S. Bureau of the Census, 2001).

0.181 mg/L, with reductions in TSS concentrations occurring in the water supply of 1,595 water systems. Of the remaining 3,914 water systems, 2,423 showed no change in TSS concentrations. The average benefit per water system for all 5,509 public drinking water systems was $111. Results were extrapolated to the national level based on the approximately 11,403 public CWSs nationwide that rely on surface waters as their primary source of water. Total national benefits for the phosphorus-based standard are estimated to range from $1.1 million to $1.7 million per year.[8] Under the nitrogen-based standard, reductions in TSS stream concentrations averaged 0.132 mg/L and occurred in the water supply of 1,401 water systems. Of the remaining 4,108 water systems, 2,472 showed no change in TSS concentrations. The average benefit per water system was $69. Estimated national benefits under this option range from $0.7 million to $1.0 million per year.

10.4 LIMITATIONS AND CAVEATS

The analysis of improvements in water quality, as it relates to reduced drinking water treatment costs, is subject to a number of uncertainties and assumptions that may lead to a potential under- or over-estimation of the benefits. Major limitations and assumptions are presented below:

- The analysis is based on a limited number of public water utilities (5,509). These public water utilities are assumed to be representative of public water utilities nationwide.
- The total population served by a public water utility was divided equally amongst the surface water intakes, where possible, for those utilities with multiple intakes.
- The default wash cycle of 24 hours is adjusted to between 8 to 96 hours (inclusive) (McGregor, 2001), when necessary, to maintain the area of the filter between the applicable range of 13-2600 m^2, as specified by WaTER. The wash cycle range is based on the economy of plant performance with wash cycles of less than 8 hours and on the risk of taste and odor problems with wash cycles greater than 96 hours. Benefits were assumed to be zero for those water utilities with wash cycles outside of the range (approximately 400 utilities).
- The cost estimates projected by WaTER are considered accurate within a +30% to -15% range and are based on average input values and default treatment design values. More accurate cost estimates can be determined given site-specific data.

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[8] A range of benefits was estimated due to the uncertainties associated with the WaTER model.

- The analysis assumes only the conventional treatment technique of gravity filtration in estimating reduced O&M costs for TSS removal. Costs associated with pretreatment and sludge disposal are not included. The cost savings associated with these components of the water treatment process may exceed those estimated for the gravity filtration element.

In addition, the analysis is limited to the impact of the revised CAFO standards on pollutant loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis is a source of downward (negative) bias in the estimated economic benefits of the final rule.

10.5 REFERENCES

Degrémont. 1991. *Water Treatment Handbook.* June 1991.

ENR (Engineering News Record). 2001. Accessed March 5, 2001. http://www.enr.com.

McGregor, S. 2001. "Know Your Filters." Accessed September 2002. http://www.awwoa.org.au.

Qasim, S.R., S.W. Lim, E.M. Motley and K.G. Heung. 1992. "Estimating Costs for Treatment Plant Construction." *Journal of American Water Works Association*. pp. 57-62, August 1992.

U.S. Bureau of the Census. 2001. *2001 Statistical Abstract of the United States*. U.S. Department of the Interior. Washington, D.C. Accessed November 2002. http://www.census.gov.

U.S. Bureau of Reclamation. 1999. *Water Treatment Estimation Routine (WaTER)*. Denver, Colorado. U.S. Department of the Interior. August 1999. Accessed September 2002. http://www.usbr.gov/water/desal.html.

U.S. DOE (Department of Energy). 2001. Accessed November 2002. http://www.eia.doe.gov.

U.S. EPA (U.S. Environmental Protection Agency). 1979. *Estimating Water Treatment Costs*. EPA-600/2-79-162a-d. August 1979.

U.S. EPA (U.S. Environmental Protection Agency). 2000a. *Safe Drinking Water Information System (SDWIS)*. Office of Groundwater and Drinking Water. Accessed September 2002. www.epa.gov/safewater/pws/factoids.html.

U.S. EPA (U.S. Environmental Protection Agency). 2000b. *Water Supply Database*. Office of Water. Downloaded February 2000.

U.S. EPA (U.S. Environmental Protection Agency). 2002. *National Water Pollution Control Assessment Model (NWPCAM) - Total Suspended Solids (TSS) Concentrations*. Office of Water, Engineering and Analysis Division. December 2002.

11.1 INTRODUCTION

This chapter summarizes EPA's estimates of the benefits associated with the revisions to the NPDES provisions and Effluent Limitation Guidelines (ELGs) pertaining to CAFOs. It first describes the Agency's approach to aggregating the results of the studies described in Chapters 4 through 10. It then describes EPA's approach to discounting future benefits and presents the aggregated benefits of the final rule, both in a single present value and as an annualized benefits stream. Finally, the chapter discusses the key limitations of the analysis and the implications of these limitations in characterizing the benefits of the revised CAFO standards.

11.2 INTEGRATION OF ANALYTIC RESULTS

To develop an integrated assessment of the benefits of the final rule, EPA simply adds the results of the analyses presented in Chapters 4 through 10. To the extent that these analyses address similar benefits, this approach may lead to double-counting and overestimation of benefits. In this case, however, EPA has determined that the potential for double-counting is small. Most of the analyses — the NWPCAM analysis of the benefits of improved surface water quality, the evaluation of potential improvements in commercial shell fishing opportunities, the assessment of potential reductions in the contamination of private wells, the evaluation of animal health benefits, the analysis of improved recreational opportunities in estuaries, and the assessment of savings in treatment costs for public water supply systems — examine different water resources and/or different uses of those resources. Thus, the benefits estimated in these analyses are clearly additive. The only possible source of double-counting lies in integrating the results of the NWPCAM analysis with EPA's evaluation of the benefits attributable to reducing the frequency and magnitude of fish kills.

The extent to which the NWPCAM analysis and the fish kills analysis may double-count benefits is unclear, but unlikely to be significant. Both analyses address changes in the quality of rivers, lakes, and streams.[1] In addition, at least some of the benefits of reducing the incidence of fish kills stem from the associated improvement in recreational fishing opportunities, a beneficial use which the NWPCAM analysis considers. Thus, some double-counting is possible. The NWPCAM analysis, however, is based upon modeling of surface water quality under steady state conditions; the analysis is not likely to capture all of the impacts of revised CAFO standards on circumstances (e.g., the overflow of a lagoon under severe storm conditions) that may lead to fish kills. This consideration suggests that at least some, if not all, of the benefits estimated in the fish kills analysis are incremental to those estimated in the NWPCAM analysis.

From a practical standpoint, the implications of any double-counting between the NWPCAM analysis and the fish kills analysis are minimal. At most, the estimated annual benefits of reducing the incidence of fish kills amount to a small percentage of the annual benefits estimated in the NWPCAM analysis. Thus, EPA has concluded that its approach to integrating the findings of the underlying analyses does not result in any significant degree of double-counting.

11.3 PRESENT VALUE OF BENEFITS

The results of the analyses in Chapters 4 through 10 are expressed as annual benefits streams. To calculate the present value of these benefits at the time new regulations are implemented, EPA employs three alternative real discount rates: three, five, and seven percent. The seven percent discount rate represents the real rate of return on private investments and is consistent with the rate mandated by the Office of Management Budget for analysis of proposed regulations. The three percent discount rate reflects the social rate of time preference for consumption of goods and services, and is consistent with the rate recommended by many economists for analysis of environmental benefits. The five percent discount rate represents the mid-point of the three to seven percent range.

In calculating the present value of benefits, EPA assumes an infinite time frame; i.e., as long as the regulations remain in effect the associated benefits will be enjoyed in perpetuity. As a practical matter, this approach is equivalent to assuming that the regulations will remain in effect for several generations, since the present value of benefits beyond this point approaches zero; however, it avoids the need to arbitrarily specify a period of time over which the regulations are assumed to remain in effect, and allows EPA to represent fully the present value of the benefits estimated. Appendix 11-A provides additional detail on the calculation of present values.

Exhibit 11-1 presents the results of the present value calculations for each of the benefit categories addressed in EPA's analysis, and for the final rule overall. The exhibit provides estimates for both the phosphorus- and nitrogen-based standards. As the exhibit shows, aggregate benefits under the phosphorus-based standard that the Agency selected range from approximately $2.2 billion

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[1] The data upon which the fish kills analysis is based include fish kill incidents below the head of tide. The NWPCAM analysis extends only to freshwater resources.

(assuming a discount rate of seven percent and employing the low-end of the underlying benefit estimates) to $11.8 billion (assuming a discount rate of three percent and employing the high-end of the underlying estimates). Under the nitrogen-based standard, which the Agency considered but did not select, aggregate benefits range from $2.0 billion to $8.0 billion. Within categories, the benefit estimates are lowest using the seven percent discount rate and highest using the three percent discount rate, reflecting the impact of alternative discounting assumptions on the present value of future benefits.

11.4 ANNUALIZED BENEFITS ESTIMATES

In addition to calculating the present value of estimated benefits, EPA has developed an estimate of the annualized benefits attributable to the final rule; these annualized values reflect the constant flow of benefits over time that would generate the associated present value. Appendix 11-B provides additional detail on the calculation of annualized benefits.

EPA assumes that benefits related to most water quality improvements will begin immediately after the revised regulations are implemented (i.e., because loadings will immediately decrease), and that these benefits will be constant from year-to-year. For these benefit categories, annualized benefits are equivalent to annual benefits, regardless of the discount rate employed. In the case of private well contamination, however, EPA assumes an uneven annual stream of benefits. As a result, EPA's estimates of the annualized benefits of reduced private well contamination depend upon the discount rate employed.

Exhibit 11-2 presents EPA's estimate of annualized benefits for each benefit category, and aggregates these estimates across benefit categories. The exhibit provides estimates for both the phosphorus- and nitrogen-based standards. As the exhibit shows, aggregate benefits under the phosphorus-based standard promulgated by EPA range from approximately $204 million per year to $355 million per year. Benefits under the alternate nitrogen-based standard, which EPA considered but did not select, range from approximately $141 million to $240 million annually. Again, note that variation in discount rates affects only the annualized benefits associated with reduced contamination of private wells; other annualized benefits remain constant regardless of the discount rate employed.

Exhibit 11-1

PRESENT VALUE OF THE ESTIMATED BENEFITS OF THE REVISED CAFO REGULATIONS UNDER ALTERNATE DISCOUNT RATES[1]
(2001 dollars, millions)

Benefits Category	Phosphorus-Based			Nitrogen-Based		
	3%	5%	7%	3%	5%	7%
Improved Surface Water Quality	$5,540 - $9,953	$3,324 - $5,972	$2,374 - $4,266	$3,413 - $6,087	$2,048 - $3,652	$1,463 - $2,609
Reduced Incidence of Fish Kills	$2 - $4	$1 - $2	$1 - $2	$1 - $2	$0.4 - $1	$0.3 - $1
Improved Commercial Shell Fishing	$10 - $113	$6 - $68	$4 - $49	$3 - $67	$2 - $40	$1 - $29
Reduced Contamination of Private Wells	$1,523	$741	$441	$1,643	$800	$476
Reduced Contamination of Animal Water Supplies	$175	$105	$75	$157	$94	$67
Reduced Eutrophication of Estuaries	not monetized	not monetized	not monetized	not monetized	not monetized	not monetized
Albemarle-Pamlico Case Study	$5 - $6	$3 - $4	$2 - $3	$2	$1	$1
Reduced Water Treatment Costs	$37 - $57	$22 - $34	$16 - $24	$23 - $33	$14 - $20	$10 - $14
All Categories[2]	$7,291 + [B] - $11,831 +[B]	$4,202 +[B] - $6,926 + [B]	$2,194 +[B] - $4,859 + [B]	$5,242 +[B] - $7,990 + [B]	$2,959 + [B] - $4,608 + [B]	$2,019 + [B] - $3,197 + [B]

[1] The analysis accounts for benefits associated with the revised regulations for Large CAFOs only. The impact of revised standards on Medium CAFOs is not included.
[2] Discrepancies between these totals and the sum of the figures in each column are due to rounding.
[B] Represents non-monetized benefits.

Exhibit 11-2

ESTIMATED ANNUALIZED BENEFITS OF THE REVISED CAFO REGULATIONS UNDER ALTERNATE DISCOUNT RATES[1]
(2001 dollars, millions)

	Phosphorus-Based			Nitrogen-Based		
Benefits Category	**3%**	**5%**	**7%**	**3%**	**5%**	**7%**
Improved Surface Water Quality	$166.2 - $298.6	$166.2 - $298.6	$166.2 - $298.6	$102.4 - $182.6	$102.4 - $182.6	$102.4 - $182.6
Reduced Incidence of Fish Kills	$0.1	$0.1	$0.1	$0.0 - $0.1	$0.0 - $0.1	$0.0 - $0.1
Improved Commercial Shell Fishing	$0.3 - $3.4	$0.3 - $3.4	$0.3 - $3.4	$0.1 - $2.0	$0.1 - $2.0	$0.1 - $2.0
Reduced Contamination of Private Wells	$45.7	$37.1	$30.9	$49.3	$40.0	$33.3
Reduced Contamination of Animal Water Supplies	$5.3	$5.3	$5.3	$4.7	$4.7	$4.7
Reduced Eutrophication of Estuaries	not monetized	not monetized	not monetized	not monetized	not monetized	not monetized
Albemarle-Pamlico Case Study	$0.2	$0.2	$0.2	$0.1	$0.1	$0.1
Reduced Water Treatment Costs	$1.1 - $1.7	$1.1 - $1.7	$1.1 - $1.7	$0.7 - $1.0	$0.7 - $1.0	$0.7 - $1.0
All Categories[2]	$218.9 + [B] - $355.0 + [B]	$210.3 + [B] - $346.4 + [B]	$204.1 + [B] - $340.2 +[B]	$157.3 + [B] - $239.8 + [B]	$148.0 + [B] - $230.5 + [B]	$141.3 + [B] - $223.8 + [B]

[1] The analysis accounts for benefits associated with the revised regulations for Large CAFOs only. The impact of revised standards on Medium CAFOs is not included.
[2] Discrepancies between these totals and the sum of the figures in each column are due to rounding. Values are rounded to the nearest $100 thousand.
[B] Represents non-monetized benefits of the rule.

11.5 LIMITATIONS OF THE ANALYSIS AND IMPLICATIONS FOR CHARACTERIZING BENEFITS

The results presented above are based on the analyses presented in Chapters 4 through 10, and are subject to the specific uncertainties and limitations that are discussed in detail in each of these chapters. Beyond these limitations, however, it is important to note that EPA's analysis does not attempt to comprehensively identify and value all potential environmental changes associated with proposed revisions to the CAFO regulations. Instead, the Agency focuses on specific identifiable and measurable benefits. The impacts of the regulatory proposal likely include additional benefits not addressed in these analyses, such as improved recreational opportunities in near-coastal waters beyond those analyzed in Chapter 9; improvements in commercial fishing; improvements in near-stream activities; and non-water related benefits, such as potential reductions in odor from waste management areas. In light of these limitations, EPA believes that the benefits quantified in this report represent a conservative estimate of the total benefits of the revised CAFO standards.

Appendix 11-A

CALCULATION OF PRESENT VALUES

The present value (PV) of a benefit (B) to be received t years from now is determined by the following equation:

$$PV = B_t / (1 + r)^t$$

where r represents the annual discount rate. Thus, the present value of an annual stream of benefits from Year 1 through Year n is calculated as follows:

$$PV = \sum_{t=1}^{n} B_t / (1 + r)^t$$

When B_t is constant – i.e., when benefits (B) each year are the same – and n approaches infinity, the equation above can be simplified to:

$$PV = B / r$$

EPA employs the above equation to calculate present values for all categories of benefits that are assumed to remain constant from Year 1 onward; i.e., for all categories except reduced contamination of private wells. In the latter case, benefits are assumed to increase in a linear fashion until Year 27, and then to remain constant. Thus, the value in Year 27 (V_{27}) of the constant, infinite stream of benefits (B) expected to accrue from that year forward is calculated as:

$$V_{27} = B / r$$

In calculating the present value of reduced contamination of private wells, EPA sets the value of B_{27} equal to that of V_{27}. The present value of benefits is then determined using the following equation:

$$PV = \sum_{t=1}^{27} B_t / (1 + r)^t$$

Appendix 11-B

CALCULATION OF ANNUALIZED BENEFITS

The constant annual benefit A that, over a period of n years, equals the estimated present value (PV) of benefits is determined by the following equation:

$$A = \mathrm{PV}(r) / (1\text{-}[1 / (1 + r)^n])$$

where r represents the annual discount rate. As n approaches infinity, this equation simplifies to:

$$A = PV(r)$$

EPA uses the equation above to calculate the annualized benefits reported in this analysis.