CHAPTER 12

POLLUTANT REDUCTION ESTIMATES

12.1 Feeding Operation Runoff Pollutant Loads

Runoff from feedlots can be a significant contributor of pollutants to surface waters. Table 12-1 presents feedlot nutrient loads for the beef, dairy, poultry, and swine industries. Beef operations have the most feedlot runoff because the animals are typically housed in open lots. During periods of heavy rain, pollutants can leave the facility as surface runoff. For the purposes of this analysis, it was assumed that no pollutant loads leached directly to ground water from feedlots because feedlot surfaces are generally trampled down by the animals and are highly impermeable to water. The pollutant load from feedlot runoff depends on the rainfall amount and varies by AFO region.

Table 12-1. Nutrient Loads from Feedlot Runoff by Animal Sector and AFO Regions

Sector	AFO Region									
	Central		Mid-Atlantic		Midwest		Pacific		South	
	N	P	N	P	N	P	N	P	N	P
	-- pounds per year --									
Beef	864	233	2,796	756	1,455	393	3,020	817	3,324	899
Dairy	195	52	117	169	117	88	117	183	117	201
Poultry	173	47	259	141	291	79	604	163	645	180
Swine	0	0	0	0	0	0	0	0	0	0

The model facility approach described in chapter 11 was used to estimate pollutant load reductions. For baseline conditions, the model assumes that beef, dairy, and swine facilities with more than 1,000 animal units have no feedlot runoff because they are covered under the current regulation. No such restriction exists for poultry operations because they are not covered under the current regulation. To estimate loads from runoff, the solids in the runoff, the excreted solids, and the constituents in the excreted solids were calculated. The annual amount of runoff from a model feedlot was calculated for each of the five AFO regions using average precipitation from the National Climatic Data Center. The volume of runoff was calculated using this amount of runoff and the estimated area of the dry lot and feedlot handling areas for each animal type (MWPS, 1987) was assumed that runoff from dry lots contains 1.5 percent solids (MWPS, 1993). From this assumption, the quantity of solids that runs off the feedlot was calculated using annual runoff estimates and the percent solids.

Characteristics of manure as-excreted from ASAE (1998) were used to estimate the mass loading per day per animal unit of each constituent of interest (Table 12-2). These loads were converted to a dry basis to calculate the total annual loading from each model feedlot. The total solids excreted were calculated using the total wet weight excreted and the moisture content. It was then assumed that the ratio of the quantity of each constituent in runoff to the quantity excreted is proportional to the ratio of the total solids in runoff to the total solids produced at the feedlot. Results for individual sectors are presented in Tables 12-3, 12-4, and 12-5.

Table 12-2. Constituents of Manure Presented in ASAE (1998).

Item	**Mature Cow**	**Calf**	**Poultry**
	pounds per 1000 pounds animal per day		
TKN	0.3400	0.2700	1.1000
Phosphorus	0.0920	0.0660	0.3000
Volatile Solids	7.2000	2.3000	17.0000
BOD_5	1.6000	1.7000	---
COD	7.8000	5.3000	16.0000
Zinc	0.0011	0.0130	0.0036
Copper	0.0003	0.00005	0.00098

TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.

Table 12-3. Annual Beef Feedlot Runoff Loading

Item	Central	Mid Atlantic	Midwest	Pacific	South
Annual Runoff (ft^3)	172,120	556,995	289,886	601,772	662,337
Solids	2,582	8,355	4,348	9,027	9,935
TKN	864	2,796	1,455	3,020	3,324
Phosphorus	234	756	394	817	900
Volatile Solids	18,294	59,201	30,811	63,960	70,397
BOD5	4,065	13,156	6,847	14,213	15,644
COD	19,818	64,134	33,378	69,290	76,263
Zinc	3	9	5	10	11
Copper	1	3	1	3	3

TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.

Table 12-4. Annual Dairy Feedlot Runoff Loading

Item	Central	Mid Atlantic	Midwest	Pacific	South
Annual Runoff (ft^3)	41,664	134,827	70,170	145,666	160,326
Solids	625	2,022	1,053	2,185	2,405
TKN	195	632	329	682	751
Phosphorus	52	169	88	183	202
Volatile Solids	3,915	12,668	6,593	13,686	15,064
BOD5	946	3,061	1,593	3,308	3,640
COD	4,421	14,306	7,445	15,456	17,011
Zinc	1	5	2	5	5
Copper	1	1	0	1	1
TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.					

Table 12-5. Annual Poultry Feedlot Runoff Loading

Item	Central	Mid Atlantic	Midwest	Pacific	South
Annual Runoff (ft^3)	34,424	111,399	57,977	120,344	132,467
Solids	516	1,671	870	1,805	1,987
TKN	173	559	291	604	665
Phosphorus	47	151	79	163	180
Volatile Solids	3,659	11,848	6,162	12,792	14,079
BOD5	---	---	---	---	---
COD	3,964	12,827	6,676	13,858	15,253
Zinc	1	2	1	2	2
Copper	<1	1	<1	1	1
TKN, total kjeldahl nitrogen; BOD_5, biochemical oxygen demand, 5-day; COD, chemical oxygen demand; ---, data not found.					

12.2 Land Application Field Runoff Loads

Nutrient, metal, and pathogen loading to surface water was estimated for beef, dairy, poultry, and swine operations with more than 300 animal units. Loads prior to implementing the proposed regulatory options (baseline loads) were compared with loads after implementation (post-regulation loads). See Chapter 5 of this document for details on the regulatory options under consideration. Estimation of nutrient, pathogen, and metal loads on a national scale required representative facility conditions to simulate loads. These facility conditions consist of animal groupings of various size classes, current management practices and animal waste management systems, and regionally based physiographic information regarding soil, rainfall, hydrology, crop rotation, and other factors for a given region of the country. Although based on model facilities from the Cost Model Documentation, Sample Farms contain more detailed information on the physiographic information. These representative Sample Farms were developed from several data sources shown in Figure 12-1. Figure 12-1 illustrates the general scope of the types of data used to develop the Sample Farms and the scale of these data sources.

Simulations were conducted using representative Sample Farm information on manure pollutant generation and the cropping system specific to animal operations as they exist under pre-regulation and post-regulation model simulation conditions. Pre-regulation (baseline) Sample Farm conditions are the current management practices in use across the Nation. Pre-regulation model facility simulations assume that all manure was applied to baseline cropland acreage (which included owned and rented acres), with additional acreage receiving commercial fertilizer.

Post-regulation Sample Farm conditions generally affect the distribution of manure on cropland acres and include land-applying manure based on agronomic requirements. Application of manure on an agronomic nitrogen basis generally results in an over application of phosphorus. Application of manure on an agronomic phosphorus basis results in a deficit of nitrogen. Under P-based conditions, supplemental commercial nitrogen fertilizer was applied to fulfill crop requirements.

12.2.1 Industry Characterization

Several sources of data were used to characterize facilities throughout the U.S. The locations of the Sample Farms were selected after an analysis of the 1997 Census of Agriculture (USDA NASS, 1999a). Animal sector-specific determinations were made to select the state with the

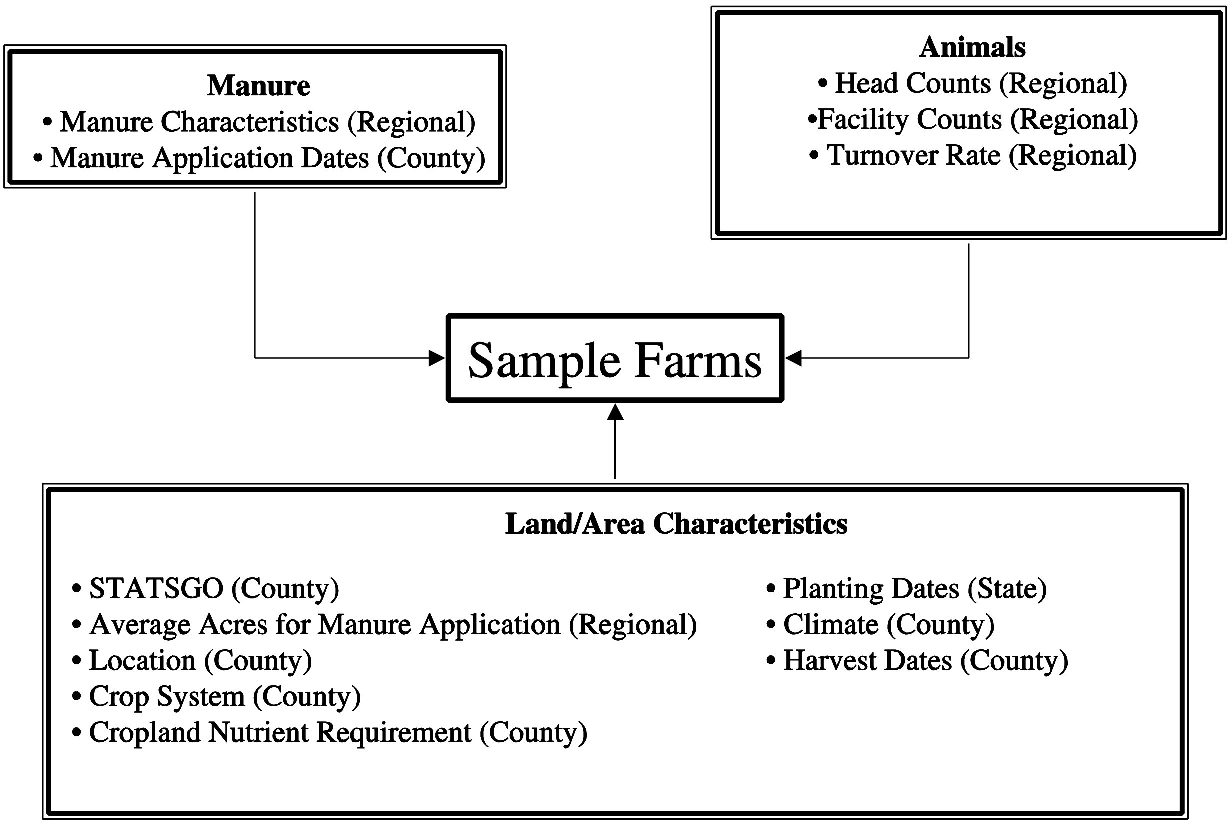

Figure 12-1. Data Used to Develop Sample Farms and the Scale of the Data Sources

largest amount of production in a given AFO region. Once this state determination was made, the county within this state with the largest amount of production was selected as the model facility location. Figure 12-2 presents the counties selected to represent the model facility for each sector and region.

Head counts on model facilities are based on queries of the 1997 Census of Agriculture (USDA NASS, 1999b). The number of animals (head) is important for calculating manure, nutrient, metal, and pathogen production. EPA animal units were used to report the results, and this entailed grouping certain size ranges from the 1997 Census of Agriculture queries (USDA NASS, 1999b).

The number of facilities was calculated using the queries from 1997 Census of Agriculture (USDA NASS, 1999b). The regional totals were split into facilities which have enough land to apply manure (Category 1 facilities), facilities that do not have enough land to apply manure (Category 2 facilities), and those facilities which have no land (Category 3 facilities). The basis for categorization was *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the U.S.* (Kellogg et al., 2000). This data source was also used to calculate the number of acres for Category 2 type facilities.

Manure production from the various animal sectors was based on an analysis performed by USDA NRCS (1998). A recoverable manure correction factor further refined the manure production figures. USDA NRCS (1998) values for nutrient content of manure were applied to the mass of manure produced. Similarly, metal and pathogen concentrations in manure as determined by the American Society of Agricultural Engineers (ASAE, 1998) were used to estimate metals and pathogens of concern produced at the sample farms. In addition, in situ soil concentrations for metals were incorporated into the analysis based on a memo from EPA (Clipper, 2000).

Typical cropping systems information was based on personal communications with state extension specialists in the counties selected to represent each model facility. Once the cropping

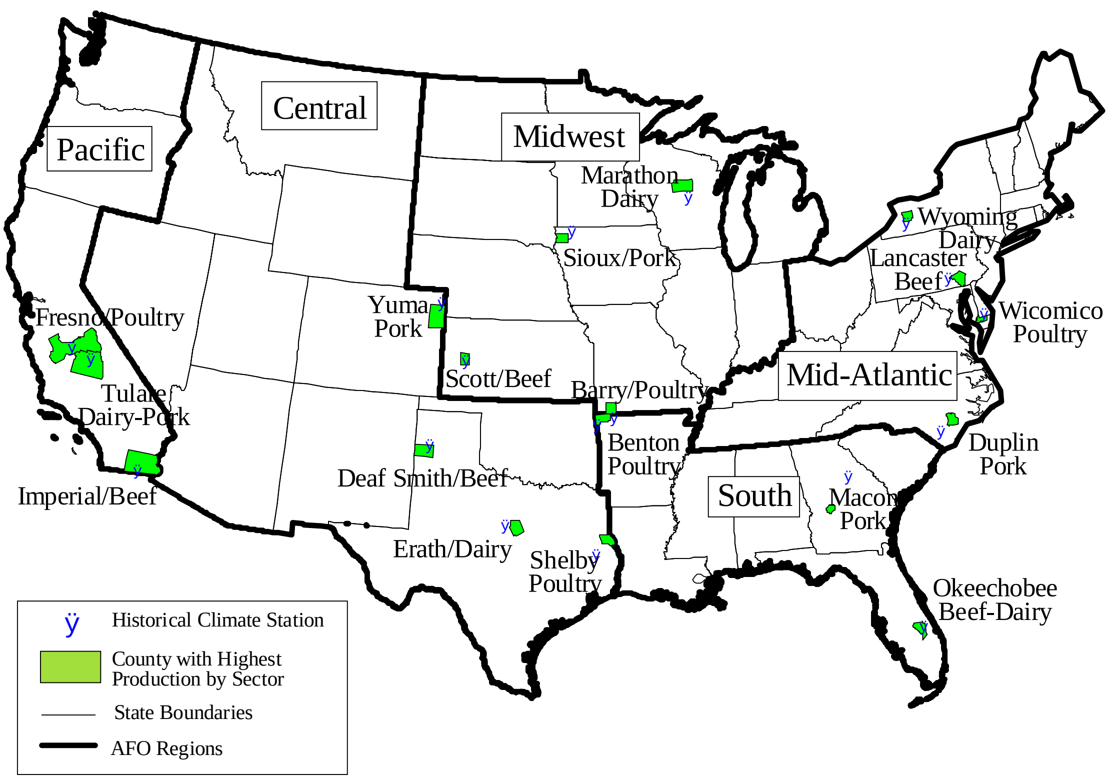

Figure 12-2. Distribution of Animal Sectors by AFO Region

systems were identified, average county yields for each of the crops were determined from the 1997 Census of Agriculture (USDA NASS, 1999a). Using common removal coefficients presented in the *Agriculture Waste Management Field Handbook* (USDA NRCS, 1996), nitrogen and phosphorus removal rates (pounds per acre) were calculated using average county yields. For nitrogen, the removal was modified according to Sutton (1985) to account for losses, mainly volatilization, after land application. The number of acres required to apply all the manure produced at Category 1 type operations was calculated by dividing the nutrient production by the removal rates.

Planting and harvesting dates for the selected crops were based on a USDA NASS (1997) report detailing typical planting and harvesting dates for U.S. field crops. Manure application dates were determined by contacting local USDA Extension agents and referring to the crop planting and harvesting data mentioned previously.

Soils information was obtained from the State Soil Geographic (STATSGO) database that is collected, stored, maintained, and distributed by the National Cooperative Service Survey under the federal leadership of the USDA's Natural Resources Conservation Service (USDA NRCS, 1999). Climate data were prepared by using the CLIGEN program, which is a synthetic climate generator that has been widely used in the Water Erosion Prediction Project (WEPP; Foster and Lane, 1987), and other sources.

12.2.2 Estimation of Sample Farm Loads

Figure 12-3 illustrates the methodology used to simulate the nutrient, pathogen, and metal model facility loads, which were subsequently extrapolated to AFO regional loads and to national pollutant loads. Because EPA's effluent limitation guidelines apply at the facility level, it was essential to use a field-scale loading estimate tool to evaluate the effect of the proposed regulation. The field-scale loading estimate tool GLEAMS (Groundwater Loading Effects of Agricultural Management Systems; Knisel et al., 1993) was selected to model edge-of-field pollutant loads in surface runoff, sediment, and ground water leaching from the sample farms.

The GLEAMS model is a field-scale, physically based continuous model that evaluates the effects of various agricultural management systems on the movement of water, soil, and agricultural pollutants to water sources. GLEAMS estimates runoff and erosion using a modified Universal Soil Loss Equation (USLE). Enhancements to the USLE allow the model to simulate daily loads to reflect manure application, plant growth stage, and changes in the hydrologic cycle that vary from day to day.

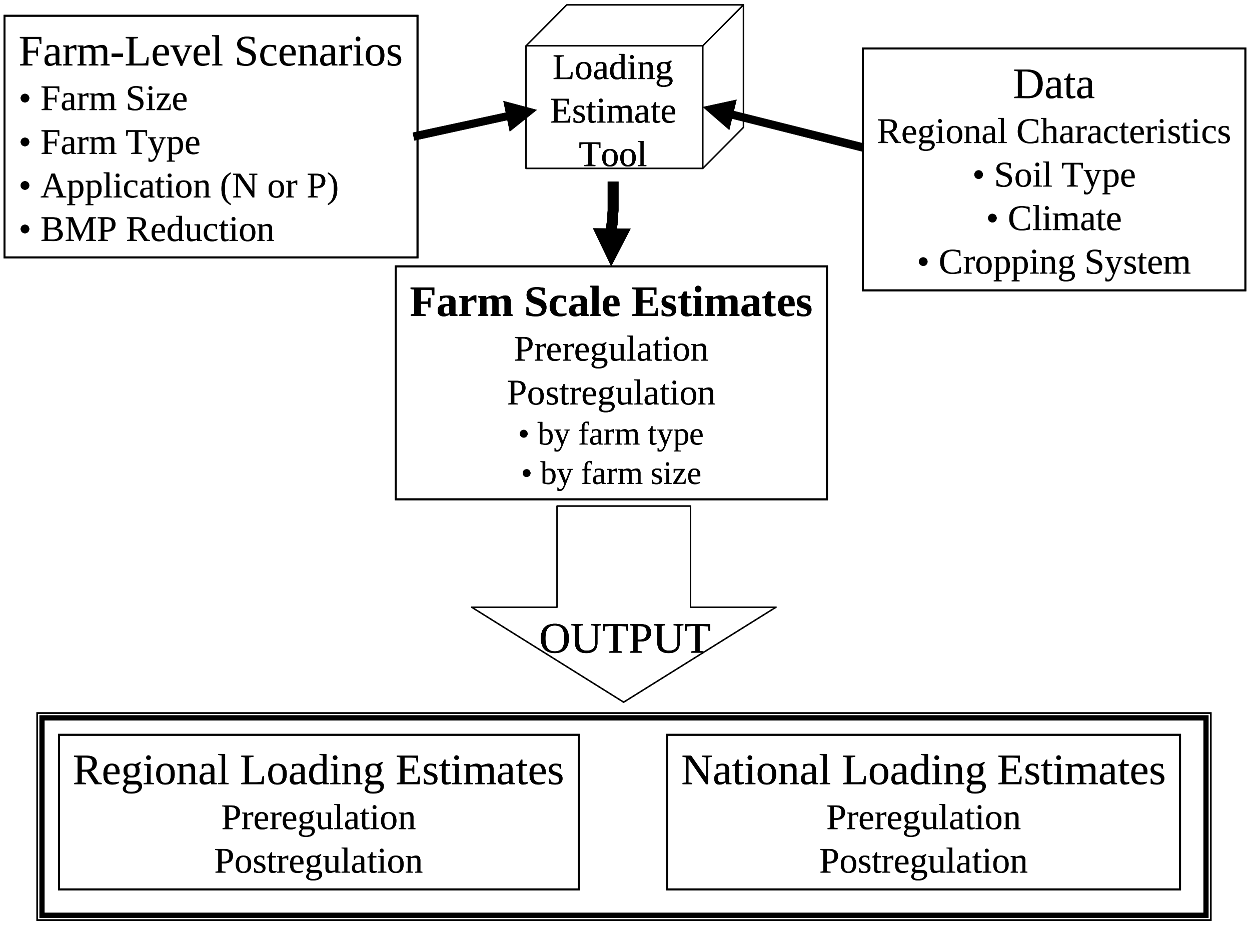

Figure 12-3. Overview of Methodology Used to Estimate Nutrient, Pathogen, and Metal Loads

12.2.3 Evaluation of Modeling Results

GLEAMS model simulations for the five AFO regions were performed for a 50-year period. Fifty years was selected to normalize results for natural variations in climate and to allow the model to equilibrate. The result of the time series is an estimate of the annual pollutant loading from runoff, erosion, and ground water leaching. Results from the second half of the 50-year period of simulated results were averaged and provided as model output. The output was compared with nutrient, metal, and pathogen loads found throughout the literature. In general, simulated results of pollutant loads were within the range of loads presented in the literature.

12.2.4 Results of the National Loading Analysis

The GLEAMS model provides edge-of-field loads in terms of pounds per acre. These rates were converted to total edge-of-field loads by multiplying them by the number of acres on each model facility. The total facility pollutant load was multiplied by the number of facilities specific to the given region, size, and sector to obtain regional pollutant loads. These regional pollutant loads were summed to obtain the national pollutant load.

The selected size classes for national nutrient loads are facilities with 300 to 500 animal units, 500 to 1,000 animal units, and more than 1,000 animal units. Additional size classes were used in the simulations, and these were grouped to produce results for the desired size classes. Nutrient loading results for the three size classes are presented in Table 12-6 for pre- and post-regulation options (see section 2 for option details). Table 12-7 presents metal and pathogen loads for facilities with 300 to 500 animal units, 500 to 1,000 animal units, and more than 1,000 animal units.

Table 12-6. Nutrient Loads (and Percentage Reduction Over Baseline) for Pre- and Post-Regulation Conditions

Size and Option	Surface Nitrogen		Surface Phosphorus	
300 to 500 AU	------------------------ pounds per year ---------------------------			
Baseline	57,060,885		101,862,258	
Option 1	39,819,463	(30.22)	48,264,373	(52.62)
Option 2	30,202,675	(47.07)	29,847,511	(70.70)
Option 3/4	30,202,675	(47.07)	29,847,511	(70.70)
Option 5	30,202,675	(47.07)	29,847,511	(70.70)
500 to 1,000 AU				
Baseline	105,117,967		194,875,167	
Option 1	75,404,509	(28.27)	81,025,690	(58.42)
Option 2	54,778,644	(47.89)	50,076,572	(74.30)
Option 3/4	54,778,644	(47.89)	50,076,572	(74.30)
Option 5	54,778,644	(47.89)	50,076,572	(74.30)
More than 1,000 AU				
Baseline	323,497,304		534,983,410	
Option 1	251,230,661	(22.34)	197,389,009	(63.11)
Option 2	175,135,392	(45.86)	117,998,827	(77.95)
Option 3/4	175,135,392	(45.86)	117,998,827	(77.95)
Option 5	175,135,392	(45.86)	117,998,827	(77.95)

Values in parentheses represent percentage reduction from baseline.
Percentage reduction = (baseline - option)/baseline.

Table 12-7. Pathogen and Metal Loads from Animal Feeding Operations

Sector	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
300-500 AU	---------- 10^{16} cfu/year[a] ----------		-- pounds per year --					
Baseline	27,911	63,707	10,328,500	667,232	15,488	276,996	440,668	104,910
Option 1	9,011 (67.81)	51,357 (19.38)	4,888,760 (52.67)	313,775 (52.97)	2,877 (81.38)	122,161 (55.90)	226,509 (48.60)	64,821 (38.21)
Options 2-5	6,521 (76.70)	37,326 (41.41)	3,140,550 (69.59)	201,163 (69.85)	1,514 (92.53)	71,797 (74.08)	150,842 (65.77)	36,243 (65.45)
500-1000 AU								
Baseline	58,350	137,572	38,511,413	2,042,789	61,447	635,912	1,667,616	212,551
Option 1	15,557 (73.34)	75,838 (42.77)	10,870,014 (71.77)	643,227 (68.51)	5,981 (90.27)	209,875 (67.00)	519,127 (68.87)	108,416 (48.99)
Options 2-5	11,808 (79.76)	56,316 (57.50)	7,027,431 (81.75)	418,751 (79.50)	2,399 (96.10)	124,002 (80.50)	347,798 (79.14)	61,092 (71.26)
>1,000 AU								
Baseline	105,980	260,423	67,398,568	3,319,711	108,948	1,020,801	2,869,196	539,818
Option 1	32,364 (69.46)	110,828 (57.44)	20,819,432 (69.11)	1,206,740 (63.65)	14,337 (86.84)	483,173 (52.67)	980,044 (65.84)	295,561 (45.25)
Options 2-5	26,514 (74.96)	92,766 (64.38)	13,325,674 (80.23)	784,528 (76.37)	5,866 (94.62)	298,207 (70.79)	649,482 (77.36)	165,094 (69.42)

[a] cfu/year, colony forming units per year.
Values in parentheses represent percentage reduction from baseline.
Percentage reduction = (baseline - option)/baseline.

12.3 Subsurface Leaching

Using the modeling results described in Section 12.2, subsurface losses from land application of nitrogen were evaluated for pre- and post-regulation conditions. Additional subsurface losses of nitrogen occur from manure storage structures. Subsurface losses from the feedlot and from land application were combined.

Potentially significant loads can occur from nutrients seeping from manure storage structures. Earthen manure storage structures are integral components of many concentrated animal operations. Manure storage structures contain high concentrations of nutrients and other constituents that are applied to cropland as fertilizer, however, while solid and liquid manures are stored in the manure storage structures, pollutants can leach into ground water.

For the purposes of this analysis, it was assumed that virtually all lagoons and other storage structures leak. Most of the lagoon leakage simulations estimated ground water loads by simulating transport of pollutants through ground water aquifers. Seepage estimates were obtained from Ham and DeSutter (1999) who measured nitrogen that leaked from three established swine-waste lagoons in Kansas. In their study, lagoon walls and bottoms had either an indigenous silt loam soil that was compacted to a thickness of 12 to 18 inches or an 18-inch-thick clay liner. Their results showed that lagoon ammonium-N export loads ranged from 1,952 pounds per acre per year to 2,434 pounds per acre per year. From these results, it was assumed that 2,000 pounds per acre per year leaked from manure storage structures lined with silt loam soils. These referenced values were used to develop direct and indirect loads form manure storage structure leakage according to soil permeabilities referenced by Clapp and Hornberger (1978). The Clapp and Hornberger (1978) soil permeability rates were matched with soil types in the areas where the Sample Farms were located. Clapp and Hornberger (1978) reported that soil permeabilities range two orders of magnitude over all soil types. For example, they reported that water flowed through sand about 100 times faster than through clayey soils and about 10 times faster than through silty soils. Using this analogy of flow rates for various textures, the ammonium export estimated by Ham and DeSutter (1999) was scaled to reflect changes in soil texture for model facilities. Thus, for silt loam soils, 2,000 pounds of nitrogen per acre per year were assumed to seep out of manure storage structures; for sandy soils, 20,000 pounds of nitrogen per acre per year; and for clay soils, only 200 pounds of nitrogen per acre per year.

The values reported by Ham and DeSutter (1999) are for ammonium, which is not mobile in soils. For ammonium to mobilize, oxygen must be present to oxidize the ammonium to nitrate. Once nitrate is formed it can leach in to ground water. Because soil under lagoons generally remains wet and anaerobic, only the outer fringe of the lagoon will oxidize and leach. It was estimated that 10 percent of the ammonia-nitrogen load that seeps out of the bottom of the manure storage structure reaches ground water in the form of nitrate-nitrogen.

Sobecki and Clipper (1999) estimated the number of storage structures that had a direct link to surface water by evaluating the ground water pollution potential of AFO manure storage structures according to AFO region land characteristics. For structures with a direct ground water to surface water link, pollutant loads were assumed to directly connect with surface water, and it was assumed that no ground water aquifer pollutant assimilation took place. Consequently, for manure storage structures that had a high groundwater pollution potential under the Sobecki and Clipper (1999) analysis, once lagoon leakage occurred it was assumed that there was no pollutant reductions before the pollutant load reached surface water. Sobecki and Clipper assumed that if regional characteristics indicated there was a relatively high ground water pollution potential, these manure storage structures would leak. Some of the criteria they used to determine ground water pollution potential were the presence of sandy soils through the soil profile, the presence of a shallow ground water table, and the presence of karst or karst-like terrain. These criteria were evaluated, and percentages of land area were developed for each AFO region. The percentages were applied to each Sample Farm in an AFO region, and these percentages defined baseline levels for manure storage structure leakage to ground water sources.

Table 12-8 presents the combined subsurface nitrogen losses from the feedlot and from land application. Although phosphorus may leach to ground water, it occurs in relatively low amounts and was not included.

Table 12-8. Direct and Indirect Subsurface Nitrogen and Phosphorus Loads

Size and Option	Subsurface Nitrogen				Subsurface Phosphorus	
	Direct		Indirect		Direct	
300 to 500 AU	--pounds per year--					
Baseline	776,427		158,530,618		177,924	
Option 1	776,424	(0.00)	65,517,112	(58.67)	177,924	(0.00)
Option 2	776,424	(0.00)	50,783,872	(67.97)	131,844	(25.90)
Option 3/4	0	(100.00)	50,783,872	(67.97)	131,844	(25.90)
Option 5	0	(100.00)	50,107,541	(68.39)	131,844	(25.90)
500 to 1,000 AU						
Baseline	1,350,312		305,760,799		363,524	
Option 1	1,350,312	(0.00)	126,258,616	(58.71)	363,524	(0.00)
Option 2	1,350,312	(0.00)	97,262,902	(68.19)	265,685	(26.91)
Option 3/4	0	(100.00)	97,262,902	(68.19)	265,685	(26.91)
Option 5	0	(100.00)	96,328,571	(68.50)	265,685	(26.91)
>1,000 AU						
Baseline	2,669,024		1,177,131,012		1,165,286	
Option 1	2,669,024	(0.00)	537,327,332	(54.31)	1,165,286	(0.00)
Option 2	2,669,024	(0.00)	362,770,757	(69.16)	815,258	(30.04)
Option 3/4	0	(100.00)	362,770,757	(69.16)	815,258	(30.04)
Option 5	0	(100.00)	356,921,180	(69.70)	815,258	(30.04)

12.4 Volatilization and Deposition

This analysis considered nutrients and metals that reach the air and are redeposited by rain on the land or directly in to surface water. Pollutants that reach the air either through volatilization or in dust will drift. All nutrients reaching the air were assumed to be eventually redeposited. The pollutant load that reaches surface water was calculated based on the surface area covered by water and the percentage of runoff. Table 12-9 shows the regional coefficients used to calculate loads from atmospheric deposition. The areal percentages of water and land were determined based on 1997 NRI data for each state. States were grouped by region and summed. The relative percentages of water range from 1.3 percent to over 5 percent depending on region. Runoff estimates were based on USGS coverages containing average annual runoff and rainfall. For example, in the southern region rainfall rates generally range from 40 to 60 inches annually, with runoff ranging from 14 to 26 inches annually. The amount of runoff was divided by the rainfall (for the southern region, 50 inches was assumed) to obtain runoff percentages from 28 percent (low) to 52 percent (high).

Nitrogen volatilization from the feedlot area was calculated based on USDA values reported by USDA NRCS (1998). The difference in "as excreted" and "after losses" values for nitrogen was used to calculate the amount of volatilization. Nitrogen volatilization after land application of manure was calculated using the GLEAMS version 2.10 (Knisel et al., 1993). The GLEAMS model takes into account common agricultural practices, and it was run for each model facility. Sulfur volatilization was calculated based on a report by Zhang et al. (1990). In their paper, they suggest sulfide emissions from swine slurry of approximately 1.5 mg S per liter manure. Thus, the manure volume was calculated and converted to pounds of sulfide per year. Little information exists on net loading of sulfur from lagoons or drier manure, and the values presented here should be used cautiously.

The remaining sources of pollutants were estimated from dust produced by the feedlot. Again, little information exists on dust production. It was assumed that 0.001 percent of manure is lost as dust. This production value probably overestimates the indirect loads from these sources. The concentrations of metals in the manure dust were assumed to be the same as those in the manure. Metal concentrations were calculated based on the ASAE standards handbook (1998).

Table 12-9. Percentages of Land and Water Areas and Runoff for Five Regions under Consideration

Region	**Water***	**Land***	**Runoff (low)†**	**Runoff (high)†**
Central	1.3%	98.7%	25.0%	50.0%
Mid Atlantic	5.3%	94.7%	24.0%	44.0%
Midwest	2.3%	97.7%	17.0%	47.0%
Pacific	2.1%	97.9%	27.0%	50.0%
South	5.2%	94.8%	28.0%	52.0%

* Data from 1997 NRI report.
† USGS Arc/View coverages.

Table 12-10 presents loads from atmospheric deposition.

Table 12-10. Annual Indirect Pollutant Loads to Surface Waters from Animal Feeding Operations With More Than 300 Animal Units

Pollutant (source)	**Lower Estimate**	**Higher Estimate**
	pounds to surface water annually	
Nitrogen (volatilization from feedlot)	755,028,602	1,539,710,650
Nitrogen (volatilization from land application)	456,566,444	878,949,831
Nitrogen (dust)	6,133	12,132
Phosphorus (dust)	3,291	6,658
Sulfur (volatilization from feedlot)	10,143,898	20,177,030
Zinc (dust)	51	103
Copper (dust)	10	21
Cadmium (dust)	0	0
Nickel (dust)	9	18
Lead (dust)	3	6
Arsenic (dust)	273	516

12.5 References

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CHAPTER 13

NON-WATER QUALITY IMPACTS

13.0 INTRODUCTION

The elimination or reduction of one form of pollution may create or aggravate other environmental problems. Sections 304(b) and 306 of the Clean Water Act (CWA) require that the U.S. Environmental Protection Agency (EPA) consider the non-water quality environmental impacts (NWQI) of effluent limitations guidelines and standards. This section presents the methodology and estimates of the NWQI for the seven Best Available Technology (BAT) regulatory options that are being considered for beef, heifer, dairy, veal, swine, and poultry (including broiler, layer, and turkey) feeding operations. These non-water quality environmental impacts include:

- Air emissions from the feedlot operation, including animal housing and animal waste storage and treatment areas;

- Air emissions from land application activities;

- Air emissions from vehicles, including those involved in off-site transport of waste and on-site composting operations; and

- Energy impacts from land application activities and the use of digesters.

Typically, NWQIs also include the generation of solid waste. Under the effluent limitations guidelines being considered, the handling of the manure by-product is affected in order to control the wastewater that is generated from animal feeding operations. Because the manure is considered a by-product of animal feeding operations and is not regulated directly, the solid waste NWQIs of the manure are not considered. In addition, although the chemical content of the manure may change, the amount of manure generated is not expected to change under any of the regulatory options being considered; therefore, a discussion of solid waste NWQIs is not included in this section. Also not addressed in this section are the benefits of water reuse/reduction that are obtained under some options; for example, under Option 5B swine and wet layers convert to dry housing, which reduces the amount of fresh water used as flush water.

The remainder of this section contains the following information:

- Section 13.1 presents an overview of the analysis and pollutants;

- Section 13.2 discusses the methodology for air emissions from animal confinement operations;

- Section 13.3 discusses the methodology for air emissions from land application activities;

- Section 13.4 discusses the methodology for air emissions from vehicles;

- Section 13.5 discusses the methodology for energy impacts;

- Section 13.6 provides a summary of the industry-wide non-water quality impacts for two regulatory thresholds considered by EPA; and

- Section 13.7 provides a list of references used in this section.

This section presents results based on available data and methodologies developed as of November 2000. A more detailed description of the analysis is provided in the Non-Water Quality Impact Report (ERG, 2000). EPA's Office of Air Quality Planning and Standards is currently conducting an in-depth study of air emissions from animal feeding operations and is expected to publish results in early 2001.

13.1 Overview of Analysis and Pollutants

Figure 13-1 identifies the pollutants that are included in the air emission analyses for the animal housing areas, the animal waste treatment and storage areas, off-site transportation of the wastes, and land application of the wastes. The pollutants included in this analysis are:

- Ammonia. Nitrogen is the primary component of animal waste that is most likely to generate air emissions. There are many different forms of nitrogen (i.e., ammonia, nitrous oxide, nitric oxide, nitrogen gas, organic nitrogen, ammonium, nitrite, nitrate) that are created during various stages of nitrogen's life cycle. Figure 13-2 depicts the basic nitrogen cycle, which consists of mineralization (organic nitrogen to ammonium), nitrification (ammonium to nitrite and nitrate), denitrification (nitrate to nitrous oxide, nitric oxide, and nitrogen gas), immobilization (ammonium and nitrate to organic nitrogen), and volatilization (urea and ammonium to ammonia).

  Ammonia is the form of nitrogen that is most readily emitted to the atmosphere from animal wastes. The major source of ammonia in animal manure is urea from urine, or uric acid in the case of poultry, which easily converts to ammonia. Urea plus ammonia nitrogen from urine usually accounts for 40 to 50 percent of the total nitrogen excreted in manure (Van Horn et al., 1994). In aqueous solution, ammonia reacts with acid to form ammonium, which is not gaseous. The chemical equilibrium in an acid environment promotes rapid conversion of ammonia to ammonium with little release of ammonia to the atmosphere. Because most animal manures, lagoons, and feedlot surfaces have a pH greater than 7.0 (i.e., a non-acidic

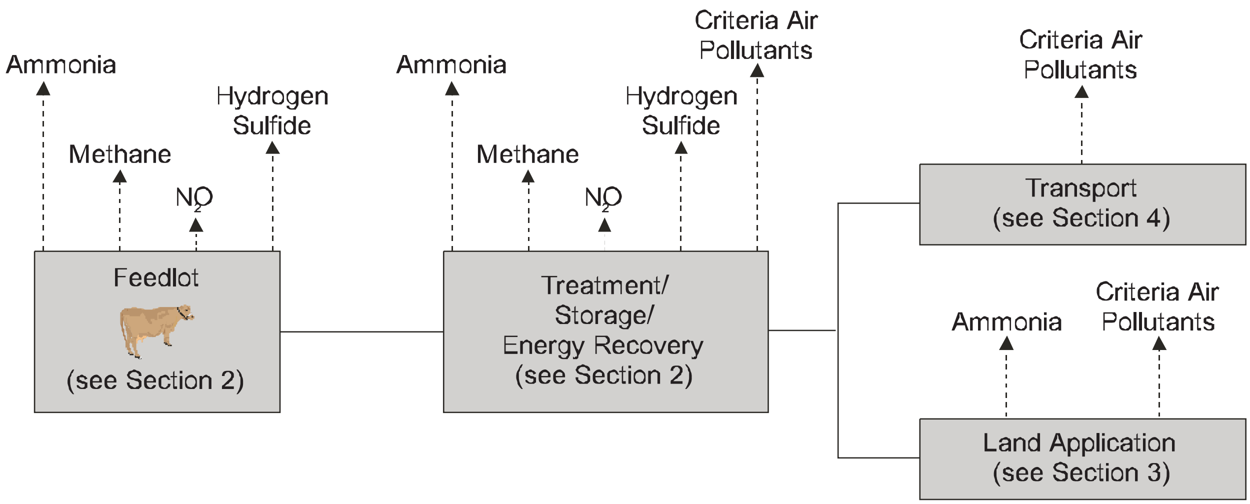

Figure 13-1. Air Emissions from Animal Feeding Operations

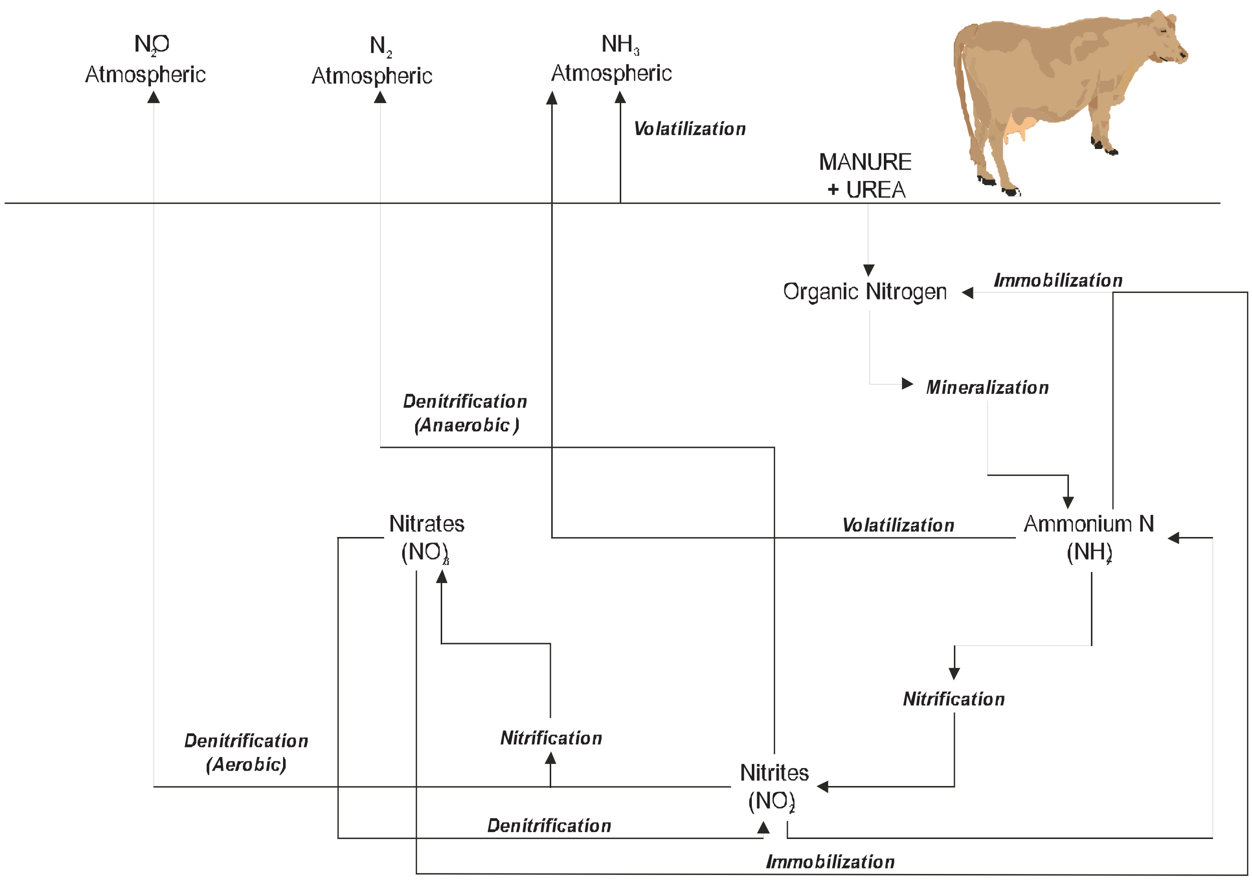

Figure 13-2. Basic Nitrogen Cycle

environment), rapid loss of ammonia to the atmosphere occurs. As a consequence, nitrogen losses from animal manures, as ammonia, can easily exceed 50 percent (Van Horn et al., 1994).

- Nitrous oxide. Most nitrous oxide from agriculture is produced in the soil during nitrification and denitrification. Both processes are carried out by bacteria living in the soil. Research indicates that aerobic manure storage, such as composting, produces more nitrous oxide than anaerobic storage, such as lagoons (AAF Canada, 2000). In general, manure that is handled as a liquid tends to produce less nitrous oxide than manure that is handled as a solid. The quantity of nitrous oxide generated, however, is typically small and varies significantly depending on environmental conditions, such as pH.

- Methane. With respect to livestock emissions, methane is produced during the normal digestive processes of animals and the decomposition of animal manure. This analysis assesses only the amount of methane produced during decomposition of animal manure. Livestock manure is principally composed of organic material. When this organic material decomposes in an anaerobic environment, methanogenic bacteria, as part of an interrelated population of microorganisms, produce methane. The principal factors affecting methane emission from animal manure are the methane-producing potential of the waste and the portion of the manure that decomposes anaerobically. The portion of manure that decomposes anaerobically depends on how the manure is managed. When manure is stored or treated as a liquid (e.g., lagoons, ponds, tanks, or pits), it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid (e.g., in stacks or pits) or when it is deposited on pastures and rangelands, it tends to decompose aerobically and little or no methane is produced (IPCC, 2000).

- Carbon dioxide. Carbon dioxide is an end product of animal respiration and the microbial degradation of animal manure under aerobic and anaerobic conditions. Note, however, that this analysis did not consider carbon dioxide emissions from animal respiration. As with methane emissions, wastes stored as a liquid produce more carbon dioxide than wastes stored as a solid. Carbon dioxide emissions can also occur from the combustion of biogas from anaerobic digesters used to recover energy.

- Hydrogen sulfide. The formation and subsequent emission of hydrogen sulfide from animal manure occurs only under anaerobic conditions and is the result of the mineralization of organic sulfur compounds and the reduction of the more oxidized inorganic forms of sulfur, including sulfites and sulfates. In animal manures, the principal organic sulfur compounds are the sulfur amino acids, and the principal sources of inorganic sulfur are minerals, such as copper and zinc, that are added to diets to correct nutritional deficiencies or to serve as growth stimulants. High concentrations of hydrogen sulfide can be released by agitation and pumping of liquid wastes. Although only small amounts of hydrogen sulfide are produced in a manure tank compared with the other major gases, this gas is heavier than air and becomes more concentrated in the tank over time. Research has determined that hydrogen sulfide production from animal feeding operations depends on the average outside air temperature, the size of the housing or waste management areas, the air retention time in the housing areas, and the daily sulfur intake of the animals.

- Criteria air pollutants. Animal feeding operations that transport their manure off site and/or compost their manure on site use equipment (e.g., trucks, tractors) that releases criteria air pollutants when operated. Criteria air pollutants are also released when biogas, generated from energy recovery systems for anaerobic digesters, is used for fuel (e.g., in an engine or flared). The criteria air pollutants included in this analysis are volatile organic compounds, nitrogen oxides, particulate matter, and carbon monoxide.

Where possible, the NWQI estimates for each regulatory option are presented in relation to the baseline conditions under which animal feeding operations generate air emissions and use energy (i.e., prior to implementation of a regulatory option). In some cases, however, there is insufficient data to quantify baseline NWQI; in these cases, the impacts presented in this section reflect only the change in impacts expected to result from implementation of the regulatory options.

13.2 Air Emissions from Animal Feeding Operations

Animal feeding operations generate various types of animal wastes, including manure (feces and urine), waste feed, water, bedding, dust, and wastewater. Air emissions are generated from the decomposition of the wastes from the point of generation through the management and treatment of these wastes on site. 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).

Air releases occurring from animal confinement areas and manure management systems have been evaluated under baseline conditions and seven regulatory options considered by EPA. The data on these releases is insufficient for a complete analysis of all possible compounds; therefore, this analysis has focused on the release of greenhouse gases (methane, carbon dioxide, and nitrous oxide) from animal confinement and waste management systems, ammonia and hydrogen sulfide from animal confinement and waste management systems, and certain criteria air pollutants (carbon monoxide, nitrogen oxides, volatile organic compounds, and particulate matter) from energy recovery systems.

This section presents the methodology and results for the following air emission calculations from the animal feeding operation:

- Section 13.2.1 - Greenhouse gases from animal confinement and waste management systems;

- Section 13.2.2 - Ammonia and hydrogen sulfide from animal confinement and waste management systems; and

- Section 13.2.3 - Criteria air pollutants from energy recovery systems.

A detailed description of the data inputs and equations used to calculate these air emissions is provided in the Non-Water Quality Impact Report (ERG, 2000).

13.2.1 Greenhouse Gas Emissions from Manure Management Systems

Manure management systems, including animal confinement areas, produce methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) emissions. Methane production is directly related to the quantity and quality of waste, the type of waste management system used, and the temperature and moisture of the waste (USEPA, 1992). In general, manure that is handled in a manner that promotes anaerobic conditions will produce more methane, while manure that is handled in aerobic management systems produces little methane. Certain animal populations, such as beef cattle on feedlots, may produce more methane if they are fed higher energy diets.

Certain regulatory options evaluated for animal feeding operations are based on the use of different waste management systems that may increase or decrease methane emissions from animal operations. Methane is also produced from the digestive processes of ruminant livestock as a result of enteric fermentation. Because the proposed regulatory options do not establish requirements dictating specific feeding strategies that affect diet, the effect on enteric fermentation methane emissions is difficult to predict and is not discussed further.

Carbon dioxide is a naturally occurring greenhouse gas and is continually emitted into and removed from the atmosphere. Certain human activities, such as fossil fuel burning, result in the release of additional quantities of carbon dioxide into the atmosphere. In animal feeding operations, the anaerobic degradation of manure generates methane and carbon dioxide emissions. In addition, certain regulatory options among those evaluated involve the use of lagoon covers to capture biogas for energy recovery or flaring. The combustion process from these options also produces carbon dioxide (while destroying methane).

Nitrous oxide is produced as part of the nitrogen cycle through the nitrification and denitrification of the organic nitrogen in livestock manure and urine. The emission of nitrous oxide from manure management systems is a function of the nitrogen content of the manure, as well as the length of time the manure is stored and the specific type of system used. In general, the amount of nitrous oxide emitted from manure management systems tends to be small because conditions are often not suitable for nitrification to occur; however, when nitrous oxide is generated, manure that is handled as a liquid tends to produce less nitrous oxide than manure that is handled as a solid. Certain regulatory options evaluated for animal feeding operations are based on the use of different waste management systems which may increase nitrous oxide emissions from animal operations.

The methane and nitrous oxide emissions presented in this section are based on the guidance developed for international reporting of greenhouse gas emissions (IPCC, 2000) and used by EPA's Office of Air and Radiation. Emission estimates for carbon dioxide are based on the relationship of carbon dioxide generation compared with methane generation.

13.2.2 Ammonia and Hydrogen Sulfide Emissions From Animal Confinement Areas and Manure Management Systems

Nitrogen is the primary component of animal waste that is most likely to generate air emissions. Total nitrogen is comprised of organic nitrogen, ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3). The primary source of nitrogen emissions from animal feeding operations to the atmosphere occurs as ammonia.

The major source of ammonia in animal manure is urea from urine, or uric acid in the case of poultry, which easily converts to ammonia. Urea plus ammonia N from urine usually accounts for 40 to 50 percent of the total N excreted in manure (Van Horn et al., 1994). In aqueous solution, ammonia reacts with acid (H^+) to form the ion ammonium (NH_4^+), which is not gaseous. The chemical equilibrium in an acid environment promotes rapid conversion of ammonia to ammonium with little loss of ammonia to the atmosphere. Most animal manures, lagoons, and feedlot surfaces have a pH greater than 7.0 (i.e., non-acidic), which permits rapid loss of ammonia to the atmosphere. As a consequence, nitrogen emissions from animal manure, as ammonia, can easily exceed 50 percent (Van Horn et al., 1994). For the purposes of this analysis, emissions of ammonia are quantified for the animal confinement and manure management areas.

Hydrogen sulfide is produced by anaerobic decomposition of organic wastes such as animal manure. High concentrations can be released by agitation and pumping of liquid wastes. Although only small amounts of hydrogen sulfide are produced in a manure tank compared with the other major gases, this gas is heavier than air and becomes more concentrated in the tank over time. Research has determined that hydrogen sulfide production from animal feeding operations depends on the average outside air temperature, the size of the housing or waste management areas, the air retention time in the housing areas, and the daily sulfur intake of the animals.

Livestock may be confined in a number of different ways that impact the type and amount of ammonia emissions. Some animals are housed in traditional confined housing (e.g., tie stall barns, freestall barns), while others are confined in outdoor areas (e.g., drylots, paddocks). Studies have shown that the type of confinement used has a great effect on the emission of ammonia (Jacobson et al., 2000). Management of waste within the confinement area (e.g., litter system, deep pit, freestall) also influences emissions.

Anaerobic lagoons and waste storage ponds are major components of the waste management systems at many animal feeding operations. These systems rely on microbes that biodegrade organic nitrogen to ammonium (NH_4^+) and ammonia (NH_3). The ammonia continuously volatilizes from the surface of lagoons and ponds. The high sulfur content of swine waste also results in hydrogen sulfide emissions from lagoons and ponds.

Under Option 6, wastewater is treated in an anaerobic digester before being released into a secondary storage lagoon. There is typically little to no ammonia gas present in digester gas collected for energy recovery. According to Jewell et al., (1997) the total nitrogen in the waste stream entering the digester equals the total nitrogen in the treated effluent (exiting the digester and entering the secondary storage lagoon); thus, it is assumed that the quantity of ammonia entering the secondary storage lagoon is the same as that entering the primary lagoon for the other options; therefore, the same nitrogen oxides emissions are generated under Option 6 as are generated under the other options, except Option 7.

Under Options 3 and 4, solid wastes are stored on impermeable pads (e.g., concrete pads). Although concrete pads have negligible leachate, the volatilization potential remains almost the same as for a stockpile; therefore, for a specific region, the percentage of ammonia that volatilizes from stockpiles and concrete pads is the same. The negligible leachate from concrete pads results in a slightly higher nitrogen content of waste for land application. The percentage of nitrogen emitted through volatilization from concrete pads and stockpiles depends primarily on the region in which the facility is located.

13.2.3 Criteria Air Emissions From Energy Recovery Systems

Criteria air pollutants are those pollutants for which a national ambient air quality standard has been set. The criteria pollutants evaluated as non-water quality impacts include volatile organic carbons (VOCs) and oxides of nitrogen (NO_x) (precursors to ozone), particulate matter (PM), and carbon monoxide (CO). These criteria pollutants are formed from the transport of waste, operation of compost equipment, and combustion of biogas.

Criteria pollutant air emissions from energy recovery systems are expected only under Option 6. Option 6 is based on the implementation of anaerobic digester systems with energy recovery for the largest swine and dairy operations. The operation of the digester system greatly reduces the emission of methane through the capture of the biogas; however, the use of the biogas in an energy recovery system does generate certain criteria air pollutants when the recovered biogas is burned for fuel.

13.3 Air Emissions from Land Application Activities

The application of animal waste from animal feeding operations on cropland generates air emissions. The emissions result primarily from the volatilization of ammonia at the point the material is applied to land (Anderson, 1994). Additional emissions of nitrous oxide are released from farmlands when nitrogen applied to the soil undergoes nitrification and denitrification. Loss through denitrification is dependent on the oxygen levels of the soil to which manure is applied. Low oxygen levels, resulting from wet, compacted, or warm soil, increase the amount of nitrate-nitrogen released into the air as nitrogen gas or nitrous oxide (OSUE, 2000). A study by Sharpe et. al., which compared losses of ammonia and nitrous oxide from sprinkler irrigation of swine effluent, concluded that ammonia emissions made the larger contribution to airborne nitrogen losses (Sharpe and Harper, 1997). The analysis of air emissions from land application activities is focused on the volatilization of nitrogen as ammonia because the emission of other constituents is expected to be less significant.

The amount of nitrogen released into the environment from the application of animal waste is affected by the rate and method by which it is applied, the quantity of material applied, and site-specific factors such as air temperature, wind speed, and soil pH. There is insufficient data to quantify the effect of site-specific factors; therefore, they are not addressed in this section.

The non-water quality impact analysis evaluated the effects of application rates and methods on air emissions, as well as the quantity of animal waste and commercial nitrogen applied to cropland. A detailed description of the data inputs and equations used to calculate these air emissions is provided in the Non-Water Quality Impact Report (ERG, 2000).

13.4 Air Emissions From Vehicles

Animal feeding operations that transport their manure off site and/or compost their manure on site use equipment (e.g., trucks, tractors) that releases criteria air pollutants when operated. The NWQI analysis evaluated the increased criteria air pollutant emissions from off-site transportation and composting of manure at animal feeding operations. A detailed description of the data inputs and equations used to calculate these air emissions is provided in the Non-Water Quality Impact Report (ERG, 2000).

Criteria air emissions from the off-site transportation of animal manure are evaluated for each of the regulatory options considered by EPA, as all options will result in an increase of off-site transportation of manure at some operations.

Two different waste transportation options are analyzed. One considers the cost of purchasing trucks to transport waste, and the other option evaluates the cost of paying a contractor to haul the waste off site. Because of the different methods used to estimate the costs of the two transportation options, two methods are used to calculate air emissions. Estimates of air emissions from operations purchasing waste transportation vehicles are based on the cost model calculations of the number of trucks purchased and the annual number of miles traveled. Estimates of contract hauling emissions are based on the cost model calculations of the annual amount of waste generated, the annual number of miles traveled, and truck sizes.

Farm equipment used in on-site composting also affects generation of air emissions. Composting of waste results in a reduction in transportation air emissions if there is a reduction in the volume or weight of material composted. Option 5 for beef and dairy is based on all operations composting their waste; therefore, criteria air emissions from on-site composting of manure are shown only for beef and dairy Option 5.

13.5 Energy Impacts

Certain regulatory options evaluated for animal feeding operations entail the use of different waste management systems and land application practices which may increase energy usage. Energy impacts related to land application, digesters, and hog high-rise housing are evaluated under baseline conditions and under the seven regulatory options considered by EPA. A detailed description of the data inputs and equations used to calculate these impacts is provided in the Non-Water Quality Impact Report (ERG, 2000).

The proposed regulatory options assume that all beef and dairy animal feeding operations that have cropland apply their manure and wastewater using agronomic application rates; therefore, the manure application rates are calculated to be no greater than the nutrient uptake requirements of the crops grown in the fields on which the manure is applied. In many instances, facilities have to limit the amount of manure applied to the land, which may result in decreased on-site energy usage; however, an equivalent amount of energy is expended elsewhere because, if there is not enough land to apply on site, the manure and wastewater are applied off site.

Option 6 includes the use of anaerobic digesters with energy recovery to manage animal waste for the largest dairy and swine operations. Digesters require a continuous input of energy to operate the holding tank mixer and an engine to convert captured methane into energy. The energy required to continuously operate these devices and the amount of energy generated by the system have been determined from the *FarmWare* model, which is used in the cost model.

Option 5B is based on the conversion of all flush swine systems to non-flush (e.g., hog high-rise systems). Additional energy is required in the hog high-rise to operate the fans and blowers.

13.6 Industry-Level NWQI Estimates

This section provides a summary of the industry-level NWQI estimates for each of the regulatory options under the two applicability thresholds being proposed.

13.6.1 Summary of Air Emissions for Beef and Dairy Subcategories

Tables 13-1 and 13-2 present estimates for Threshold 1 and Tables 13-7 and 13-8 present estimates for Threshold 2.

Option 1

Emissions of methane and carbon dioxide from beef and dairy operations decrease under Option 1 due to the added step of solids separation in the waste management system. The separated solids are stockpiled rather than held in waste storage ponds or anaerobic lagoons. Using this drier method of handling the waste, anaerobic conditions and the potential for the volatile solids to convert to methane decrease. This method also results in the conversion of more nitrogen to nitrous oxide; thus, nitrous oxide emissions from dairies increase.

No changes in losses of ammonia are associated with confinement areas. Because less manure nitrogen is applied under this option, on-site emissions of ammonia generally decrease.

Option 1 is based on the application of animal waste to cropland at agronomic rates for nitrogen. Animal feeding operations that have excess nitrogen for their crops need to transport their waste to another location. Due to the additional transportation of waste off site, the generation of criteria pollutants under Option 1 increases from baseline.

Options 2-4 and 7

No change in the emissions of methane, carbon dioxide, or nitrous oxide under Option 1 occurs because no further changes in waste management are needed. Under Options 2-4 and Option 7, emissions of ammonia decrease slightly compared with Option 1. Facilities are required to apply animal waste at agronomic phosphorus rates, which means there will be less application of animal nitrogen to cropland. The application of animal waste is supplemented with commercial nitrogen fertilizer. Although the same amount of nitrogen is applied to cropland as in Option 1, there will be fewer emissions of ammonia because commercial nitrogen is expected to be more stable.

Under these options, the generation of criteria pollutants increases in relation to Option 1, for beef because of an increase in the amount of waste transported off site. Although dairies also experience an increase in waste requiring transport, it is expected that more facilities will find hiring a contract hauler more affordable. Emissions from contract haul vehicles are expected to be less overall because waste from more than one farm may be transported in the same trip.

Option 5B

Emissions of greenhouse gases and ammonia from beef and dairy operations increase under Option 5B (i.e., mandated technology of composting). Compost operations include the addition of organic material to the waste pile to aid in the decomposition of the waste. This additional material also decomposes and contributes to increased methane emissions compared with other options. In addition, compost operations release more emissions than stockpiles because the windrows are turned regularly. Stockpiles tend to form outer crusts that reduce the potential for air emissions to occur.

Option 5B generates slightly more criteria air pollutants compared with Option 2 for beef and dairy operations because composting operations require turning equipment which uses fuel and generates additional air emissions from tractors.

Option 6

Emissions of methane from dairy waste under Option 6 significantly decrease because an anaerobic digester is used. A significant portion of the methane generated is collected as biogas and converted to energy. Drylot areas at the dairy still generate methane. Carbon dioxide emissions significantly increase as methane is converted during the combustion process.

No change in beef ammonia emissions occur compared with Option 2, because there is no change in land application or housing practices. Although large dairy waste is digested, no change in ammonia emissions occurs. The nitrogen stays in solution in the digester, and when the digester effluent is stored in an open lagoon, the ammonia is released.

Option 6 emissions of criteria pollutants at beef operations are similar to the emissions under Options 2-4 and 7, because there is little difference in the amount of waste transported off site. Option 6 emissions of criteria pollutants for dairy operations slightly decrease compared with Options 2-4 and 7.

13.6.2 Summary of Air Emissions for Swine, Poultry, and Veal Subcategories

Tables 13-3 through 13-6 present estimates for Threshold 1 and Tables 13-9 through 13-12 present estimates for Threshold 2.

Option 1

Emissions of greenhouse gases from dry poultry operations (broilers, turkeys, and dry layers) do not change under Option 1 in relation to the baseline because no change in the waste handling practices are expected. These operations are already handling the waste as a dry material. Although indoor storage of poultry litter is included in this option, it is not expected to significantly alter air emissions from the litter (only runoff). Emissions of greenhouse gases from veal, swine, and wet poultry operations also do not change because the waste handling practices are not expected to change.

Ammonia emissions occur primarily from liquid waste storage areas, which are not expected to change under Option 1. Because less manure nitrogen is applied under this option, ammonia emissions decrease slightly. Option 1 is based on the application of animal waste to cropland at agronomic rates for nitrogen. Animal feeding operations that have excess nitrogen for their crops transport their waste to another location. The generation of criteria pollutants increases under Option 1 in relation to baseline due to the additional transportation of waste off site.

Options 2-4 and 7

No change in emissions of greenhouse gases occurs because under these options no change in the waste handling practices are expected. There is no change in ammonia emissions compared with Option 1 as there are no changes in waste management systems.

Under these options, emissions of ammonia decrease compared with Option 1. These options are based on facilities applying animal waste at agronomic phosphorus rates where conditions warrant, which results in decreased application of animal nitrogen to cropland. The application of animal waste is supplemented with commercial nitrogen fertilizer. Although the same amount of nitrogen is applied to cropland as in Option 1, commercial nitrogen is more stable and results in lower emissions of ammonia.

Because these options are based on the application of animal waste to cropland at agronomic rates for phosphorus where necessary, animal feeding operations that have excess phosphorus for their crops transport their waste to another location. The generation of criteria pollutants increases in relation to Option 1 because more waste is transported off site to meet agronomic rates for phosphorus.

Option 5A

Emissions of greenhouse gases significantly decrease under Option 5A, which is based on covered lagoons. Because it is assumed that animal operations included in this option (veal, poultry, and swine) flare the gas that is generated in the lagoon, the methane will be converted, which will result in an increase in carbon dioxide emissions.

Because the lagoon cover prevents the ammonia from leaving solution, on-site ammonia emissions decrease. Ammonia in the effluent from the covered lagoon is released as soon as it is exposed to air. Option 5A, however, is based on covered storage at all times; thus, depending on the application methods (e.g., if the waste is incorporated into the soil), ammonia emissions could substantially decrease. Due to the restriction of nitrogen application at the animal feeding operation, there is no change in relation to Option 2 in the amount of material applied to on-site land; therefore, the use of a covered lagoon lowers the on-site ammonia emissions. It should be noted, however, that ammonia is lost from material transported off site, either during transport or at the point of off-site application.

Option 5A emissions of criteria air pollutants for poultry operations are equal to the emissions under Options 2-4 and 7, because there is little difference in the amount of waste transported off site. The emissions of criteria air pollutants for swine operations increase compared with Options 2-4 and 7; however, the emissions of SO_x decrease.

Option 5B

Emissions of methane and carbon dioxide under Option 5B are lower than under Option 2 due to the conversion of liquid manure handling systems (e.g., flush lagoons) to dry manure handling systems for chickens and swine. Dry manure generates less methane than liquid systems. Because turkey operations are already dry, the emissions of methane and carbon dioxide remain the same. Nitrous oxide emissions for swine and chickens operations, however, increase under Option 5B in relation to Option 2.

Ammonia emissions from the confinement of chickens and ammonia and hydrogen sulfide emissions for swine decrease under Option 5B in relation to Option 2 due to the conversion of liquid manure handling systems (e.g., flush lagoons) to dry manure handling; however, there is no change in ammonia emissions due to land application.

Option 5B emissions of criteria pollutants for poultry operations are equal to the emissions under Options 2-4 and 7, because there is no difference in the amount of waste transported off site. The emissions from swine operations are significantly lower than under Option 2 because the conversion of flush operations to dry housing significantly decreases the volume of waste transported off site.

Option 6

Emissions of methane from swine waste under Option 6 are significantly lower than under Option 2 due to the addition of the anaerobic digester. A significant portion of the methane generated is collected as biogas and converted to energy. Carbon dioxide emissions significantly increase because methane is converted during the combustion process.

No change in ammonia emissions occur compared with Option 2 because there is no change in land application or housing practices. Although large swine waste is digested, essentially no change will occur to ammonia emissions. The ammonia nitrogen, which is highly soluble, remains in solution in the digester. When the digester effluent is stored in an open lagoon, the ammonia is released.

Option 6 emissions of criteria pollutants for poultry operations are equal to the emissions under Options 2-4 and 7 because there is no difference in the amount of waste transported off site. The VOCs, NO_x, SO_x, and CO emissions from swine operations decrease. Hydrogen sulfide contained in the biogas is collected in the digester and is subsequently combusted and converted into to SO_x.

13.6.3 Energy Impacts

Certain regulatory options evaluated for animal feeding operations are based on the use of different waste management systems and land application practices which may affect energy usage. Increased electricity usage occurs at beef and dairy operations under all options for the land application of surface runoff from the feedlot which is collected and stored. Increased electricity usage occurs at swine operations under Option 6 due to the conversion of wet operations to high-rise housing because additional energy is required to operate the fans and blowers.

An overall decrease in energy occurs at those operations which use anaerobic digesters in Option 6. Large swine and dairies that digest their waste and recover and use the biogas to operate an engine will have excess energy that can be used to operate other machinery or that can be sold.

Table 13-1. Threshold 1 NWQIs for Beef (Includes Heifers)

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	80,800	77,600	77,600	77,600	77,600		104,000	77,600	77,600
Carbon Dioxide (CO_2)	34,600	33,300	33,300	33,300	33,300		44,500	33,300	33,300
Nitrous Oxide (N_2O)	37,000	37,000	37,000	37,000	37,000		37,900	37,000	37,000
Ammonia (NH_3)	536,000	537,000	529,000	529,000	529,000		759,000	529,000	530,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 519	Baseline + 597	Baseline + 597	Baseline + 597		Baseline + 632	Baseline + 598	Baseline + 597
Nitrogen Oxides (NO_x)	NC	Baseline + 1,995	Baseline + 2,298	Baseline + 2,298	Baseline + 2,298		Baseline + 2,430	Baseline + 2,299	Baseline + 2,298
Particulate Matter (PM)	NC	Baseline + 39.9	Baseline + 46.0	Baseline + 46.0	Baseline + 46.0		Baseline + 48.6	Baseline + 46.0	Baseline + 46.0
Carbon Monoxide (CO)	NC	Baseline + 6,180	Baseline + 7,120	Baseline + 7,120	Baseline + 7,120		Baseline + 7,540	Baseline + 7,130	Baseline + 7,120
Baseline + Energy Usage (kW-hr/yr)									
Electricity Usage	432,000,000	454,000,000	701,000,000	701,000,000	701,000,000		701,000,000	701,000,000	701,000,000

NC = Not calculated

Table 13-2. Threshold 1 NWQIs for Dairy

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	214,000	137,000	137,000	137,000	137,000		176,000	44,500	137,000
Carbon Dioxide (CO_2)	92,500	59,300	59,300	59,300	59,300		92,400	316,000	59,300
Nitrous Oxide (N_2O)	4,390	8,420	8,420	8,420	8,420		30,900	9,490	8,420
Ammonia (NH_3)	188,000	185,000	182,000	182,000	182,000		223,000	182,000	179,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 456	Baseline + 386	Baseline + 386	Baseline + 386		Baseline + 393	Baseline + 378	Baseline + 386
Nitrogen Oxides (NO_x)	NC	Baseline + 1,750	Baseline + 1,480	Baseline + 1,480	Baseline + 1,480		Baseline + 1,510	Baseline + 1,460	Baseline + 1,480
Particulate Matter (PM)	NC	Baseline + 35.1	Baseline + 29.7	Baseline + 29.7	Baseline + 29.7		Baseline + 30.3	Baseline + 29.1	Baseline + 29.7
Carbon Monoxide (CO)	NC	Baseline + 5,430	Baseline + 4,600	Baseline + 4,600	Baseline + 4,600		Baseline + 4,690	Baseline + 4,510	Baseline + 4,600
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline + 158,000,000	Baseline + 170,000,000	Baseline + 170,000,000	Baseline + 170,000,000		Baseline + 170,000,000	Baseline + (972,000,000)	Baseline + 170,000,000

NC = Not calculated

Table 13-3. Threshold 1 NWQIs for Veal

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	79.8	79.8	79.8	79.8	79.8	30.3	79.8	79.8	79.8
Carbon Dioxide (CO_2)	34.2	34.2	34.2	34.2	34.2	149.0	34.2	34.2	34.2
Nitrous Oxide (N_2O)	11.8	11.8	11.8	11.8	11.8	11.2	11.8	11.8	11.8
Ammonia (NH_3)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Volatile Organic Compounds (VOCs)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Nitrogen Oxides (NO_x)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Particulate Matter (PM)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Carbon Monoxide (CO)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Energy Usage (kW-hr/yr)									
Electricity Usage	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000	3,870,000

NC = Not calculated

Table 13-4. Threshold 1 NWQIs for Swine

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	296,000	296,000	296,000	296,000	296,000	133,000	125,000	115,000	296,000
Carbon Dioxide (CO_2)	127,000	127,000	127,000	127,000	127,000	575,000	537,000	625,000	127,000
Nitrous Oxide (N_2O)	569	569	569	569	569	364	11,400	241	569
Ammonia (NH_3)	155,000	155,000	155,000	155,000	155,000	139,000	139,000	155,000	167,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 29.0	Baseline + 32.6	Baseline + 32.6	Baseline + 32.6	Baseline + 116	Baseline + 0.985	Baseline + 12.1	Baseline + 32.6
Nitrogen Oxides (NO_x)	NC	Baseline + 112	Baseline + 125	Baseline + 125	Baseline + 125	Baseline + 447	Baseline + 3.79	Baseline + 46.6	Baseline + 125
Particulate Matter (PM)	NC	Baseline + 2.23	Baseline + 2.51	Baseline + 2.51	Baseline + 2.51	Baseline + 8.95	Baseline + 0.076	Baseline + 1.83	Baseline + 2.51
Carbon Monoxide (CO)	NC	Baseline + 331	Baseline + 418	Baseline + 418	Baseline + 418	Baseline + 684	Baseline + 11.7	Baseline + 155	Baseline + 418
Hydrogen Sulfide (H_2S)	70,000	70,000	70,000	70,000	70,000	7,700	11,500	69,200	101,000
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline + 356,000,000	Baseline + (1,247,213,400)	Baseline

NC = Not calculated

Table 13-5. Threshold 1 NWQIs for Chickens

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	69,900	69,900	69,900	69,900	69,900	28,600	29,600	69,900	69,900
Carbon Dioxide (CO_2)	29,900	29,900	29,900	29,900	29,900	143,000	12,700	29,900	29,900
Nitrous Oxide (N_2O)	18,000	18,000	18,000	18,000	18,000	18,000	18,600	18,000	18,000
Ammonia (NH_3)	153,000	152,000	144,000	144,000	144,000	141,000	142,000	144,000	144,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 4.78	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9	Baseline + 10.9
Nitrogen Oxides (NO_x)	NC	Baseline + 18.4	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8	Baseline + 41.8
Particulate Matter (PM)	NC	Baseline + 0.368	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837	Baseline + 0.837
Carbon Monoxide (CO)	NC	Baseline + 57.0	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130	Baseline + 130
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

Table 13-6. Threshold 1 NWQIs for Turkeys

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons\yr)									
Methane (CH_4)	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
Carbon Dioxide (CO_2)	3,390	3,390	3,390	3,390	3,390	3,390	3,390	3,390	3,390
Nitrous Oxide (N_2O)	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250
Ammonia (NH_3)	26,300	26,000	23,500	23,500	23,500	23,500	23,500	23,500	23,500
Volatile Organic Compounds (VOCs)	NC	Baseline + 1.12	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05	Baseline + 4.05
Nitrogen Oxides (NO_x)	NC	Baseline + 4.31	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58	Baseline + 15.58
Particulate Matter (PM)	NC	Baseline + 0.086	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312	Baseline + 0.312
Carbon Monoxide (CO)	NC	Baseline + 13.4	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3	Baseline + 48.3
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

Table 13-7. Threshold 2 NWQIs for Beef (Includes Heifers)

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	79,700	76,500	76,500	76,500	76,500		102,000	76,500	76,500
Carbon Dioxide (CO_2)	34,200	32,800	32,800	32,800	32,800		43,900	32,800	32,800
Nitrous Oxide (N_2O)	36,500	36,500	36,500	36,500	36,500		37,400	36,500	36,500
Ammonia (NH_3)	355,000	321,000	314,000	314,000	314,000		540,000	314,000	315,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 513	Baseline + 591	Baseline + 591	Baseline + 591		Baseline + 626	Baseline + 591	Baseline + 591
Nitrogen Oxides (NO_x)	NC	Baseline + 1,970	Baseline + 2,270	Baseline + 2,274	Baseline + 2,274		Baseline + 2,406	Baseline + 2,275	Baseline + 2,274
Particulate Matter (PM)	NC	Baseline + 39.5	Baseline + 45.5	Baseline + 45.5	Baseline + 45.5		Baseline + 48.1	Baseline + 45.5	Baseline + 45.5
Carbon Monoxide (CO)	NC	Baseline + 6,120	Baseline + 7,051	Baseline + 7,051	Baseline + 7,051		Baseline + 7,460	Baseline + 7,052	Baseline + 7,051
Energy Usage (kW-hr/yr)									
Electricity Usage	427,000,000	457,000,000	705,000,000	705,000,000	705,000,000		705,000,000	705,000,000	705,000,000

NC = Not calculated

Table 13-8. Threshold 2 NWQIs for Dairy

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	225,000	144,000	144,000	144,000	144,000		186,000	51,700	144,000
Carbon Dioxide (CO_2)	97,000	62,400	62,400	62,400	62,400		98,100	319,000	62,400
Nitrous Oxide (N_2O)	4,840	8,770	8,770	8,770	8,770		27,000	9,830	8,770
Ammonia (NH_3)	195,000	191,000	189,000	189,000	189,000		229,000	189,000	186,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 447	Baseline + 371	Baseline + 371	Baseline + 371		Baseline + 379	Baseline + 363	Baseline + 371
Nitrogen Oxides (NO_x)	NC	Baseline + 1,720	Baseline + 1,430	Baseline + 1,430	Baseline + 1,430		Baseline + 1,460	Baseline + 1,400	Baseline + 1,430
Particulate Matter (PM)	NC	Baseline + 34.4	Baseline + 28.5	Baseline + 28.5	Baseline + 28.5		Baseline + 29.2	Baseline + 27.9	Baseline + 28.5
Carbon Monoxide (CO)	NC	Baseline + 5,330	Baseline + 4,420	Baseline + 4,420	Baseline + 4,420		Baseline + 4,520	Baseline + 4,330	Baseline + 4,420
Baseline + Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline + 132,000,000	Baseline + 230,000,000	Baseline + 230,000,000	Baseline + 230,000,000		Baseline + 230,000,000	Baseline + (912,000,000)	Baseline + 230,000,000

NC = Not calculated

Table 13-9. Threshold 2 NWQIs for Veal

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	80.1	80.1	80.1	80.1	80.1	30.4	80.1	80.1	80.1
Carbon Dioxide (CO_2)	34.3	34.3	34.3	34.3	34.3	150	34.3	34.3	34.3
Nitrous Oxide (N_2O)	11.7	11.7	11.7	11.7	11.7	11.1	11.7	11.7	11.7
Ammonia (NH_3)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Volatile Organic Compounds (VOCs)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Nitrogen Oxides (NO_x)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Particulate Matter (PM)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Carbon Monoxide (CO)	NC	NC	NC	NC	NC	NC	NC	NC	NC
Energy Usage (kW-hr/yr)									
Electricity Usage	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000	4,550,000

NC = Not calculated

Table 13-10. Threshold 2 NWQIs for Swine

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	275,000	275,000	275,000	275,000	275,000	118,000	115,000	93,900	275,000
Carbon Dioxide (CO_2)	118,000	118,000	118,000	118,000	118,000	549,000	49,100	616,000	118,000
Nitrous Oxide (N_2O)	518	518	518	518	518	321	10,400	190	518
Ammonia (NH_3)	142,000	142,000	142,000	142,000	142,000	128,000	128,000	142,000	154,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 27.4	Baseline + 34.0	Baseline + 34.0	Baseline + 34.0	Baseline + 60.0	Baseline + 0.848	Baseline + 11.2	Baseline + 34.0
Nitrogen Oxides (NO_x)	NC	Baseline + 105	Baseline + 116	Baseline + 116	Baseline + 116	Baseline + 231	Baseline + 3.26	Baseline + 43.2	Baseline + 116
Particulate Matter (PM)	NC	Baseline + 2.11	Baseline + 2.32	Baseline + 2.32	Baseline + 2.32	Baseline + 4.62	Baseline + 0.065	Baseline + 0.86	Baseline + 2.32
Carbon Monoxide (CO)	NC	Baseline + 327	Baseline + 360	Baseline + 360	Baseline + 360	Baseline + 716	Baseline + 10.1	Baseline + 133	Baseline + 360
Hydrogen Sulfide (H_2S)	66,000	64,900	64,900	64,900	64,900	6,780	10,800	64,100	6,780
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline + 342,000,000	Baseline + (1,250,000,000)	Baseline

NC = Not calculated

Table 13-11. Threshold 2 NWQIs for Chickens

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	68,300	68,300	68,300	68,300	68,300	28,900	29,900	68,300	68,300
Carbon Dioxide (CO_2)	29,300	29,300	29,300	29,300	29,300	138,000	12,800	29,300	29,300
Nitrous Oxide (N_2O)	18,300	18,300	18,300	18,300	18,300	18,300	18,900	18,300	18,300
Ammonia (NH_3)	156,000	155,000	147,000	147,000	147,000	145,000	146,000	147,000	149,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 4.49	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2	Baseline + 10.2
Nitrogen Oxides (NO_x)	NC	Baseline + 17.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3	Baseline + 39.3
Particulate Matter (PM)	NC	Baseline + 0.345	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785	Baseline + 0.785
Carbon Monoxide (CO)	NC	Baseline + 53.5	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122	Baseline + 122
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

Table 13-12. Threshold 2 NWQIs for Turkeys

NWQI	Baseline	Regulatory Option							
		Option 1	Option 2	Option 3	Option 4	Option 5A	Option 5B	Option 6	Option 7
Air Emissions (Tons/yr)									
Methane (CH_4)	8,330	8,330	8,330	8,330	8,330	8,330	8,330	8,330	8,330
Carbon Dioxide (CO_2)	3,570	3,570	3,570	3,570	3,570	3,570	3,570	3,570	3,570
Nitrous Oxide (N_2O)	5,520	5,520	5,520	5,520	5,520	5,520	5,520	5,520	5,520
Ammonia (NH_3)	28,700	28,400	26,000	26,000	26,000	26,000	26,000	26,000	26,000
Volatile Organic Compounds (VOCs)	NC	Baseline + 1.01	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63	Baseline + 3.63
Nitrogen Oxides (NO_x)	NC	Baseline + 3.88	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0	Baseline + 14.0
Particulate Matter (PM)	NC	Baseline + 0.078	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279	Baseline + 0.279
Carbon Monoxide (CO)	NC	Baseline + 12.0	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3	Baseline + 43.3
Energy Usage (kW-hr/yr)									
Electricity Usage	NC	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

NC = Not calculated

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CHAPTER 14

GLOSSARY

aeration	the process of bringing air into contact with a liquid by one or more of the following methods: (1) spraying the liquid in the air, (2) bubbling air through the liquid, and (3) agitating the liquid to promote absorption of oxygen through the air liquid interface
aerobic	having or occurring in the presence of the free oxygen
aerobic lagoon	a holding and/or treatment pond that speeds up the natural process of biological decomposition of organic waste by stimulating the growth and activity of bacteria that degrade organic waste in an oxygen-rich environment
Ag Census	the census of agriculture conducted every 5 years; a major source of information about the structure and activities of agricultural production at the national, state, and county levels
agitation	thorough mixing of liquid or slurry manure at a storage structure to provide a more consistent fertilizer material and allow the producer to empty as much of the storage as possible
agronomic rates	the land application of animal wastes at rates of application that provide the crop or forage growth with needed nutrients for optimum health and growth
air emissions	release of any pollutant into the air
ammonia volatilization	the loss of ammonia gas to the atmosphere
anaerobic	the absence of molecular oxygen, or capable of living and growing in the absence of oxygen, such as anaerobic bacteria
anaerobic lagoon	a holding and/or treatment pond that speeds up the natural process of biological decomposition of organic waste by stimulating the growth and activity of bacteria that degrade organic waste in an oxygen-depleted environment

animal feeding operation (AFO)	a lot or facility (other than an aquatic animal production facility) 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 the animal confinement areas do not sustain crops, vegetation, forage growth, or postharvest residues in the normal growing season. Two or more animal feeding operations under common ownership are a single animal feeding operation if they adjoin each other or if they use a common area or system for the disposal of wastes.
APHIS	Animal and Plant Health Inspection Service, United States Department of Agriculture
baffle	a device (as a plate, wall, or screen) to deflect, check, or regulate flow (fluid, light, or sound)
barrow	a castrated male pig
berm	a narrow shelf, path, or ledge typically at the top or bottom of a slope; a mound or wall of earth
best available technology (BAT)	the best available technology that is economically achievable established under 301(b) and 402 of the Federal Water Pollution Control Act as amended, also known as the Clean Water Act, found at 33 USC 1251 et seq. The criteria and standards for imposing technology-based treatment requirements are listed in 40 CFR 125.3.
best conventional technology (BCT)	the best conventional pollutant control technology that is economically achievable established under 301(b) and 402 of the Federal Water Pollution Control Act as amended, also known as the Clean Water Act, found at 33 USC 1251 et seq. The criteria and standards for imposing technology-based treatment requirements are listed in 40 CFR 125.3.
best management practice (BMP)	a practice or combination of practices found to be the most effective, practicable (including economic and institutional considerations) means of preventing or reducing the amount of pollution generated
bioavailability	the degree and rate at which a substance is absorbed into a living system or is made available at the site of physiological activity
biochemical oxygen demand (BOD)	an indirect measure of the concentration of biodegradable substances present in an aqueous solution. Determined by the amount of dissolved oxygen required for the aerobic degradation of the organic matter at 20 °C. BOD_5 refers to that oxygen demand for the initial 5 days of the degradation process

biogas	a mixture of methane and carbon dioxide produced by the bacterial decomposition of organic wastes and used as a fuel
biosecurity	a defensive health plan and hygiene procedures that can help keep an animal feeding operation disease free
biosolids	solid organic matter recovered from a sewage treatment process and used especially as fertilizer
BPJ	best professional judgement
BPT	best practicable technology
broadcasting	method of application (seed or fertilizer) to the soil surface
broilers	chickens of either sex specifically bred for meat production and marketed at approximately 8 weeks of age
carcass-weight	weight of the dead body of an animal, slaughtered and gutted
certified specialist	someone who has been certified to prepare Comprehensive Nutrient Management Plans (CNMPs) by USDA or a USDA sanctioned organization
compaction	an increase in soil bulk density, limiting both root penetration, and water and nutrient uptake induced by tillage- and vehicular-traffic
composting	a process of aerobic biological decomposition of organic material characterized by elevated temperatures that, when complete, results in a relatively stable product suitable for a variety of agricultural and horticultural uses
concentrated animal feeding operation (CAFO)	an "animal feeding operation" that meets the criteria in 40 CFR Part 122, Appendix B, or an operation designated as a significant contributor of pollution pursuant to 40 CFR 122.23
costing	a systematic method or procedure used to develop the estimated costs of a technology or practice
cover crop	a close-growing crop, whose main purpose is to protect and improve the soil and use excess nutrients or soil moisture during the absence of the regular crop, or in the nonvegetated areas of orchards and vineyards

crop removal rate	the application rate for manure or wastewater which is determined by the amount of phosphorus which will be taken up by the crop during the growing season and subsequently removed from the field through crop harvest. Field residues do not count towards the amount of phosphorus removed at harvest.
crop rotation	a planned sequence of crops
denitrification	the chemical or biological reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen (N_2) or as an oxide of nitrogen (N_2O)
detention pond	a basin whose outlet has been designed to detain the storm water runoff from a design storm (e.g., 25 year/24 hour storm) for some minimum time to allow particles and associated pollutants to settle
digestion	the process whereby organic matter breaks down into simpler and/or more biologically stable products, e.g., ammonia to organic nitrogen
disking	cultivating with an implement that turns and loosens the soil with a series of discs
dry lots	open feedlots sloped or graded from 4 to 6 percent to promote drainage away from the lot to provide consistently dry areas for cattle to rest
effluent	the liquid discharge from a waste treatment process
endogenous	growing or produced by growth from deep tissue (e.g., plant roots)
ephemeral erosion	a shallow, concentrated flow path that develops as a response to a specific storm and disappears as a result of tillage or natural processes
erosion	the wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep
ERS	Economic Research Service, United States Department of Agriculture
evapotranspiration	the loss of water from an area by evaporation from the soil or snow cover and transpiration by plants
farrowing	the act of giving birth to pigs by the sow
farrow-to-finish	contains all three hog production phases: farrow, nursery, finish
fecal coliform	the bacterial count (Parameter 1) at 40 CFR 136.3 in Table 1A, which also cites the approved methods of analysis.

feedlot	a concentrated, confined animal or poultry growing operation for meat, milk, or egg production, or stabling, in pens or houses wherein the animals or poultry are fed at the place of confinement and crop or forage growth or production is not sustained in the area of confinement, and is subject to 40 CFR 412
fertilizer value	the value of noncommercial fertilizer (e.g., manure)
flushing system	a system that collects and transports or moves waste material with the use of water, such as in washing of pens and flushing of confinement livestock facilities
freeboard	the height above the recorded high-water mark of a structure (as a dam) associated with the water
FRN	federal registrar notice
frequency factor	the regional compliance of animal feeding operations with BMPs associated with a nutrient management plan, facility upgrades, or strategies to reduce excess nutrients
FORTRAN	one of the most widely used programming languages for solving problems in science and engineering
gilt	a young or immature female pig
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
ground water	water filling all the unblocked pores of underlying material below the water table
hen	a mature female chicken
incorporation	mixing manure into the soil, either by tillage or by subsurface injection, to increase manure nutrient availability for use by crops
injection	a tillage implement that cuts into the soil depositing liquid or slurry
integrators	poultry companies, under contract with growers, who supply birds, feed, medicines, transportation, and technical help
irrigation	application of water to lands for agricultural purposes (Soil Conservation Society of America, 1982)

lagoon	an all-inclusive term commonly given to a water impoundment in which organic wastes are stored or stabilized, or both. Lagoons may be described by the predominant biological characteristics (aerobic, anaerobic, or facultative), by location (indoor, outdoor), by position in a series (primary, secondary, or other), and by the organic material accepted (sewage, sludge, manure, or other)
land application	application of manure, sewage sludge, municipal wastewater, and industrial wastes to land for reuse of the nutrients and organic matter for their fertilizer and soil conditioning values
land application area	any land under the control of the CAFO operator, whether it is owned, rented, or leased, to which manure and process wastewater is or may be applied
layer	a mature hen that is producing eggs
leaching	(1) the removal of soluble constituents, such as nitrates or chlorides, from soils or other material by the movement of water; (2) the removal of salts and alkali from soils by irrigation combined with drainage; (3) the removal of a liquid through a non-watertight artificial structure, conduit, or porous material by downward or lateral drainage, or both, into the surrounding permeable soil
load	quantity of substance entering the receiving body
macronutrient	a chemical element required, in relatively large amounts, for proper plant growth
manure	the fecal and urinary excretions of livestock and poultry
micronutrient	a chemical element required, in relatively small amounts, for proper plant growth
mulch	any substance that is spread on the soil surface to decrease the effects of raindrop impact, runoff, and other adverse conditions and to retard evaporation
NAHMS	National Animal Health Monitoring System, United States Department of Agriculture
NASS	National Agricultural Statistics Service, United States Department of Agriculture

new source	a source that is subject to subparts C or D of 40 CFR 412 and, not withstanding the criteria codified at 40 CFR 122.29(b)(1): (i) is constructed at a site at which no other source is located; or (ii) replaces the housing including animal holding areas, exercise yards, and feedlot, waste handling system, production process, or production equipment that causes the discharge or potential to discharge pollutants at an existing source; or (iii) constructs a production area that is substantially independent of an existing source at the same site. Whether processes are substantially independent of an existing source, depends on factors such as the extent to which the new facility is integrated with the existing facility; and the extent to which the new facility is engaged in the same general type of activity as the existing source.
nitrification	the biochemical transformation by oxidation of ammonium (NH_4^+) to nitrite (NO_2^-) or nitrate (NO_3^-)
nitrogen	a chemical element, commonly used in fertilizer as a nutrient, that is also a component of animal wastes. Plant available nitrogen forms include nitrate (NO_3^-) and ammonium (NH_4^+).
no-till	a planting procedure that requires no tillage except that done in the immediate area of the crop row
NRCS	Natural Resource Conservation Service, United States Department of Agriculture
NSPS	New Source Performance Standards are uniform national EPA air emission and water effluent standards that limit the amount of pollution allowed from new sources or from modified existing sources
nutrient management	a planning tool used to control the amount, source, placement, form, and timing of the application of nutrients and soil amendments (USDA, 1999)
nutrient management plan	an approach for managing the form, rate, timing, and method of application of nutrients, including nutrients from biosolids, being applied to the soil in a manner that provides adequate plant nutrition but minimizes the environmental impact of these nutrients
nutrient removal rate	the removal of nutrients in harvested material on a per acre basis
NWPCAM	National Water Pollution Control Assessment Model
organic matter	the organic fraction of the soil exclusive of undecayed plant and animal residue

overflow	the process wastewater discharge resulting from the filling of wastewater or liquid manure storage structures to the point at which no more liquid can be contained by the structure
permit nutrient plan (PNP)	a plan developed in accordance with 40 CFR 412.33 (b) and §412.37. This plan shall define the appropriate rate for applying manure or wastewater to crop or pasture land. The plan accounts for soil conditions, concentration of nutrients in manure, crop requirements and realistic crop yields when determining the appropriate application rate.
phosphorus	one of the primary nutrients required for the growth of plants. Phosphorus is often the limiting nutrient for the growth of aquatic plants and algae.
phosphorus level	a system of weighing a number of measures that relate the potential for phosphorus loss due to site and transport characteristics. The phosphorus index must at a minimum include the following factors when evaluating the risk for phosphorus runoff from a given field or site: (1) Soil erosion. (2) Irrigation erosion. (3) Run-off class. (4) Soil phosphorus test. (5) Phosphorus fertilizer application rate. (6) Phosphorus fertilizer application method. (7) Organic phosphorus application rate. (8) Method of applying organic phosphorus.
phosphorus threshold (TH level)	a specific soil test concentration of phosphorus established by states. The concentration defines the point at which soluble phosphorus may pose a surface runoff risk.
photoperiod	the time between sunrise and sunset
phytase	an enzyme effective at increasing the breakdown of phytase phosphorus in the digestive tract and reducing the phosphorous excretion in the feces
point source	the release of a contaminant or pollutant, often in concentrated form, from a conveyance system, such as a pipe, into a waterbody
porous dam	a runoff control structure that reduces the rate of runoff so that solids settle out in the settling terrace or basin. The structure may be constructed of rock, expanded metal, or timber arranged with narrow slots.

potassium	one of the primary nutrients required for the growth of plants
poult	a young, immature turkey
precipitation	a deposit on the earth of hail, mist, rain, sleet, or snow; *also* **:** the quantity of water deposited
pretreatment	a process used to reduce, eliminate, or alter the nature of wastewater pollutants from nondomestic sources before they are discharged into publicly owned treatment works
process wastewater	water directly or indirectly used in the operation of the CAFO for any or all of the following: spillage or overflow from animal or poultry watering systems; washing, cleaning, or flushing pens, barns, manure pits, or other CAFO facilities; direct contact swimming, washing or spray cooling of animals; litter or bedding; dust control; and stormwater which comes into contact with any raw materials, products or by-products of the operation.
production area	that part of the CAFO that includes the animal confinement area, the manure storage area, the raw materials storage area, and the waste containment areas. The animal confinement area includes but is not limited to open lots, housed lots, feedlots, confinement houses, stall barns, free stall barns, milkrooms, milking centers, cowyards, barnyard, exercise yards, animal walkways, and stables. The manure storage area includes but is not limited to lagoons, sheds, under house or pit storage, liquid impoundments, static piles, and composting piles. The raw materials storage area includes but is not limited to feed silos, silage bunkers, and bedding materials. The waste containment area includes but is not limited to settling basins, and areas within berms, and diversions which separate uncontaminated stormwater . Also included in the definition of production area is any egg washing or egg processing facility.
production phase	the animal life cycles grouped into discreet categories based on age and maturity
protease	any of numerous enzymes that hydrolyze proteins and are classified according to the most prominent functional group (as serine or cysteine) at the active site
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
pullet	an immature female chicken

reduced-till	a management practice whereby the use of secondary tillage operations is significantly reduced
residue cover	unharvested material left on the soil surface designed to reduce water and wind erosion, maintain or increase soil organic matter, conserve soil moisture, stabilize temperatures, and provide food and escape cover for wildlife
RFA	Regulatory Flexibility Analysis
rill erosion	an erosion process in which numerous small channels of only several centimeters in depth are formed; occurs mainly on recently cultivated soils
runoff	the part of precipitation or irrigation water that appears in surface streams of waterbodies; expressed as volume (acre-inches) or rate of flow (gallons per minute, cubic feet per second)
SBA	Small Business Administration
SBREFA	Small Business Regulatory Enforcement Fairness Act
setback	a specified distance from surface waters or potential conduits to surface waters where manure and wastewater may not be land applied. Examples of conduits to surface waters include, but are not limited to, tile line intake structures, sinkholes, and agricultural well heads.
sheet erosion	soil erosion occurring from a thin, relatively uniform layer of soil particles on the soil surface; also called interrill erosion
side-dressing	the application of fertilizer alongside row crop plants, usually on the soil surface. Nitrogen materials are most commonly side-dressed.
sludge	settled sewage solids combined with varying amounts of water and dissolved materials that are removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion
slurry	a thin mixture of a liquid and finely divided particles
soil test phosphorus	the measure of the phosphorus content in soil as reported by approved soil testing laboratories using a specified analytical method
sow	a mature female hog
spreader	a farm implement used to scatter fertilizer
supernatant	the liquid fraction in a lagoon

surface runoff	the portion of precipitation on an area that is discharged from the area through stream channels
surface water	all water whose surface is exposed to the atmosphere (Soil Conservation Society of America, 1982)
suspended solids	(1) undissolved solids that are in water, wastewater, or other liquids and are largely removable by filtering or centrifuging; (2) the quantity of material filtered from wastewater in a laboratory test, as prescribed in APHA Standard Methods for the Examination of Water and Wastewater or similar reference
tanker	a vehicle constructed to transport bulk liquids
tom	a male turkey
total suspended solids (TSS)	the weight of particles that are suspended in water. Suspended solids in water reduce light penetration in the water column, can clog the gills of fish and invertebrates, and are often associated with toxic contaminants because organics and metals tend to bind to particles. Differentiated from total dissolved solids by a standardized filtration process whereby the dissolved portion passes through the filter.
USDA	United States Department of Agriculture
volatilization	the loss of gaseous components, such as ammonium nitrogen, from animal manure
waste management system	a combination of conservation practices formulated to appropriately manage a waste product that, when implemented, will recycle waste constituents to the fullest extent possible and protect the resource base in a nonpolluting manner
wastewater	the spent or used water from a home, a community, a farm, or an industry that contains dissolved or suspended matter
water quality	the excellence of water in comparison with its intended use or uses