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

CHAPTER 4

4.1 INTRODUCTION AND OVERVIEW

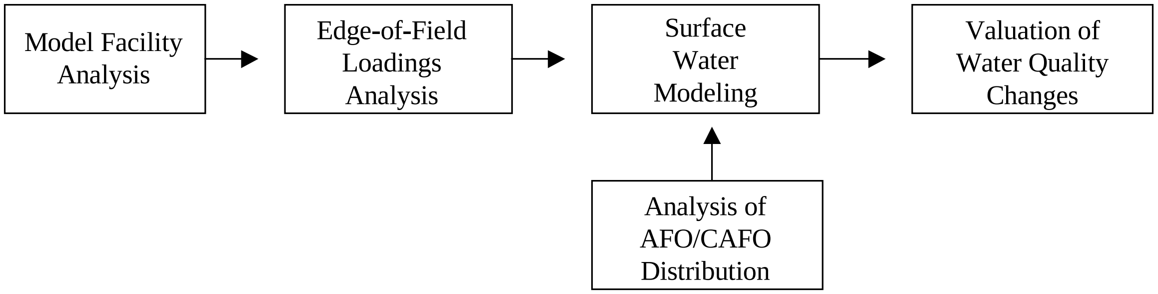
A major component of EPA's CAFO benefits analysis is an assessment of how water quality in freshwater rivers and lakes would be influenced by reduced CAFO pollution, accompanied by an evaluation of the economic value of these changes to society. EPA has developed a comprehensive analysis of these benefits 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.

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[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

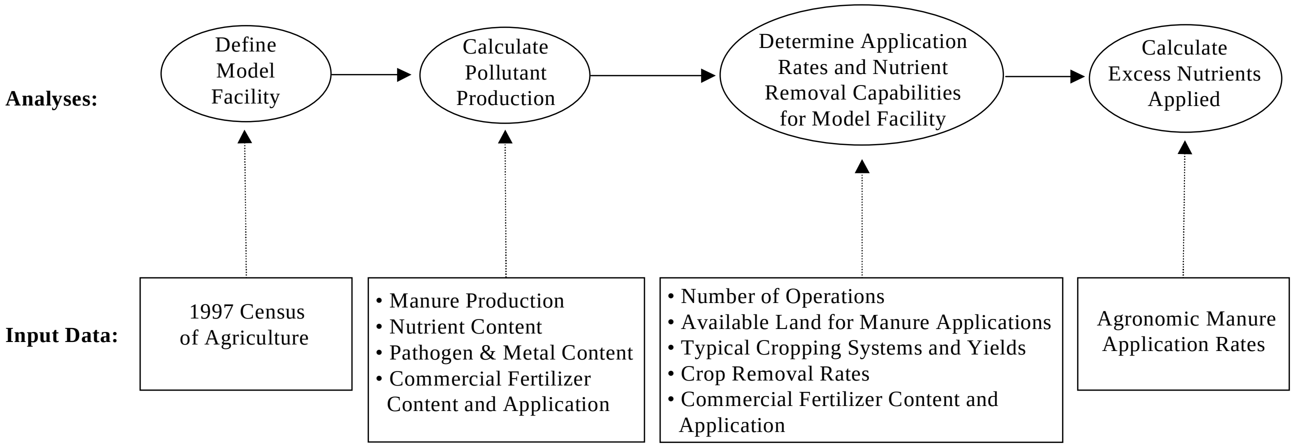
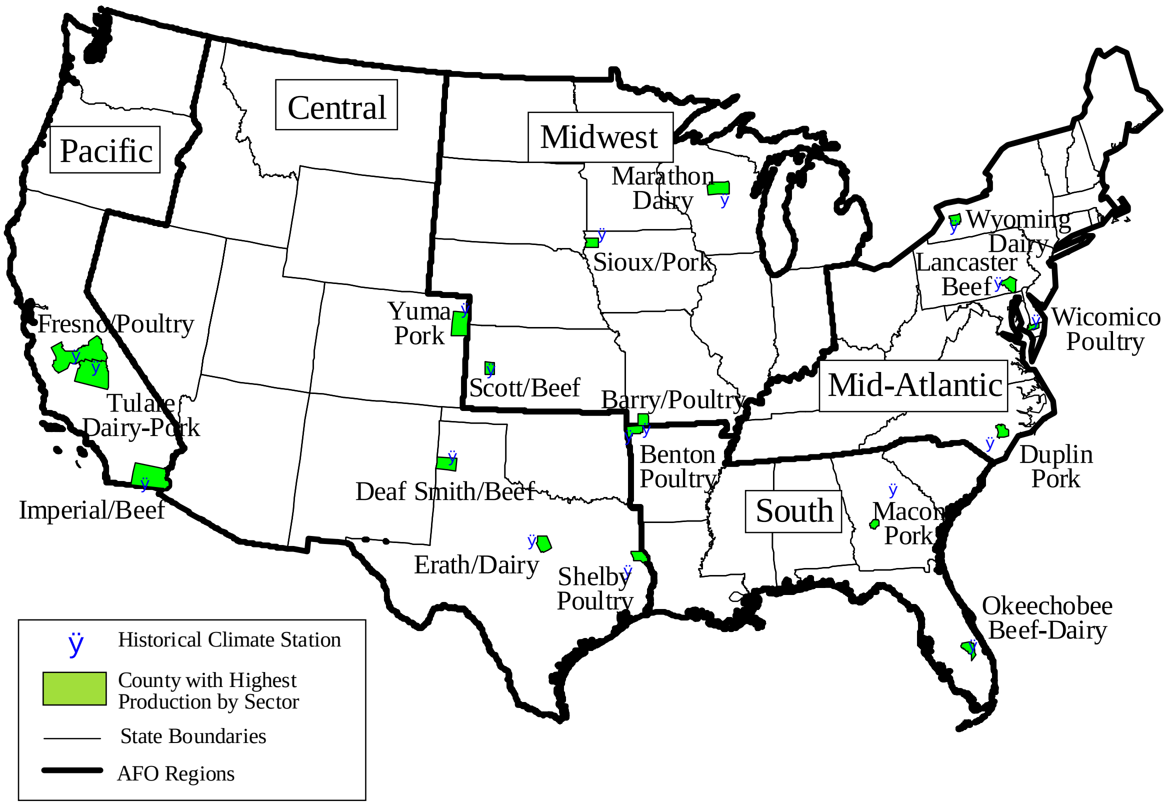


Exhibit 4-3

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

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[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

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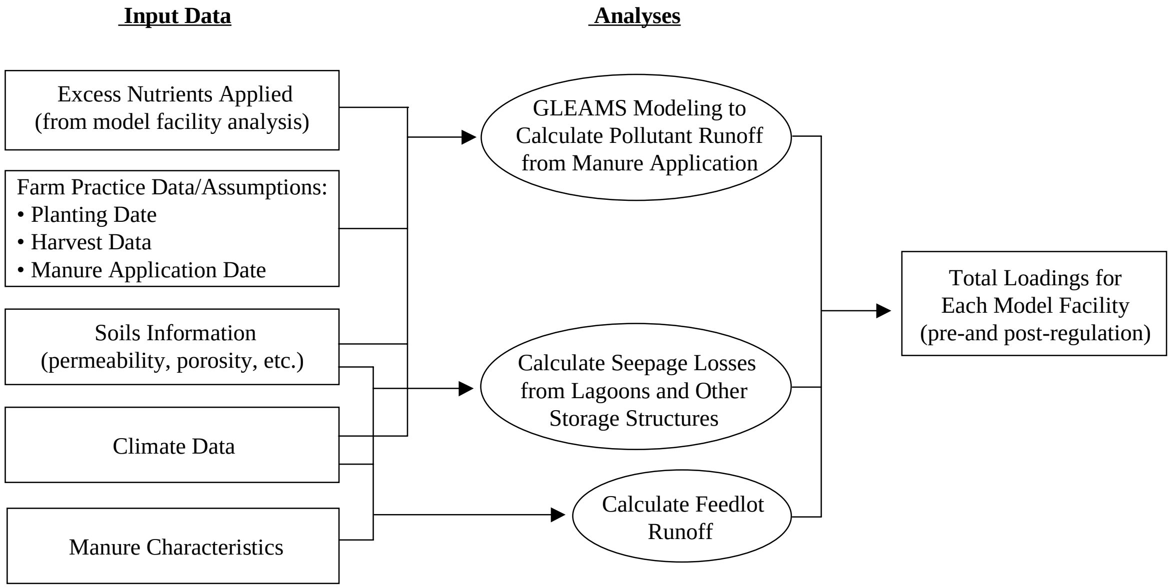
[5] For consistency, pollutant loadings from the off-site cropland to which these facilities are assumed to ship manure are also captured in the baseline analysis. The modeling of baseline conditions assumes the application of commercial fertilizer to this land.

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.

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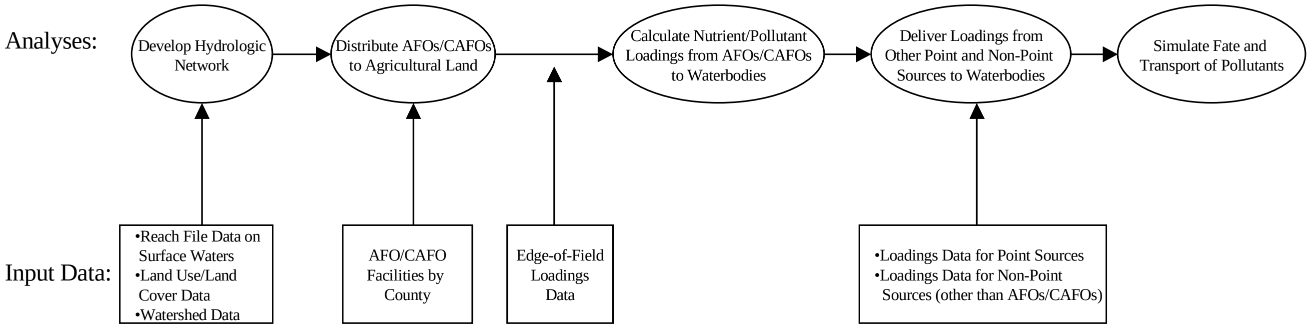
[9] NWPCAM does not address water quality benefits in bays, estuarine waters, or other coastal or marine waters.

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

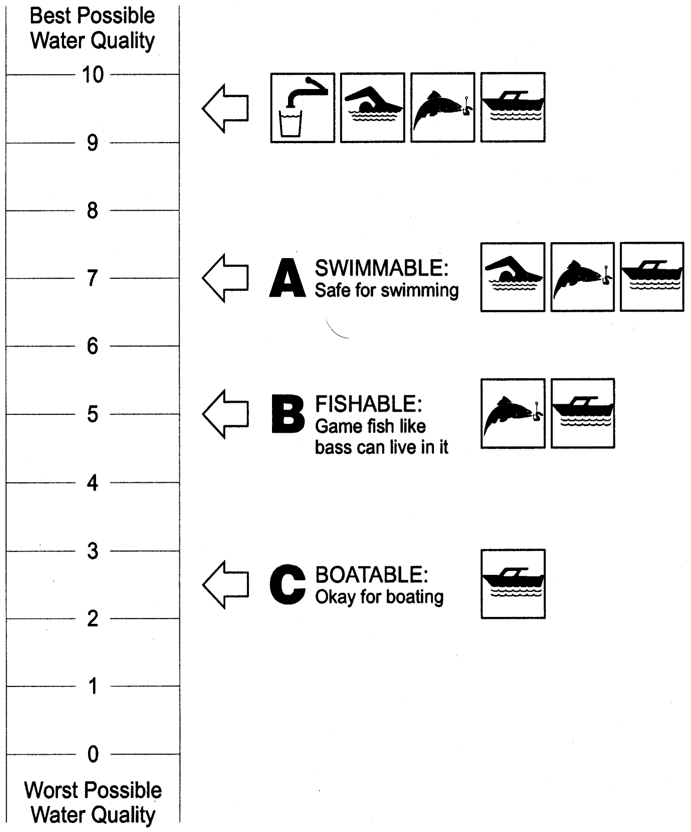
The water quality ladder approach entails relating changes in water quality parameters to the ability of a body of water to support activities such as boating, fishing, or swimming. Once the potential improvement in the ability of modeled rivers and streams to support these uses is determined, the analysis 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.