4. NATIONAL AND LOCAL IMPACTS OF ANIMAL AGRICULTURE

4.1 NATIONAL WATER QUALITY INVENTORY RESULTS

Agricultural operations, including AFOs, are a significant source of water pollution in the United States. The recently released *National Water Quality Inventory: 1998 Report to Congress* (USEPA, 2000a) was prepared under Section 305(b) of the Clean Water Act.[11] Under this section of the Act, states and tribes report their impaired water bodies to the EPA, including the suspected sources of those impairments. The most recent report indicates that agriculture (which includes crop production, pasture and range grazing, concentrated and other confined animal feeding operations, and aquaculture) is the leading contributor to identified water quality impairments in the nation's rivers and lakes, and the fifth leading contributor to identified water quality impairments in the nation's estuaries (Exhibit 4-1).

EXHIBIT 4-1
Five Leading Sources of Water Quality Impairment in the United States

Rank	Rivers	Lakes	Estuaries
1	**Agriculture** (59%)	**Agriculture** (31%)	Municipal Point Sources (28%)
2	Hydromodification (20%)	Hydromodification (15%)	Urban Runoff/Storm Sewers (28%)
3	Urban Runoff/Storm Sewers (11%)	Urban Runoff/Storm Sewers (12%)	Atmospheric Deposition (23%)
4	Municipal Point Sources (10%)	Municipal Point Sources (11%)	Industrial Discharges (15%)
5	Resource Extraction (9%)	Atmospheric Deposition (8%)	**Agriculture** (15%)

Source: USEPA (2000a).
Fraction of impairment attributed to each source is shown in parentheses. For example, agriculture is listed as a source of impairment in 59 percent of impaired river miles. The portion of "agricultural" impairment attributable to animal waste (as compared to crop production, pasture grazing, range grazing, and aquaculture) is not specified. Figure totals exceed 100 percent because water bodies may be impaired by more than one source.

Exhibit 4-2 presents additional summary statistics from the 1998 *National Water Quality Inventory*. These figures indicate that agriculture contributes to the impairment of at least 170,000 river miles, 2.4 million lake acres, and almost 2,000 estuarine square miles. The total portion of impairment attributable to animal agriculture nationwide is unknown, because only a portion of all states and tribes identified specific agricultural sources. Some conclusions, however, can be made based on the reporting states, as indicated in Exhibit 4-3.

[11] This report can be found on the Internet at http://www.epa.gov/305b/98report.

EXHIBIT 4-2
Summary of U.S. Water Quality Impairment Survey

Total Quantity in U.S.	Waters Assessed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture [a]
Rivers 3,662,255 miles	23% of total 840,402 miles	35% of assessed 291,263 miles	**59% of impaired** **170,750 miles**
Lakes, Ponds, and Reservoirs 41.6 million acres	42% of total 17.4 million acres	45% of assessed 7.9 million acres	**31% of impaired** **2,417,801 acres**
Estuaries 90,465 square miles	32% of total 28,687 square miles	44% of assessed 12,482 square miles	**15% of impaired** **1,827 square miles**

Source: USEPA (2000a).
[a] AFOs are a subset of the agriculture category. Summaries of impairment by non-agricultural sources are not presented here.

EXHIBIT 4-3
Percent of Total Agricultural Impairment Contributed by Animal Agriculture

Type of Animal Agriculture	Rivers, Streams[a]	Lakes, Ponds, Reservoirs[b]
AFOs (Feedlots, Holding Areas, Other)	16	4
Range and Pasture Grazing	17	39

[a] Based on reports from 28 states.
[b] Based on reports from 16 states.
Note: Impairment due to land application of manure was not reported.

Exhibit 4-4 lists the leading pollutants impairing surface water quality in the United States. AFOs are a potential source of all listed pollutants, but are most commonly associated with nutrients, pathogens, oxygen-depleting substances, and solids (siltation). AFOs can also contribute to the growth of noxious aquatic plants due to the discharge of excess nutrients. Further, AFOs may contribute loadings of priority toxic organic chemicals and oil and grease, but probably to a lesser extent than the other leading pollutants.

Pollutants associated with AFOs can also originate from a variety of other sources, such as cropland, municipal and industrial wastewater discharges, urban runoff, and septic systems. The national analyses described in the following section are useful in assessing the significance of animal waste as a potential or actual contributor to water quality degradation across the United States.

EXHIBIT 4-4
Five Leading Causes of Water Quality Impairment in the United States

Rank	Rivers	Lakes	Estuaries
1	**Siltation** (38%)	**Nutrients** (44%)	**Pathogens** (47%)
2	**Pathogens** (36%)	Metals (27%)	**Oxygen-Depleting Substances** (42%)
3	**Nutrients** (29%)	**Siltation** (15%)	Metals (27%)
4	**Oxygen-Depleting Substances** (23%)	**Oxygen-Depleting Substances** (14%)	**Nutrients** (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

Source: USEPA (2000a).
Note: Percent impairment attributed to each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 38 percent of impaired river miles. Items in bold print are those commonly associated with animal feeding operations, although they are also associated with other sources. Figure totals exceed 100 percent because water bodies may be impaired by more than one source.

4.2 NATIONAL ANALYSES OF NUTRIENT CONTRIBUTIONS

The national contribution and importance of nitrogen and phosphorus from animal operations has been estimated in several analyses. The first two analyses (Sections 4.2.1 and 4.2.2) focus on the production of nitrogen/phosphorus (and therefore, the potential for animal waste to contribute to nutrient loadings in water), whereas the last analysis (Section 4.2.3) uses sophisticated modeling techniques to estimate the amount of nutrients that reach surface water due to disposal and use of animal manure.

4.2.1 1994 USGS Study on Nitrogen Production from Various Sources

USGS analyzed nitrogen sources (manure, fertilizers, point sources, and atmospheric deposition)[12] in 107 U.S. watersheds, and found that the proportion of nitrogen originating from each source differs according to climate, hydrologic conditions, land use, population, and physical geography (Puckett, 1994).

Exhibit 4-5 displays results of the analysis for selected watersheds using information from 1987. As shown, the production of manure nitrogen relative to other sources varies by watershed. The "manure" source estimates include waste from both confined and unconfined animals. Puckett (1994) does not address whether the proportion of waste from confined facilities is larger or smaller than the fraction from unconfined animals. In some cases, manure nitrogen is a large

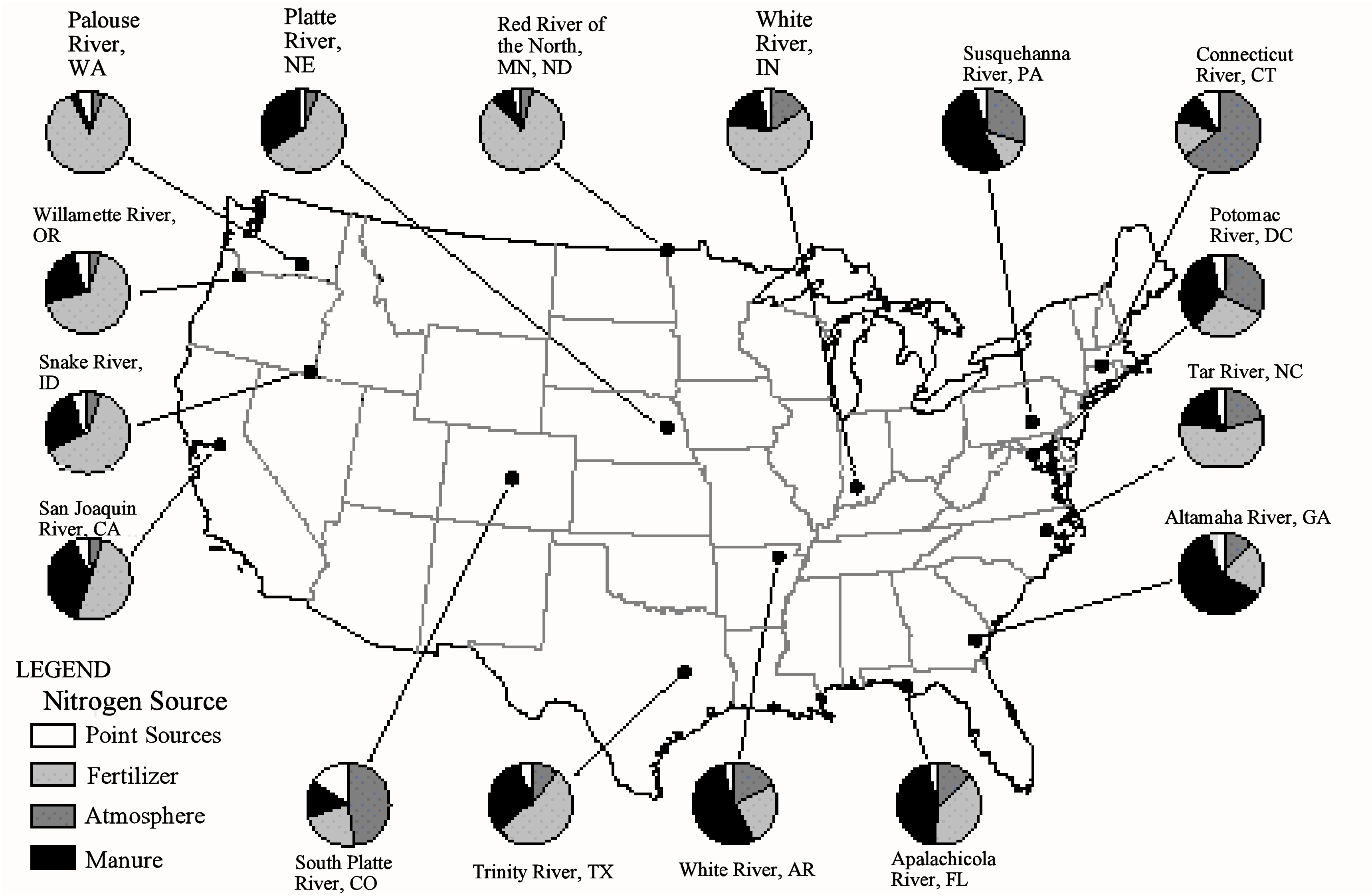
[12]The analysis does not include other potentially significant sources of nitrogen, such as urban runoff, sewer overflows, septic systems, and contaminated ground water.

portion of the total nitrogen added to the watershed. In the following watersheds, more than 25 percent of nitrogen originates from manure:

- Trinity River, Texas
- White River, Arkansas
- Apalachicola River, Florida
- Altamaha River, Georgia
- Potomac River, District of Columbia
- Susquehanna River, Pennsylvania
- Platte River, Nebraska
- Snake River, Idaho
- San Joaquin River, California

As indicated by the wide distribution of these geographic areas, significant contributions of nitrogen from animal manure occur throughout the U.S.

EXHIBIT 4-5
Proportions of Nitrogen Sources in Selected Watersheds (1987 Base Year)



Source: Puckett (1994). Note: CAFO point sources are included in the "manure" category.

4.2.2 1998 USDA Study of Nitrogen and Phosphorus Production Relative to Crop Uptake Potential

Because of its nutrient content, animal manure is a valuable crop fertilizer. However, if nutrients are applied in excess of amounts that can be used by plants, there may be a greater potential for releases to the environment. Based on data from the 1992 Census of Agriculture (USDC/Census Bureau, 1994), USDA evaluated the quantity of nutrients available from recoverable livestock manure relative to crop growth requirements, by county (Lander et al., 1998).[13] The analyses are intended to reflect the amount of manure that can be recovered and utilized; the analyses therefore do not consider manure from unconfined animals.

Exhibits 4-6 and 4-7 show the estimated useable manure nitrogen and phosphorus production from confined livestock, including swine, chickens, turkeys, and cattle. The figures account for the inability to completely recover manure, as well as typical nutrient losses during storage and treatment. These losses can be significant, particularly for nitrogen, due to the high volatilization potential of ammonia.[14] Considering typical management systems, average manure nitrogen losses range from 31 to 50 percent for poultry, 60 to 70 percent for cattle (beef, dairy, and other categories), and 75 percent for swine. By contrast, the typical phosphorus loss is 15 percent (Lander et al., 1998).

Exhibits 4-8 and 4-9 illustrate the potential for available manure nitrogen and phosphorus to meet or exceed plant uptake and removal in each of the 3,141 mainland counties, considering harvested non-legume[15] cropland and hayland. (See Lander et al. [1998] for results of additional analyses which also consider legume cropland and pastureland.) Based on this analysis, available manure nitrogen exceeds crop system needs in 266 counties, and available manure phosphorus exceeds crop needs in 485 counties. The relative excess of phosphorus compared to nitrogen is not surprising, since manure is typically nitrogen-deficient relative to crop needs. Therefore, when manure is applied to meet a crop's nitrogen requirement, phosphorus is typically applied in excess of its crop requirement (Sims, 1995).

Several points underscore the magnitude of the problem. First, in several of the counties where animal manure nutrients exceeded crop capacities, excesses would occur even if manure were applied to all suitable land in those counties. In addition, county-wide nutrient balances likely

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[13]County level data are not yet available for the 1997 Census. However, in Chapter 2, Exhibit 2-4 presents the national production of recoverable manure and nutrients generated by animal sector based on the 1997 Census data (USDA/NRCS, 2000; USDA/NASS, 1999).

[14]As noted earlier, volatilized ammonia can have significant impacts on air quality and water quality (via atmospheric deposition).

[15]Legumes (e.g., alfalfa, clovers, peas, and beans), through symbiotic biological nitrogen fixation, can "fix" atmospheric nitrogen gas into plant-available ammonia (Follett, 1995). Thus, legumes do not require nitrogen application.

understate occurrences of local nutrient excesses, because most manure remains on the farm where it was generated, and confined animal production farms often do not have enough land to accommodate the manure (Letson and Gollehon, 1998). Specifically, large, specialized animal production farms typically have a relatively high animal/acre ratio when compared to smaller, integrated farms, as indicated by information on consolidation trends presented in Chapter 2. Information is not available on the number of AFOs that lease land for manure application or distribute the manure to others.

In a more recent evaluation of manure nutrients relative to the capacity of cropland to assimilate nutrients, USDA estimated that 1.5 billion pounds of farm-level excess manure nitrogen and 0.9 billion pounds of farm-level excess phosphorus were produced in 1997, representing about 60 percent of the recoverable manure nitrogen and 65 percent of the recoverable manure phosphorus. Excess farm level nutrients increased by more than 60 percent for both phosphorus and nitrogen between 1982 and 1997, and most were associated with large farms by 1997. For example, AFOs accounted for 64 percent of the excess nitrogen and 67 percent of the excess phosphorus in 1997 (Kellogg et al., 2000).

These USDA analyses are not intended to reflect actual manure management practices, but rather the *potential* for manure nutrient usage, without consideration of economic conditions, land ownership limitations, and other nutrient sources (e.g., commercial fertilizers). Additionally, the analyses do not account for environmental transport of applied manure nutrients. Therefore, an excess of nutrients does not necessarily indicate that a water quality problem exists; likewise, a lack of excess nutrients does not imply the absence of water quality problems. Nevertheless, the analyses are useful as a general indicator of excess nutrients on a broad-scale basis.[16]

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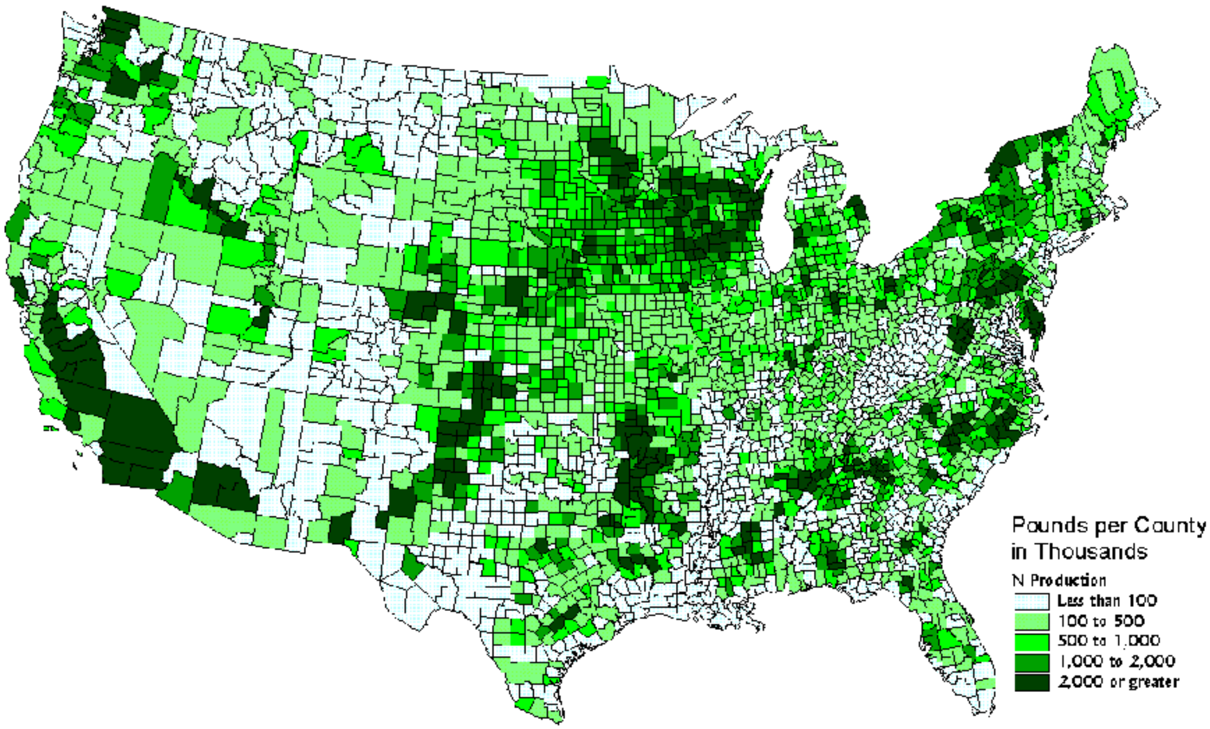
[16]See Lander et al. (1998) for a complete list of assumptions and limitations.

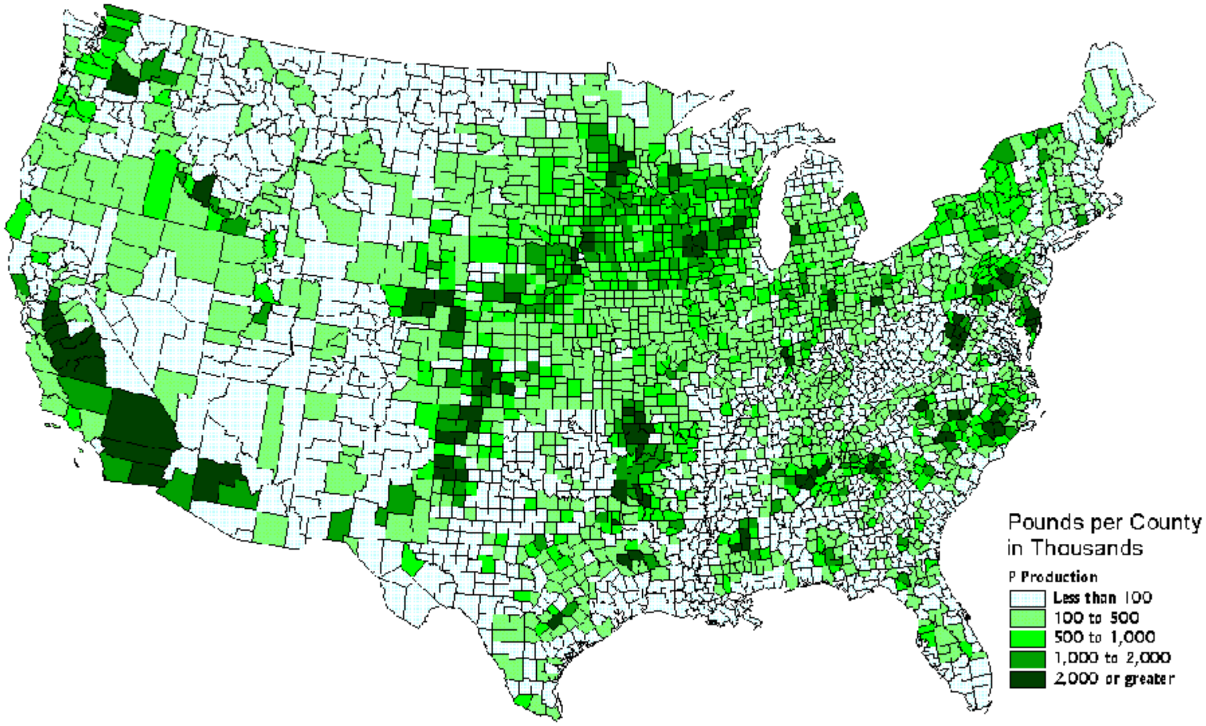
EXHIBIT 4-6
Estimated Manure Nitrogen Production from Confined Livestock



Source: Lander et al., 1998

Note: Manure nitrogen production includes recoverable manure nitrogen, after treatment/storage losses.

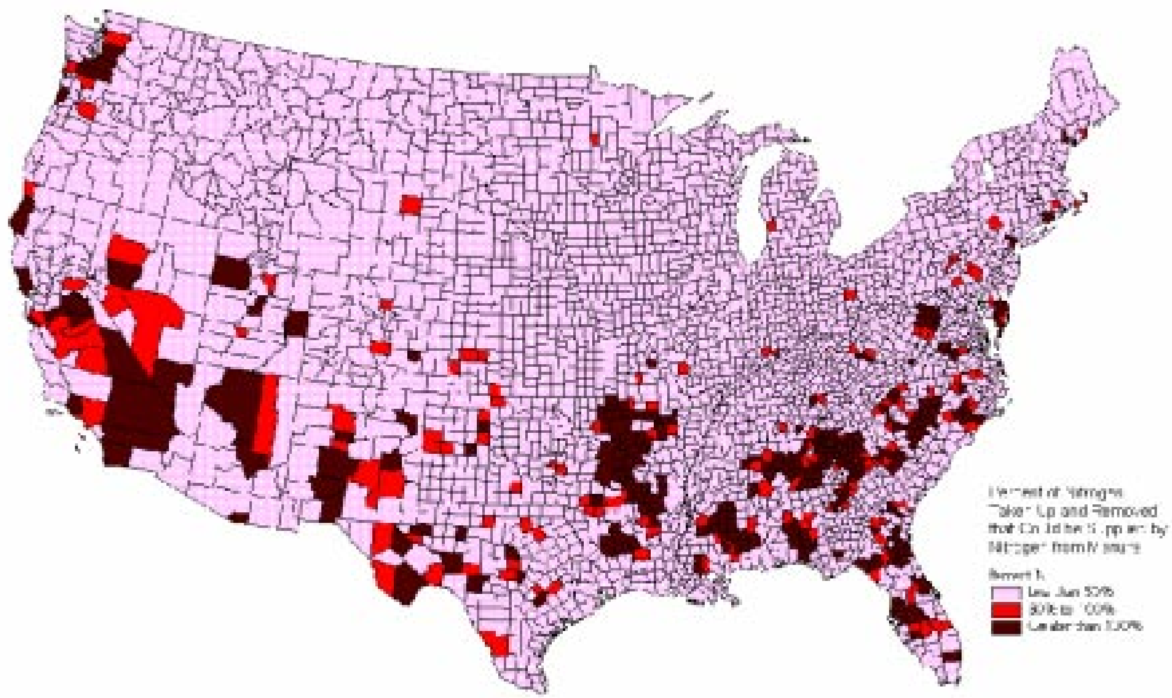
EXHIBIT 4-7
Estimated Manure Phosphorus Production from Confined Livestock



Source: Lander et al., 1998

Note: Manure phosphorus production includes recoverable manure phosphorus, after treatment/storage losses.

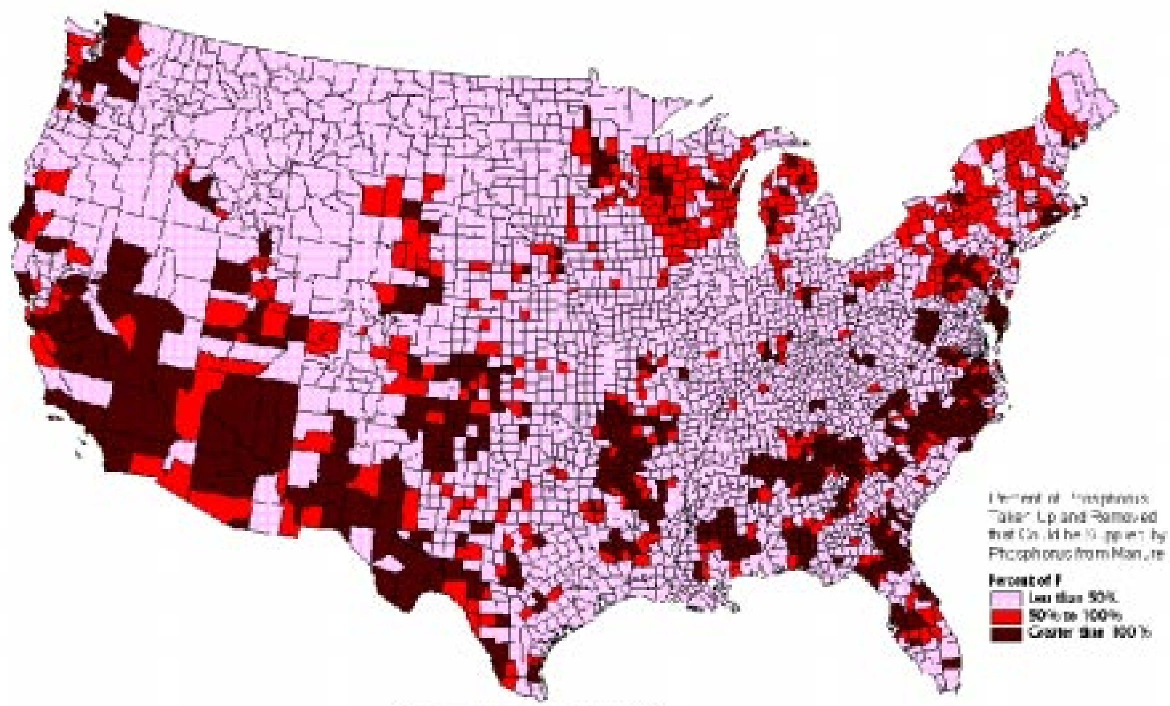
EXHIBIT 4-8
Potential for Nitrogen Available from Animal Manure to Meet or Exceed Uptake and Removal on Non-Legume, Harvested Cropland and Hayland



Source: Lander et al., 1998

Note: Nitrogen available from animal manure includes recoverable manure nitrogen, after treatment/storage losses.

EXHIBIT 4-9
Potential for Phosphorus Available from Animal Manure to Meet or Exceed Uptake and Removal on Non-Legume, Harvested Cropland and Hayland



Source: Lander et al., 1998

Note: Phosphorus available from animal manure includes recoverable manure phosphorus, after treatment/storage losses.

4.2.3 1997 USGS Modeling Study of Nitrogen and Phosphorus Loadings to Surface Waters

The analyses described in Sections 4.2.1 and 4.2.2 are land-based and are not intended to represent in-stream water quality conditions. Delivery of nutrients to surface water is affected by many watershed characteristics, such as soil permeability, stream density, temperature, slope, and precipitation. Other watershed attributes, such as stream depth, stream velocity, and reservoir retention, further affect nutrient delivery along stream networks. USGS's SPARROW (SPAtially Referenced Regressions On Watershed attributes) water quality model accounts for these characteristics. SPARROW is a statistical method that relates measured water quality data to spatially referenced pollutant sources and watershed attributes. The model's regression equations express in-stream nutrient loads as a function of stream and land-surface characteristics. The equations incorporate point and non-point pollutant sources, as well as factors associated with material transport through the watershed (e.g., soil permeability and stream velocity). The model is used to describe spatial and temporal patterns in water quality and to identify factors and processes that influence those conditions (Smith et al., 1997).

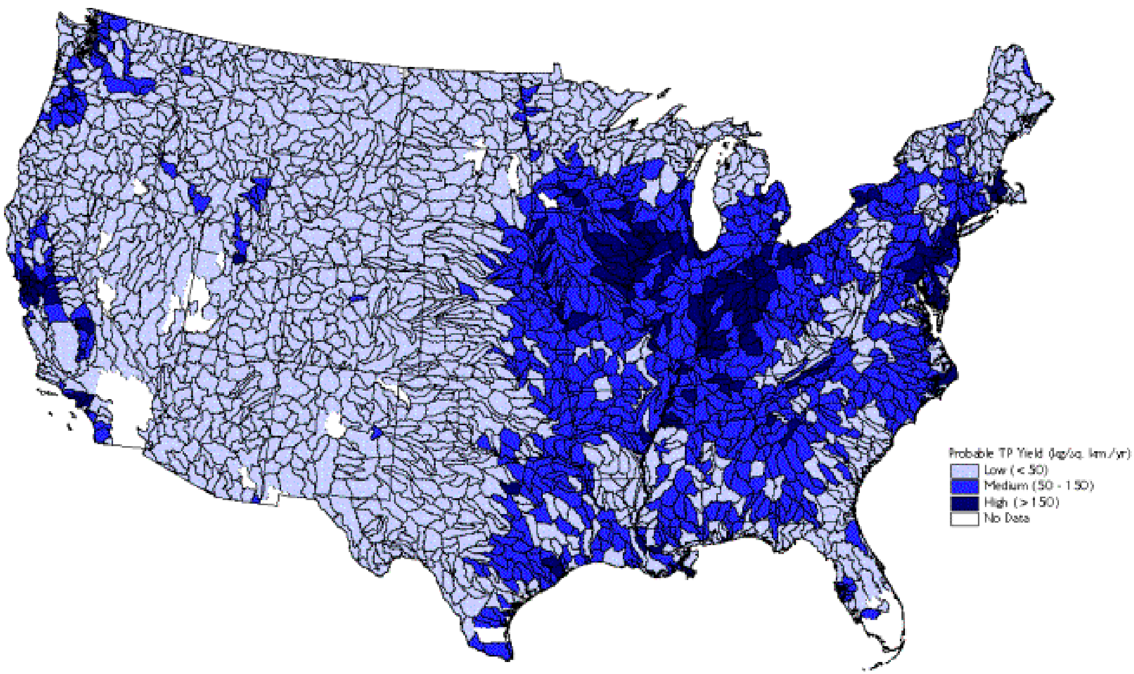
As described by Smith et al. (1997), USGS scientists applied the SPARROW model nationally to the 2,056 hydrologic cataloging units (watersheds) in the contiguous United States to estimate total nitrogen (TN) and total phosphorus (TP) export from various point and non-point sources (including commercial fertilizers, livestock waste, atmospheric nitrogen deposition, and non-agricultural land). Annual average livestock waste from both confined and unconfined animals was estimated for 1987, using data from the 1987 Census of Agriculture.[17]

Exhibits 4-10 and 4-11 present the predicted total local nitrogen and phosphorus yields (mass exported per unit of watershed area), from local (not upstream) sources. Exhibits 4-12 and 4-13 present the predicted percent contribution from animal waste to those local yields. The latter exhibits show that animal waste is a significant source (relative to other local sources) of in-stream nutrient concentrations in many watershed outlets, particularly in the central and eastern United States.

Smith et al. (1997) found that in general, commercial fertilizer contributes significantly more than livestock waste to local TN yield. By contrast, the analysis shows that livestock waste contributes more than commercial fertilizer to local TP yield. This may be due to the typically low N:P ratio in manure relative to crop N:P needs, which results in over-application of phosphorus when manure is applied to meet crop nitrogen requirements (Sims, 1995).

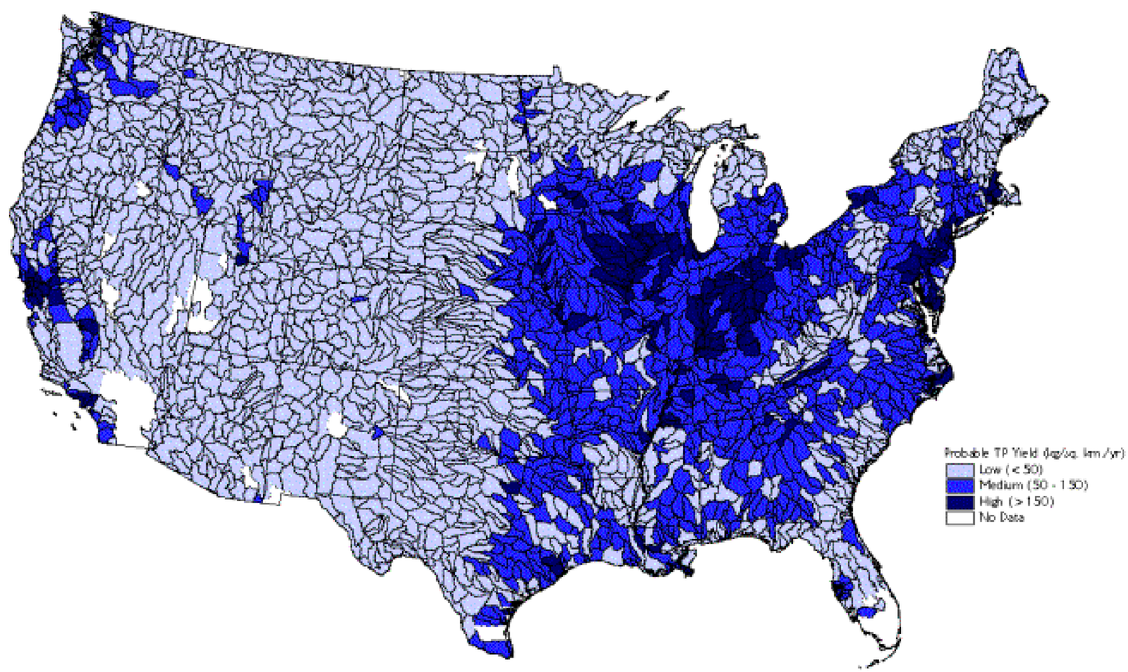
[17] Although CAFOs are designated as point sources in the Clean Water Act, they are included in the "livestock waste" category in this analysis. Point source data used in the analysis were obtained from a 1977 -1981 inventory (Smith et al., 1997).

EXHIBIT 4-10
Predicted Local Nitrogen Yield in Hydrologic Cataloging Units



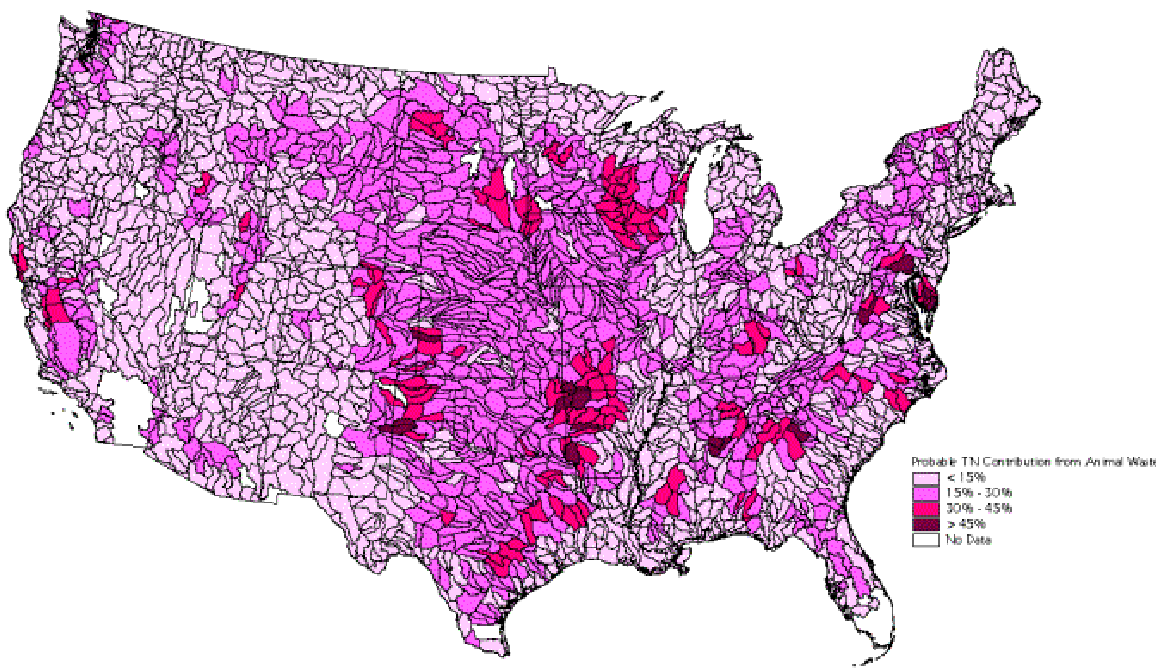
Based on information from "Regional Interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, and nonagricultural land.

EXHIBIT 4-11
Predicted Local Total Phosphorus Yield in Hydrologic Cataloging Units



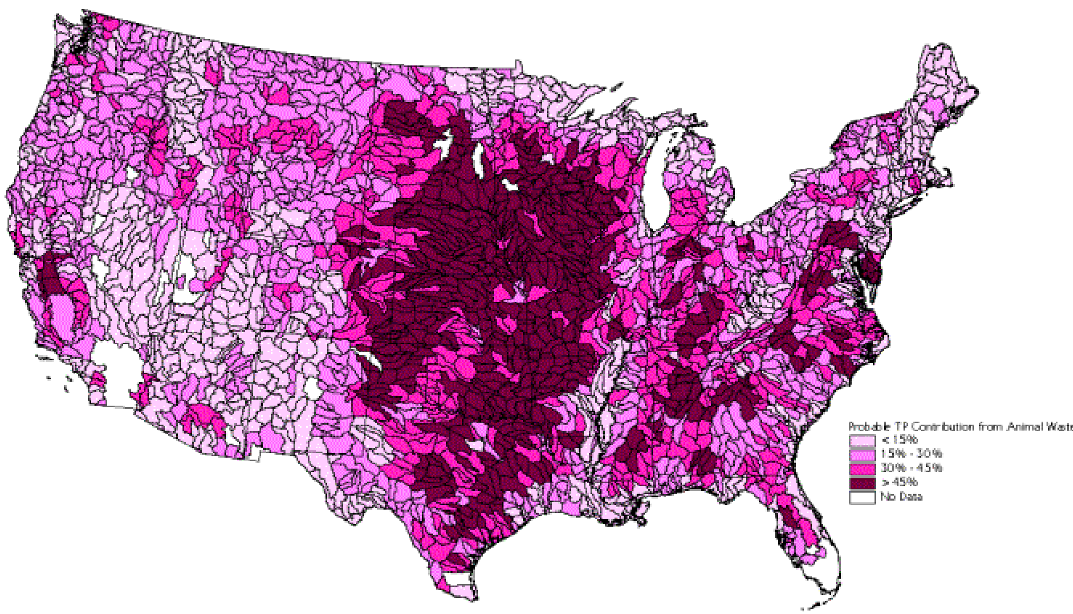
Based on information from "Regional Interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, and nonagricultural land.

EXHIBIT 4-12
Predicted Percentage Contribution of Animal Waste to Local Total Nitrogen Export from Hydrologic Cataloging Units



Based on information from "Regional Interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, atmospheric deposition, and nonagricultural land.

EXHIBIT 4-13
Predicted Percentage Contribution of Animal Waste to Local Total Phosphorus Export from Hydrologic Cataloging Units



Based on information from "Regional Interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, and nonagricultural land.

4.3 NATIONAL ANALYSIS OF SHELLFISH BED IMPAIRMENT

In *The 1995 National Shellfish Register of Classified Growing Waters*, the National Oceanic and Atmospheric Association (NOAA) characterizes the status of 4,230 shellfish-growing water areas in 21 coastal states, reflecting an assessment of nearly 25 million acres of estuarine and non-estuarine waters. These waters support a significant amount of shellfish produced in the United States. Specifically, over 77 million pounds were harvested from these waters in 1995, with a commercial value of $200 million (NOAA, 1997).

Results of this analysis are presented in Exhibit 4-14, which lists the number of shellfish beds impaired by feedlots, according to impairment classifications and estimated level of contribution. NOAA found that 3,404 shellfish areas had some level of impairment (i.e., a classification other than "approved" or "unclassified"). Of these, 110 (3 percent) were impaired to varying degrees by feedlots, and 280 (8 percent) were impaired by "other agriculture" (which could include land where manure is applied).

EXHIBIT 4-14
Shellfish Beds Impaired by Feedlots

Estimated Level of Contribution from Feedlots	Level of Impairment (Harvest Classification)				Total Impaired by Feedlots
	Conditionally Approved	Conditionally Restricted	Restricted	Prohibited	
Actual Contributor (High)	6	0	12	22	40
Actual Contributor (Medium)	3	1	16	23	43
Actual Contributor (Low)	2	1	2	9	14
Potential Contributor	1	0	8	4	13
TOTAL	12	2	38	58	110

Source: NOAA (1997).

4.4 LOCAL IMPACTS

This section presents documented local-level environmental incidents and impacts from animal feeding operations. The exhibits are organized by animal type and present information in three areas: (1) a listing of discharges directly to surface water revealing violations of the "no discharge" requirement; (2) human health related impacts; and (3) ecological, recreational, and other impacts. Exhibit 4-15 shows the organization of this information in the subsequent exhibits. Because this compilation resulted from a non-exhaustive literature search, it cannot be considered comprehensive. However, these exhibits show that a large number of events have been reported over time.

EXHIBIT 4-15
Description of Environmental Incidents and Impacts Tables

Topic/Animal Category	Swine	Poultry	Beef and Dairy	Unspecified or Multiple
Listing of Discharges to Surface Water	Exhibit 4-16 110 items	Exhibit 4-19 18 items	Exhibit 4-22 57 items	Exhibit 4-25 53 items
Human Health Related Impacts	Exhibit 4-17 6 items	Exhibit 4-20 2 items	Exhibit 4-23 2 items	Exhibit 4-26 3 items
Ecological, Recreational, Other Impacts	Exhibit 4-18 50* items	Exhibit 4-21 9* items	Exhibit 4-24 9* items	Exhibit 4-27 28* items

*Includes items from exhibits of discharge to surface water that indicated fish kills resulting from the discharge.

The relatively high number of reported surface discharges compared to fewer documented impacts probably reflects the higher visibility of the discharge events. Documenting environmental impacts from animal waste can be difficult, because as noted above, several manure constituents can also originate from other sources, and extensive investigations are sometimes required to estimate the relative contribution of each source. The events reported here are confined to impacts where AFOs were reported as a significant causative factor. Other contributing factors are identified to the extent that they were included in the literature. Examples of areas affected by animal waste are described in the following subsections.

Following Exhibits 4-16 through 4-27 are three examples that are discussed in more detail.

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
7/1/97	IL	Swine operation	800,000 gallons discharged	Contaminated drinking water of at least 5 homes with *Escherichia coli*; Illinois EPA levies fines totaling $9,600 or more, which will partially fund creek restoration	Illinois Stewardship Alliance (1997) Macomb Journal (1999)
10/17/97	Clear Creek, IA	Swine operation	28,134 fish killed	$4,000 direct cost + $2,000 fine	Iowa Department of Natural Resources (1998)
10/9/97	Brooke Creek, IA	Swine operation	4194 fish killed	$267.50 direct cost + $2,500 fine	Iowa Department of Natural Resources (1998)
9/18/97	Prairie Creek, IA	Swine operation	93,403 fish killed	$16,140.84 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
8/27/97	South Fork of Iowa River, IA	Swine operation	3,232 fish killed	$264.23 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/26/97	Crane Creek, IA	3,200 head swine operation	109,172 fish killed	Blocked pipe resulted in discharge. $33,882.73 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
9/4/96	North Buffalo Creek, IA	Swine operation	More than 100,000 gallons pumped into Creek; 586,753 fish killed	$30,000 direct cost + $3,000 fine	Iowa Department of Natural Resources (1998)
8/26/96	Rock Creek, IA	Swine operation	871 fish killed	$237 direct cost	Iowa Department of Natural Resources (1998)
8/19/96	Cedar County, IA	Swine operation	3,676 fish killed	$408.76 direct cost	Iowa Department of Natural Resources (1998)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
8/19/96	Tipton Creek, IA	Swine operation	46,315 fish killed	$3,908 direct cost + $3,000 fine	Iowa Department of Natural Resources (1998)
11/15/95	Indian Creek, IA	Swine operation	4,928 fish killed	$418 direct cost + $3,000 fine	Iowa Department of Natural Resources (1998)
9/25/95	Williams Creek, IA	Swine operation	60,650 fish killed	$21,436 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/23/95	Elk Creek tributary, IA	Swine operation	16,280 fish killed	$1,410 direct cost + $2,500 fine	Iowa Department of Natural Resources (1998)
7/20/95	Little Volga River, IA	Swine operation	23,416 fish killed	$8,155 direct cost + $1,500 fine	Iowa Department of Natural Resources (1998)
7/16/95	South Fork of Iowa River, IA	Swine operation	8,861 fish killed	$6,000 direct cost + $2,000 fine	Iowa Department of Natural Resources (1998)
7/1/95	Hamilton, IA	700 head swine operation	1.5 million gallons discharged; 8,800 fish killed	$8,000 fine	Clean Water Action Alliance (1998)
3/28/95	South English River tributary, IA	Swine operation	Fish kill	$4,000 fine	Iowa Department of Natural Resources (1998)
9/94	Kossuth County, IA	Swine operation	408 fish killed	$73 direct cost + $2,250 fine	Iowa Department of Natural Resources (1998)
9/94	Williams Creek, IA	Swine operation	Fish kill	$2,000 fine	Iowa Department of Natural Resources (1998)
8/94	Otter Creek, IA	Swine operation	1,882 fish killed	$968 direct cost	Iowa Department of Natural Resources (1998)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
5/94	Church Creek, IA	Swine operation	5,750 fish killed	$2,118 direct cost	Iowa Department of Natural Resources (1998)
5/94	Hickory Creek tributary, IA	Swine operation	8,397 fish killed	$722 direct cost + $300 fine	Iowa Department of Natural Resources (1998)
3/94	Eagle Creek, IA	Swine operation	Fish kill	$3,000 fine	Iowa Department of Natural Resources (1998)
12/93	Boone River, IA	Swine operation	Fish kill	$5,000 fine	Iowa Department of Natural Resources (1998)
11/93	Union County, IA	Swine operation	Fish kill	$1,000 fine	Iowa Department of Natural Resources (1998)
10/93	Middle Avery Creek, IA	Swine operation	Fish kill	$9,700 fine split between operation and waste management design company	Iowa Department of Natural Resources (1998)
9/93	South English River tributary, IA	Swine operation	Fish kill	$1,650 fine	Iowa Department of Natural Resources (1998)
7/93	Iowa River tributary	Swine operation	Fish kill	$3,000 fine	Iowa Department of Natural Resources (1998)
6/93	Keokuk County, IA	Swine operation	Fish kill	$4,500 fine	Iowa Department of Natural Resources (1998)
5/93	Brush Creek, IA	Swine operation	265,000 fish killed	$10,000 direct cost + $2,500 fine	Iowa Department of Natural Resources (1998)
4/93	Brookside Creek tributary, IA	Swine operation	Fish kill	$2,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
4/93	Iowa River tributary, IA	Swine operation	Fish kill	$300 fine	Iowa Department of Natural Resources (1998)
8/92	East Nishnabotna River, IA	Swine operation	Fish kill	$1,000 fine	Iowa Department of Natural Resources (1998)
8/92	Tipton Creek, IA	Swine operation	34,994 fish killed	$200 fine	Iowa Department of Natural Resources (1998)
7/92	Skunk River, IA	Swine operation		$100 fine	Iowa Department of Natural Resources (1998)
7/92	South River, IA	Swine operation	6,264 fish killed	From land application of lagoon contents; effects lasted for 2 months. $3,448 direct cost + $19,500 fine	Iowa Department of Natural Resources (1998)
7/92	Wright County, IA	Swine operation	Fish kill	$400 fine	Iowa Department of Natural Resources (1998)
3/92	Cedar River, IA	Swine operation		Retention basin overflow. $250 fine	Iowa Department of Natural Resources (1998)
2/92	Beaverdam Creek, IA	Swine operation		Below-building pit overflow. $300 fine	Iowa Department of Natural Resources (1998)
6/19/97	Renville County, MN	9,000 swine	100,000 gallons discharged; 690,000 fish killed	Lagoon overflow caused by timer malfunction. Fined for failure to notify.	Clean Water Action Alliance (1998)
8/96	Meeker County, MN	200 head swine operation	Overflowing lagoon		Clean Water Action Alliance (1998)
4/96	Blue Earth County, MN	500 head swine operation	Siphoned basin into a stream and had an un-permitted basin		Clean Water Action Alliance (1998)
4/96	Blue Earth County, MN	200 head swine operation	Siphoned pit/ un-permitted basin		Clean Water Action Alliance (1998)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
4/96	Nobles County, MN	Swine operation	Overflowing basin		Clean Water Action Alliance (1998)
4/96	Watonwan County, MN	700 head swine operation	Overflowing basin		Clean Water Action Alliance (1998)
2/96 - 4/96	Osborne Township, MN	Swine operation	Overflow from pit onto ground and into Rock River, at rate up to 12 gpm		Clean Water Action Alliance (1998)
10/95	Traverse County, MN	2,500 head swine operation	Overflowing pits		Clean Water Action Alliance (1998)
9/95	Lincoln County, MN	2,500 head swine operation	Pumped manure basin into a river		Clean Water Action Alliance (1998)
8/1/95	Lincoln, MN	Swine operation	5,000- 10,000 fish killed		Clean Water Action Alliance (1998)
5/95	Renville County, MN	700 head swine operation	Manure and contaminated wastewater flowed into a surface tile inlet in a county ditch		Clean Water Action Alliance (1998)
4/94 - 8/94	Lone Tree Township, MN	Swine operation	Pumped about 5,000 gallons of wastewater containing manure into a ditch every two weeks		Clean Water Action Alliance (1998)
4/94	Meeker County, MN	1,500 head swine operation	Multiple runoff problems		Clean Water Action Alliance (1998)
9/1/95	Gentry, MO	Swine operation	Unknown		NRDC (1995)
8/1/95	Greencastle MO	30,000 head swine operation	Over 20,000 gallons discharged; 173,000 fish killed		NRDC (1995)
8/96	Four-Mile Creek, NE	Swine operation	300-500 bullhead, 100 carp, 100 cyprinids killed	Lagoon discharge	Nebraska Department of Environmental Quality (1996)
6/95	Scholz Pond, NE	Swine operation	96 fish killed	Land application and pipeline break. $13.25 direct cost + $1,000 fine	Nebraska Department of Environmental Quality (1995b)
3/95	Swan Creek, NE	Swine operation	Fish kill	$971.66 direct cost + $10,000 fine	Nebraska Department of Environmental Quality (1995a)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
2/1/97	Pamlico, NC	4,000 swine	1,000 gallon discharge	No noticeable fish kill	Leavenworth (1997)
8/1/95	Brunswick County, NC	6,400 head swine operation	2 million gallons discharged	6th major livestock discharge in 2 weeks	Warrick (1995a)
8/1/95	Onslow, NC	Swine operation	Under 1 million gallons discharged		Warrick (1995a)
7/1/95	Bladen, NC	Swine operation	1 million gallons discharged over 2 days		NRDC (1995)
6/1-21/95	New River, Onslow County, NC	10,000 head swine operation	25 million gallons discharged; 3,000-4,000 fish killed	$110,000 fine, including $6,200 for fish kill and $92,000 in civil penalties	Meadows (1995); NRDC (1995); Warrick (1995b)
6/1/95	Sampson County, NC	Swine operation	1 million gallons discharged		NRDC (1995)
5/1/91	Duplin County, NC	Swine operation	“Tons of water” discharged		Stith and Warrick (1995)
12/10/96	West Branch Tontagony Creek, OH	Swine manure	Manure leaked into barn and into creek		Ohio Department of Natural Resources (1997)
10/10/96	Tributary to Beaver Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/03/96	West Branch Wolf Creek/Aldrich Run, OH	Swine manure	Manure ran off into ditch and into creek		Ohio Department of Natural Resources (1997)
35280	Tributary to Beaver Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/03/96	Tributary to Auglaize River (RM 87.75), OH	Swine manure	Liquid manure applied too heavily; runoff into tile		Ohio Department of Natural Resources (1997)
07/09/96	Little Tymochtee Creek, OH	Swine manure	Broken pipe on truck allowed manure to enter creek		Ohio Department of Natural Resources (1997)
05/17/96	Painter Creek, OH	Swine manure	Runoff from manure spreading		Ohio Department of Natural Resources (1997)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
02/27/96	Tributary to Pipe Creek, OH	Swine manure	Manure spread on fields, followed by snow melt and rain		Ohio Department of Natural Resources (1997)
12/06/95	Tributary to Stillwater River, OH	Swine manure	2,000,000 gallons pumped onto 54 acres		Ohio Department of Natural Resources (1997)
12/02/95	Little Tymochtee Creek, OH	Swine manure	Liquid manure pumped onto fields into tiles into creek		Ohio Department of Natural Resources (1997)
11/26/95	Leatherwood Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
10/25/95	Tributary to Spring Creek (RM 1.25), OH	Swine manure	Manure pumped onto fields, ran into tiles and to stream		Ohio Department of Natural Resources (1997)
10/20/95	Wolf Creek, OH	Swine manure	Unknown amount leaked from storage pit into stream		Ohio Department of Natural Resources (1997)
08/27/95	Indian Creek, OH	Swine manure	Lagoon pumped onto small field; drained into creek		Ohio Department of Natural Resources (1997)
34917	Indian Run, OH	Swine manure		Heavy rain after manure application to fields	Ohio Department of Natural Resources (1997)
07/03/95	Oak Run, OH	Swine manure	Accidental release from drain pipe during application		Ohio Department of Natural Resources (1997)
10/01/94	Second Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/24/94	Tributary to Lake Fork Mohican River, OH	Swine manure	Liquid manure entered field tile and creek		Ohio Department of Natural Resources (1997)
09/21/94	East Branch Salt Creek, OH	Swine manure	Swine fenced to stream, defecated on land - runoff to stream		Ohio Department of Natural Resources (1997)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
09/20/94	North Branch Salt Creek, OH	Swine manure	Swine fenced to stream, defecated on land - runoff to stream		Ohio Department of Natural Resources (1997)
09/11/94	Carter Creek, OH	Swine manure	800,000 gallons of manure applied to 8 acre field; discharged into tile into creek		Ohio Department of Natural Resources (1997)
05/31/94	Grog Run, OH	Swine manure	Lagoon drained via hose to field at edge of creek		Ohio Department of Natural Resources (1997)
07/15/93	Barcer Run, OH	Swine manure	Spray-irrigated manure ran off into stream		Ohio Department of Natural Resources (1997)
04/08/93	Tributary to Wabash River, OH	Swine manure			Ohio Department of Natural Resources (1997)
11/18/92	Tributary to Lick Creek, OH	Swine manure	Accidental discharge due to clogged pump		Ohio Department of Natural Resources (1997)
33841	Little Sugar Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/12/92	Tributary to Auglaize River, OH	Swine manure	Irrigated manure runoff into tile into creek		Ohio Department of Natural Resources (1997)
09/18/91	Salt Creek, OH	Swine manure	Manure washed into stream		Ohio Department of Natural Resources (1997)
08/24/90	Thompson Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/08/90	Bear Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
06/25/90	Cloverlick Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
06/13/90	Lees Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
05/01/90	Tributary to Caesar Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/27/89	Jennings Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
05/31/89	Grassy Fork, OH	Swine manure			Ohio Department of Natural Resources (1997)
04/28/89	Kale Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
32579	Wolf Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
11/15/87	Jennings Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/02/87	Mill Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/04/87	Painter Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/03/87	Camp Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
06/27/87	Buck Run, OH	Swine manure			Ohio Department of Natural Resources (1997)
05/21/87	Camp Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
05/05/87	Chapman Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
01/17/87	Unnamed creek, OH	Swine manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-17
Documented Human Health Related Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1990	Delmarva Peninsula (DE, MD, VA)	Swine operation	Ammonium-nitrogen concentrations of 1,000 mg/L in shallow monitoring wells around swine waste lagoons	Scientific study	Ritter and Chirnside (1990)
4/98	Duplin County, NC	Swine operation	Ground water contamination	Nitrate levels five times state standards	The Associated Press (1998)
12/1/95	Four Oaks, NC	Swine operations	13 private wells contaminated		Warrick (1995e)
10/1/95	Shannon, NC	1,200 head swine operation	Family complains of overpowering stench and mist of manure when farmer sprays his fields		Warrick (1995d)
10/1/95	NC	Swine operation	4 private wells were found to have nitrate levels 10 times the health standard equal to the MCL of 10 mg/L	Linked conclusively to the swine operations	Warrick (1995c; 1995d)
4/1/95	Browntown, NC	Swine operations	Residents fighting with swine farmers over odor		Stith and Warrick (1995)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1997	NC rivers	Swine operations	450,000 fish killed	*Pfisteria piscicida* outbreak	U.S. Senate (1997)
1985-1995	Sampson County, NC	Mainly swine (Livestock responsible for 93% of ammonia emissions across NC. Swine account for 78% of ammonia emissions from livestock operations in the southern coastal plain of NC, where Sampson County is located.)	100% increase in amount of ammonia in rainwater corresponds with growth of pork industry	Contributes to eutrophication via atmospheric deposition	Aneja et al. (1998)
9/1/95	NC	Swine	Zinc and copper in manure building to potentially harmful levels on fields	Zinc and copper added to feed	Warrick and Stith (1995)
9/1/95	Neuse River, NC	Swine	500,000 fish killed	Toxic dinoflagellate outbreak	Leavenworth (1995c)
6/13/95	Neuse River, NC	Swine	1 billion fish killed	Toxic dinoflagellate outbreak	Leavenworth (1995a)
1995	Coastal wetlands of NC	Swine operations	Closed shellfish beds		U.S. Senate (1997)
	NC	Swine	Low dissolved oxygen, fish kills, loss of submerged vegetation	Total Maximum Daily Load (TMDL) case study	USEPA (1999)
10/17/97	Clear Creek, IA	Swine operation	28,134 fish killed	$4,000 direct cost + $2,000 fine	Iowa Department of Natural Resources (1998)
10/9/97	Brooke Creek, IA	Swine operation	4194 fish killed	$267.50 direct cost + $2,500 fine	Iowa Department of Natural Resources (1998)
9/18/97	Prairie Creek, IA	Swine operation	93,403 fish killed	$16,140.84 direct cost; fine was pending	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
8/27/97	South Fork of Iowa River, IA	Swine operation	3,232 fish killed	$264.23 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/26/97	Crane Creek, IA	3,200 head swine operation	109,172 fish killed	Blocked pipe resulted in discharge. $33,882.73 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
9/4/96	North Buffalo Creek, IA	Swine operation	More than 100,000 gallons pumped into Creek; 586,753 fish killed	$30,000 direct cost + $3,000 fine	Iowa Department of Natural Resources (1998)
8/26/96	Rock Creek, IA	Swine operation	871 fish killed	$237 direct cost	Iowa Department of Natural Resources (1998)
8/19/96	Cedar County, IA	Swine operation	3,676 fish killed	$408.76 direct cost	Iowa Department of Natural Resources (1998)
8/19/96	Tipton Creek, IA	Swine operation	46,315 fish killed	$3,908 direct cost + $3,000 fine	Iowa Department of Natural Resources (1998)
11/15/95	Indian Creek, IA	Swine operation	4,928 fish killed	$418 direct cost + $3,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
9/25/95	Williams Creek, IA	Swine operation	60,650 fish killed	$21,436 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/23/95	Elk Creek tributary, IA	Swine operation	16,280 fish killed	$1,410 direct cost + $2,500 fine	Iowa Department of Natural Resources (1998)
7/20/95	Little Volga River, IA	Swine operation	23,416 fish killed	$8,155 direct cost + $1,500 fine	Iowa Department of Natural Resources (1998)
7/16/95	South Fork of Iowa River, IA	Swine operation	8,861 fish killed	$6,000 direct cost + $2,000 fine	Iowa Department of Natural Resources (1998)
7/1/95	Hamilton, IA	700 head swine operation	1.5 million gallons discharged; 8,800 fish killed	$8,000 fine	Clean Water Action Alliance (1998)
3/28/95	South English River tributary, IA	Swine operation	Fish kill	$4,000 fine	Iowa Department of Natural Resources (1998)
9/94	Kossuth County, IA	Swine operation	408 fish killed	$73 direct cost + $2,250 fine	Iowa Department of Natural Resources (1998)
9/94	Williams Creek, IA	Swine operation	Fish kill	$2,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
8/94	Otter Creek, IA	Swine operation	1,882 fish killed	$968 direct cost	Iowa Department of Natural Resources (1998)
5/94	Church Creek, IA	Swine operation	5,750 fish killed	$2,118 direct cost	Iowa Department of Natural Resources (1998)
5/94	Hickory Creek tributary, IA	Swine operation	8,397 fish killed	$722 direct cost + $300 fine	Iowa Department of Natural Resources (1998)
3/94	Eagle Creek, IA	Swine operation	Fish kill	$3,000 fine	Iowa Department of Natural Resources (1998)
12/93	Boone River, IA	Swine operation	Fish kill	$5,000 fine	Iowa Department of Natural Resources (1998)
11/93	Union County, IA	Swine operation	Fish kill	$1,000 fine	Iowa Department of Natural Resources (1998)
10/93	Middle Avery Creek, IA	Swine operation	Fish kill	$9,700 fine split between operation and waste management design company	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
9/93	South English River tributary, IA	Swine operation	Fish kill	$1,650 fine	Iowa Department of Natural Resources (1998)
7/93	Iowa River tributary	Swine operation	Fish kill	$3,000 fine	Iowa Department of Natural Resources (1998)
6/93	Keokuk County, IA	Swine operation	Fish kill	$4,500 fine	Iowa Department of Natural Resources (1998)
5/93	Brush Creek, IA	Swine operation	265,000 fish killed	$10,000 direct cost + $2,500 fine	Iowa Department of Natural Resources (1998)
4/93	Brookside Creek tributary, IA	Swine operation	Fish kill	$2,000 fine	Iowa Department of Natural Resources (1998)
4/93	Iowa River tributary, IA	Swine operation	Fish kill	$300 fine	Iowa Department of Natural Resources (1998)
8/92	East Nishnabotna River, IA	Swine operation	Fish kill	$1,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
8/92	Tipton Creek, IA	Swine operation	34,994 fish killed	$200 fine	Iowa Department of Natural Resources (1998)
7/92	South River, IA	Swine operation	6,264 fish killed	From land application of lagoon contents; effects lasted for 2 months. $3,448 direct cost + $19,500 fine	Iowa Department of Natural Resources (1998)
7/92	Wright County, IA	Swine operation	Fish kill	$400 fine	Iowa Department of Natural Resources (1998)
6/19/97	Renville County, MN	9,000 swine	100,000 gallons discharged; 690,000 fish killed	Lagoon overflow caused by timer malfunction. Fined for failure to notify.	Clean Water Action Alliance (1998)
8/1/95	Lincoln, MN	Swine operation	5,000- 10,000 fish killed		Clean Water Action Alliance (1998)
8/1/95	Greencastle MO	30,000 head swine operation	Over 20,000 gallons discharged; 173,000 fish killed		Clean Water Action Alliance (1998)
8/96	Four-Mile Creek, NE	Swine operation	300-500 bullhead, 100 carp, 100 cyprinids killed	Lagoon discharge	Nebraska Department of Environmental Quality (1996)
6/95	Scholz Pond, NE	Swine operation	96 fish killed	Land application and pipeline break; $13.25 direct cost + $1,000 fine	Nebraska Department of Environmental Quality (1995b)
3/95	Swan Creek, NE	Swine operation	Fish kill	$971.66 direct cost + $10,000 fine	Nebraska Department of Environmental Quality (1995a)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
6/21/95	New River, NC	Swine operation	25 million gallons discharged; 3,000-4,000 fish killed	$6,200 direct cost + $92,000 fine	Meadows (1995); Warrick (1995b)
6/1/95	Onslow County, NC	10,000 head swine operation	25 million gallons discharged; 3,000-4,000 fish killed	$110,000 fine, including $6,200 for fish kill and $92,000 in civil penalties	NRDC (1995); Warrick (1995b)

EXHIBIT 4-19
Documented Discharges from Poultry Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
9/5/95	East Branch Beaverdam Creek, IA	Poultry operation	9,002 fish killed	$839 direct cost + $500 fine	Iowa Department of Natural Resources (1998)
10/1/91	Deep Run, MD	Poultry operation	10,000 fish killed		Maryland Department of the Environment (1987)
3/97	Grant County, MN	2,000 chicken poultry operation	Pumped waste into wetland		Clean Water Action Alliance (1998)
7/1/95	Duplin, NC	75,000 chicken operation	8.6 million gallons discharged; fish kill resulted		NRDC (1995)
02/04/97	Tributary to Town Run, OH	Poultry manure	Manure spread on frozen fields, followed by rainfall		Ohio Department of Natural Resources (1997)
10/22/96	Dahlinghaus Ditch, OH	Chicken manure	Manure entered field tiles and into stream		Ohio Department of Natural Resources (1997)
10/10/96	Dahlinghaus Ditch, OH	Chicken manure	Manure entered field tiles and into stream		Ohio Department of Natural Resources (1997)
07/15/96	Tributary to Beaver Creek, OH	Chicken manure	Manure entering stream from field tile		Ohio Department of Natural Resources (1997)
07/10/96	Dahlinghaus Ditch, OH	Chicken manure	Runoff from field application of manure		Ohio Department of Natural Resources (1997)
06/24/96	Little Chippewa Creek and Tributary, OH	Chicken manure	Manure runoff into ditch from farm (retention pond overflow)		Ohio Department of Natural Resources (1997)
03/20/95	Little Chippewa Creek	Chicken manure	Chicken manure possibly dumped into field tile		Ohio Department of Natural Resources (1997)
12/03/94	Kraut Creek, OH	Chicken manure	Manure entered field tile	Accidental removal of plank allowed manure to enter tile	Ohio Department of Natural Resources (1997)

EXHIBIT 4-19
Documented Discharges from Poultry Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
9/13/94	Stillwater River, OH	Chicken manure	Manure entered tile, then stream		Ohio Department of Natural Resources (1997)
05/09/93	Henry Ditch, OH	Chicken manure		Approximately 4 miles affected in Indiana	Ohio Department of Natural Resources (1997)
08/14/92	Mississinewa River, OH	Chicken manure			Ohio Department of Natural Resources (1997)
11/03/91	Sugar Creek, OH	Chicken manure			Ohio Department of Natural Resources (1997)
09/13/90	Tributary to Blanchard River, OH	Chicken manure	Runoff from fields into creek		Ohio Department of Natural Resources (1997)
11/02/87	Powderlick Run, OH	Chicken manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-20
Documented Human Health Related Impacts from Poultry Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1982	Sussex County, DE	Poultry operations	Nitrate levels greater than 10 mg/L in 32 percent of wells		Chapman (1996)
	FL	Poultry operations	Nitrate levels greater than 10 mg/L in one-third of wells		Chapman (1996)

EXHIBIT 4-21
Documented Ecological, Recreational, and Other Impacts from Poultry Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1997	Chesapeake Bay	Poultry operations	30,000 fish killed	*Pfiesteria piscicida* outbreak	U.S. Senate (1997)
	DE	Poultry industry	Eutrophication, fish kills and red tide	Not clear how much to attribute to poultry waste	Delaware's Center for the Inland Bays (1995)
8/97	Pokomoke River, MD	Poultry operations	20,000-30,000 fish killed	*Pfiesteria piscicida* outbreak; 13 humans also affected	Shields (1997)
6/20/95	Kings Creek, MD	Poultry operations	Fish kill	*Pfiesteria piscicida* outbreak	Shields and Meyer (1997)
6/19/95	MD	Poultry	Extensive fish kill in the Chesapeake Bay	*Pfiesteria piscicida* outbreak	New York Times (1997)
	Double Pipe Creek, MD	Poultry (700,000 chickens)	High fecal coliform counts	Threatens water supply as well as aquatic life and recreation	Gale et al. (1993)
1998	Tulsa, OK	Poultry (82.5 million chickens in the watershed)	Excessive algal growth in Lake Eucha; impacts on drinking water taste and odor	Tulsa spends $100,000 per year to address taste and odor problems in the drinking water	Lassek (1998); Lassek (1997)
9/5/95	East Branch Beaverdam Creek, IA	Poultry operation	9,002 fish killed	$839 direct cost + $500 fine	Iowa Department of Natural Resources (1998)
10/1/91	Deep Run, MD	Poultry operation	10,000 fish killed		Maryland Department of the Environment (1987)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
3/1/98	Olmsted, MN	Dairy feedlot	125,000 gallons discharged	Contaminated local wells	Clean Water Action Alliance (1998)
7/97	Lyon County, MN	250 head cattle operation	runoff		Clean Water Action Alliance (1998)
5/97	Wabasha County, MN	Dairy operation	16,500 minnows and white suckers killed	Fish kill caused by ammonia.	Clean Water Action Alliance (1998)
4/97	Lyon County, MN	800 head cattle operation	Open lot runoff		Clean Water Action Alliance (1998)
3/97	LeSueur County, MN	1,960 head cattle operation	Overapplication and runoff		Clean Water Action Alliance (1998)
3/97	Lyon County, MN	1,000 head cattle operation	Open lot runoff		Clean Water Action Alliance (1998)
8/96	Nicollet County, MN	1,400 head cattle operation	Overapplication and runoff		Clean Water Action Alliance (1998)
6/96	Clay County, MN	500 head cattle operation	Multiple runoff culverts to river		Clean Water Action Alliance (1998)
4/96	Crow Wing, MN	100 head dairy operation	Stockpile runoff		Clean Water Action Alliance (1998)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
4/96	Houston County, MN	1,500 head cattle operation	Overflowing basin		Clean Water Action Alliance (1998)
11/95	Morrison County, MN	100 head cattle operation	Runoff to river		Clean Water Action Alliance (1998)
11/95	Olmsted County, MN	10,000 head cattle operation	Multiple runoff concerns		Clean Water Action Alliance (1998)
5/95	Slayton Township, MN	Steer operation	Runoff into a tributary of Beaver Creek		Clean Water Action Alliance (1998)
3/95	Lyon County, MN	400 head cattle operation	Tile inlet in feedlot		Clean Water Action Alliance (1998)
3/95	Lyon County, MN	2,000 head cattle operation	Runoff and unpermitted construction		Clean Water Action Alliance (1998)
4/94	LeSueur County, MN	1,000 head cattle operation	Multiple runoff concerns		Clean Water Action Alliance (1998)
4/94	Redwood County, MN	750 head cattle operation	Unpermitted basin and discharge		Clean Water Action Alliance (1998)
1985 - 1994	Tyrone Township, MN	950 steer cattle operation	Various problems, including massive runoff		Clean Water Action Alliance (1998)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
1/92	Green Isle Township, MN	Dairy operation	225,000 gallons of manure pumped onto a field in 5 hours, flowed through a drainage tile into Curran Lake		Clean Water Action Alliance (1998)
5/19/97	Tributary to Chickasaw Creek, OH	Cattle manure	Manure from cattle yard discharged to stream via tile		Ohio Department of Natural Resources (1997)
3/25/97	Prairie Outlet, OH	Cattle manure	Manure leached from holding ponds into creek		Ohio Department of Natural Resources (1997)
2/4/97	Tributary to Little Scioto River (RM 23.66), OH	Cattle manure	Manure spray gun malfunctioned and flooded field		Ohio Department of Natural Resources (1997)
11/13/96	Scherman Ditch, OH	Cattle manure			Ohio Department of Natural Resources (1997)
10/27/96	Little Tymochtee Creek, OH	Cattle manure	Manure leaking from pit at dairy operation		Ohio Department of Natural Resources (1997)
9/30/96	Tributary to Coldwater Creek, OH	Cattle manure	Manure spread on fields ran into creek		Ohio Department of Natural Resources (1997)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
9/25/96	Tributary to Chickasaw Creek, OH	Cattle manure	Runoff from cattle feedlot into field tile into creek		Ohio Department of Natural Resources (1997)
8/13/96	Blacklick Creek, OH	Cattle manure	Manure sprayed on field ran into tile drain		Ohio Department of Natural Resources (1997)
7/15/96	Tributary to Beaver Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)
6/20/96	Threemile Creek, OH	Cattle manure	Runoff from field application of manure		Ohio Department of Natural Resources (1997)
5/23/96	Tributary to Pymatining Creek (RM 23.95), OH	Cattle manure	Runoff after spreading manure		Ohio Department of Natural Resources (1997)
5/22/96	Little Bear Creek, OH	Cattle manure	300,000 gallons of manure spread on fields, washed into creek		Ohio Department of Natural Resources (1997)
5/16/96	Tributary to Red Run, OH	Cattle manure	Manure spread directly into several ditches		Ohio Department of Natural Resources (1997)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
3/29/96	Tributary to Little Short Creek, OH	Cattle manure	Manure pumped into ravine and into stream		Ohio Department of Natural Resources (1997)
2/21/96	East Branch Sugar Creek, OH	Cattle manure		No fish kill; unsure if pollutants entered stream	Ohio Department of Natural Resources (1997)
1/9/96	Tributary to East Fork White Eyes Creek, OH	Cattle manure		No fish kill; unsure if pollutants entered stream	Ohio Department of Natural Resources (1997)
9/1/95	Indian Creek, OH	Cattle manure	600,000 - 800,000 gallons pumped onto 40 acres		Ohio Department of Natural Resources (1997)
8/20/95	Montezuma Creek, OH	Cattle manure	Sprinkling system to cool animals created excess runoff		Ohio Department of Natural Resources (1997)
8/19/95	Tributary to Anderson Fork, OH	Cattle manure	Tractor got stuck; manure tank emptied; rain washed manure into creek		Ohio Department of Natural Resources (1997)
7/10/95	East Fork White Eyes Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-22

Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
5/3/95	Tributary to Killbuck Creek, OH	Cattle manure	Periodic discharges of manure to stream		Ohio Department of Natural Resources (1997)
5/3/95	Sugar Creek, OH	Cattle manure	Broken pipe at pit, manure flow into tile and then creek		Ohio Department of Natural Resources (1997)
12/5/94	Big Run, OH	Cattle manure	Runoff from pasture and feedlots		Ohio Department of Natural Resources (1997)
6/16/94	Harmon Brook, OH	Cattle manure	Crack in lagoon led to manure leak		Ohio Department of Natural Resources (1997)
12/15/93	Tributary to Grand Lake St. Mary's, OH	Cattle manure	Manure in ditch and tile leading to stream		Ohio Department of Natural Resources (1997)
8/20/93	Stony Creek, OH	Cattle manure	Runoff from feedlot entered creek		Ohio Department of Natural Resources (1997)
8/11/93	Middle Fork Sugar Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
7/12/92	Tributary to Black Fork Mohican River, OH	Cattle manure	Drainage from manure pit through field tile to creek		Ohio Department of Natural Resources (1997)
4/18/91	Tributary to Little Scioto River, OH	Cattle manure	Manure liquids ran off farm into ditch		Ohio Department of Natural Resources (1997)
2/20/91	Mohican River, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/20/90	Olentangy River, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/18/90	Tributary to Cowan Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/16/90	Schenck Creek, OH	Cattle manure	Manure pit overflowed into ditch		Ohio Department of Natural Resources (1997)
6/16/90	Clear Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
8/12/89	North Fork of Deer Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)
6/29/89	Painter Run, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/2/88	Tributary to Red Run, OH	Cattle manure			Ohio Department of Natural Resources (1997)
5/2/87	Big Run, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-23
Documented Human Health Related Impacts from Beef and Dairy Operations

Date	Location	Source	Environmental Impact	Comments	Reference
	WI	Dairy operation	Contamination of surface waters; ear and skin infections, as well as intestinal illnesses common to swimmers in manure-contaminated waterways		Behm (1989)
	Door County, WI	Dairy operations	Well contamination	State will spend $3 million to protect Door County ground water. Families have had to drill new wells.	Behm (1989)

EXHIBIT 4-24
Documented Ecological, Recreational, and Other Impacts from Beef and Dairy Operations

Date	Location	Source	Environmental Impact	Comments	Reference
	Taylor Creek, FL	Dairy and beef operations	Eutrophication of Lake Okeechobee		Gale et al. (1993)
	Tillamook Bay, OR	Dairy operations	High fecal coliform levels in the waters of the Bay	Affecting tourism and oyster industries. May be causing health hazards as well.	Gale et al. (1993)
6/18/95	Waco, TX	Dairy operations, as well as urban runoff and crop fertilization	An algal bloom of Anabaena, which caused a foul-smelling and -tasting chemical in water supplies		Wallace (1997)
6/16/95	Erath, TX	Dairy operations	Total N and P above screening levels in Upper North Bosque River		Pratt et al. (1997)
1991	Tierra Blanca Creek, TX	Cattle operations	Elevated sediment concentrations of copper and zinc; elevated aqueous concentrations of ammonia, chemical oxygen demand, chlorophyll *a*, coliform bacteria, chloride, conductivity, total Kjeldahl nitrogen, and volatile suspended solids	Relative contribution from various sources (e.g., runoff, lagoon discharges, leachate) was not assessed	USFWS (1991)
	Eau Claire, WI	Dairy operations	Swimming and water skiing are prohibited in Tainter Lake because of bacterial contamination	Sedimentation from development and crop runoff also causing problems	Behm (1989)
	Osh Kosh, WI	Dairy operations, as well as development	Algal blooms in Lake Winnebago	Lake Winnebago represents 17% of the state's water surface. City of Osh Kosh spends $30,000 a year to kill algae.	Behm (1989)
	Black Earth Creek Watershed, WI	Dairy operations	Eutrophication		USGAO (1995a)
5/97	Wabasha County, MN	Dairy operation	16,500 minnows and white suckers killed	Fish kill caused by ammonia.	USGAO (1995a)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
7/1/95	Fayette, IA		16,000 gallons discharged; 584 smallmouth bass, 22,011 minnows/ shiners killed		NRDC (1995)
7/1/95	Howard, IA		110 black bullheads, 16,000 minnows killed		NRDC (1995)
3/92	Hamilton County, IA	Swine, turkey, and dairy operation	Fish kill	$1,000 fine	Iowa Department of Natural Resources (1998)
7/11/95	Tuscarora Creek, MD	Manure (animal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)
7/26/94	Toms Run, MD	Manure (animal type unknown)	1,500 fish killed		Maryland Department of the Environment (1987)
6/22/90	Wagram Creek, MD	Manure (animal type unknown)	19,000 fish killed		Maryland Department of the Environment (1987)
9/24/87	Farm Pond, MD	Manure (animal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)
3/30/87	Morgan Creek, MD	Manure (animal type unknown)	2,500 fish killed		Maryland Department of the Environment (1987)
7/30/86	Liitle Pipe Creek, MD	Manure (animal type unknown)	150 fish killed		Maryland Department of the Environment (1987)
7/15/86	Cabbage Run, MD	Manure (animal type unknown)	175 fish killed		Maryland Department of the Environment (1987)
9/30/85	Deep Run, MD	Manure (animal type unknown)	Hundreds of fish killed		Maryland Department of the Environment (1987)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
9/29/85	Jennings Run, MD	Manure (animal type unknown)	3,900 fish killed		Maryland Department of the Environment (1987)
8/10/85	Deer Creek, MD	Manure (animal type unknown)	100,000 fish killed		Maryland Department of the Environment (1987)
1994	Belle River, MI	Manure (animal type unknown)	Fish kill	Overflow and misapplication of manure. $5,150 direct cost + $5,000 fine	Michigan Department of Environmental Quality
1994	Macon Creek, MI	Manure (animal type unknown)	Fish kill	Euipment failure caused manure discharge. $1,330 direct cost + $5,000 fine	Michigan Department of Environmental Quality
1994	Salt River, MI	Manure (animal type unknown)	Fish kill	Over-application of manure to field, causing runoff. $20,000 direct cost + $2,500 fine	Michigan Department of Environmental Quality
1993	Crockery Creek, MI	Manure (animal type unknown)		$1,650 enforcement costs +$2,500 fine	Michigan Department of Environmental Quality
1993	Deer Creek tributary, MI	Manure (animal type unknown)		$4,000 enforcement costs + $20,000 fine	Michigan Department of Environmental Quality
2/98	Lake Wagonga, MN	Manure (animal type unknown)	Manure-contaminated runoff discharged to lake		Clean Water Action Alliance (1998)
1/98	Nokasippi, MN	Manure (animal type unknown)	Manure-contaminated runoff (from feedlot and stockpile) discharged to river	Failed to notify authorities, made no attempt to abate or recover discharge	Clean Water Action Alliance (1998)
9/97	Blue Earth River, MN	Manure (animal type unknown)	Fish kill of 6,626 catfish, small-mouth bass, rock bass, white bass, and minnows		Clean Water Action Alliance (1998)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
8/97	Hay Creek, MN	Manure (animal type unknown)	Fish kill of 6,000 brown trout and white suckers.		Clean Water Action Alliance (1998)
8/97	Speltz Creek, MN	Manure (animal type unknown)	300 gallons discharged; 130 minnows killed		Clean Water Action Alliance (1998)
6/97	Roseau County, MN	Manure (animal type unknown)	Manure discharge	Discharge from un-permitted tank, caused by improper construction and pump failure.	Clean Water Action Alliance (1998)
1996	Mankato, MN	Manure (animal type unknown)	Drained manure into Watonwan and Blue Earth Rivers		Clean Water Action Alliance (1998)
8/95 - 9/95	Larkin Township, MN	Various animals	3 weeks worth of overflow from lagoon through trench and into Kanaranzi Creek		Clean Water Action Alliance (1998)
7/95 - 8/95	Drammen Township, MN	Manure (animal type unknown)	Overflow of pits which drained into a ditch; 19,641 fish killed in Medary Creek		Clean Water Action Alliance (1998)
1994	Nicollet County, MN	Manure (animal type unknown)	Constant diversion of manure into streams from unknown facilities		Clean Water Action Alliance (1998)
6/96	Lost Creek, NE	Unclear if swine or cattle	2,120 fish killed	$1,079.50 direct cost; fine was pending	Nebraska Department of Environmental Quality (1996)
10/28/96	Apple Ditch, OH	Manure	Manure coming from field tile		Ohio Department of Natural Resources (1997)
09/18/96	Tributary to Beaver Creek, OH	Manure			Ohio Department of Natural Resources (1997)
07/31/96	Montezuma Creek, OH	Cattle and swine manure	Manure entered stream from field tile		Ohio Department of Natural Resources (1997)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
7/7/96	Cedar Fork, OH	Manure	Hose sprung leak and manure spread onto ground and into tile		Ohio Department of Natural Resources (1997)
07/05/96	Wabash River, OH	Manure	Manure runoff from milkhouse into field tile		Ohio Department of Natural Resources (1997)
07/04/96	Wabash River, OH	Cattle and swine manure	Runoff from field application of manure		Ohio Department of Natural Resources (1997)
06/17/96	East Fork Vermilion River, OH	Manure			Ohio Department of Natural Resources (1997)
10/26/95	Tributary to Mile Creek (RM 4.15), OH	Manure	Liquid manure applied too heavily		Ohio Department of Natural Resources (1997)
09/03/95	Tributary to Poplar Creek, OH	Manure	Accidental manure spill		Ohio Department of Natural Resources (1997)
08/24/95	Martins Creek, OH	Manure and milk products	Manure and milk washed into drains into creek		Ohio Department of Natural Resources (1997)
07/05/95	Rock Creek, OH	Manure			Ohio Department of Natural Resources (1997)
04/22/95	Newman Creek, OH	Manure			Ohio Department of Natural Resources (1997)
03/27/95	Kiber Run, OH	Cattle and swine manure	Runoff from spraying fields ran into field tiles		Ohio Department of Natural Resources (1997)
10/16/94	Prairie Creek, OH	Manure	Irrigated manure entered tile into creek		Ohio Department of Natural Resources (1997)
08/29/94	Tributary to Beaver Creek, OH	Cattle and swine manure	Crack in holding pit into tile		Ohio Department of Natural Resources (1997)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
7/17/94	Black Run, OH	Manure			Ohio Department of Natural Resources (1997)
09/08/93	Little Beaver Creek, OH	Milkhouse wastewater and manure			Ohio Department of Natural Resources (1997)
09/09/92	Subtributary to Pawpaw Creek, OH	Cattle and swine manure	Possible runoff from feedlots		Ohio Department of Natural Resources (1997)
08/18/92	Tributary to Coldwater Creek, OH	Manure	Manure applied to field entered creek		Ohio Department of Natural Resources (1997)
07/08/92	Little Miami River, OH	Manure	Runoff and leachate into stream		Ohio Department of Natural Resources (1997)
04/29/91	Tributary to Bear Creek, OH	Manure	Manure entered field tile and into stream		Ohio Department of Natural Resources (1997)
03/02/91	Middle Fork Little Beaver Creek, OH	Manure			Ohio Department of Natural Resources (1997)
07/30/90	Sycamore Creek, OH	Manure and household wastes			Ohio Department of Natural Resources (1997)
11/09/89	Tributary to Beaver Creek, OH	Manure			Ohio Department of Natural Resources (1997)
08/19/89	Tributary to Jerome Fork, OH	Manure			Ohio Department of Natural Resources (1997)
08/07/89	Elkhorn Creek, OH	Manure			Ohio Department of Natural Resources (1997)
10/20/88	Indian Creek, OH	Manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
9/27/87	Big Run, OH	Manure			Ohio Department of Natural Resources (1997)
09/18/87	Spring Creek, OH	Manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-26
Documented Human Health-Related Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
3/1/91	Des Moines, IA	Animal waste, as well as fertilizers	Contamination of drinking water with nitrate	Waterworks will spend $5 million on a nitrate removal system	Hubert (1991)
6/15/95	Wichita, KS	Nutrients from farm runoff, including animal manure	Contamination of drinking water supply	Some algal strains growing in the reservoir are thought to produce a liver toxin linked to stomach flu. Wichita is installing a special filtering mechanism which will cost $1 million per year to operate	Hays (1993)
	WI	Varied (including AFOs)	WI DNR estimates that 10% of the state's 700,000 wells exceed health standards	Major pollutant sources include CAFOs, development, crop farms, and ski slopes.	Behm (1989)

EXHIBIT 4-27
Documented Ecological, Recreational, and Other Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
	Appoquinimink River, DE	Poultry, dairy, and beef	Eutrophication	Fish kills and hindered boating	Gale et al. (1993)
	GA, AL, FL	Animal waste	Excess nutrients in the Apalachicola-Chattahoochee-Flint watershed		USGS (1996)
6/15/95	KS	Feedlots, as well as farms	Eutrophication in Arkansas River	37 species of fish are in danger	Hays (1993)
1995	NC	Livestock waste	8-fold increase in ammonia emissions	Contributes to eutrophication via atmospheric deposition.	Leavenworth (1995b)
	Tar-Pamlico River Basin, NC		Eutrophication resulting in die-off of benthic life and toxic dinoflagellate growth	Winter algal blooms occur regularly. Shellfish beds have been closed because of fecal coliform.	North Carolina Division of Environmental Management (1995); USGAO (1995a)
	Nansemond-Chuckatuck watershed, VA	448,000 chickens 24,000 swine, 2724 beef cows, 125 dairy cows	Eutrophication and contamination with fecal coliform	Major source is runoff from agricultural areas. Shellfish areas have been closed.	Gale et al. (1993)
	WI	Excessive nutrients	90% decline in bass population in one year		Behm (1989)
7/1/95	Fayette, IA		16,000 gallons discharged; 584 smallmouth bass, 22,011 minnows/ shiners killed		NRDC (1995)
7/1/95	Howard, IA		110 black bullheads, 16,000 minnows killed		NRDC (1995)
3/92	Hamilton County, IA	Swine, turkey, and dairy operation	Fish kill	$1,000 fine	Iowa Department of Natural Resources (1998)
7/11/95	Tuscarora Creek, MD	Manure (animal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)

EXHIBIT 4-27
Documented Ecological, Recreational, and Other Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
7/26/94	Toms Run, MD	Manure (animal type unknown)	1,500 fish killed		Maryland Department of the Environment (1987)
6/22/90	Wagram Creek, MD	Manure (animal type unknown)	19,000 fish killed		Maryland Department of the Environment (1987)
9/24/87	Farm Pond, MD	Manure (animal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)
3/30/87	Morgan Creek, MD	Manure (animal type unknown)	2,500 fish killed		Maryland Department of the Environment (1987)
7/30/86	Liitle Pipe Creek, MD	Manure (animal type unknown)	150 fish killed		Maryland Department of the Environment (1987)
7/15/86	Cabbage Run, MD	Manure (animal type unknown)	175 fish killed		Maryland Department of the Environment (1987)
9/30/85	Deep Run, MD	Manure (animal type unknown)	Hundreds of fish killed		Maryland Department of the Environment (1987)
9/29/85	Jennings Run, MD	Manure (animal type unknown)	3,900 fish killed		Maryland Department of the Environment (1987)
8/10/85	Deer Creek, MD	Manure (animal type unknown)	100,000 fish killed		Maryland Department of the Environment (1987)
1994	Belle River, MI	Manure (animal type unknown)	Fish kill	Overflow and misapplication of manure. $5,150 direct cost + $5,000 fine	Michigan Department of Environmental Quality
1994	Macon Creek, MI	Manure (animal type unknown)	Fish kill	Equipment failure caused manure discharge. $1,330 direct cost + $5,000 fine	Michigan Department of Environmental Quality

EXHIBIT 4-27
Documented Ecological, Recreational, and Other Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
1994	Salt River, MI	Manure (animal type unknown)	Fish kill	Over-application of manure to field, causing runoff. $20,000 direct cost + $2,500 fine	Michigan Department of Environmental Quality
9/97	Blue Earth River, MN	Manure (animal type unknown)	Fish kill of 6,626 catfish, small-mouth bass, rock bass, white bass, and minnows		Michigan Department of Environmental Quality
8/97	Hay Creek, MN	Manure (animal type unknown)	Fish kill of 6,000 brown trout and white suckers.		Michigan Department of Environmental Quality
8/97	Speltz Creek, MN	Manure (animal type unknown)	300 gallons discharged; 130 minnows killed		Michigan Department of Environmental Quality
7/95 - 8/95	Drammen Township, MN	Manure (animal type unknown)	Overflow of pits which drained into a ditch; 19,641 fish killed in Medary Creek		Michigan Department of Environmental Quality
6/96	Lost Creek, NE	Unclear if swine or cattle	2,120 fish killed	$1,079.50 direct cost; fine was pending	Nebraska Department of Environmental Quality (1996)

4.4.1 Lake Eucha

Lake Eucha is located in the Lower Neosho Watershed in northeast Oklahoma. It is a major drinking water source for the city of Tulsa. Lake Eucha was included on the Oklahoma List of Impaired Waters for 1998 as a result of nutrients. Recently, there have been taste and odor problems in Tulsa's drinking water due to accelerated eutrophication (Lassek, 1998a; Front, 2000; Keyworth et al., 2000).

Officials estimate that approximately 750 chicken houses are located within the lake's watershed, each containing about 110,000 birds (Lassek, 1998b). In the Lake Eucha basin, a popular method of fertilizing permanent pasture is the surface application of poultry litter. Litter is highly effective, due to its high content of nutrients (nitrogen, phosphorus, and potassium) and organic matter. However, if not properly managed, these nutrients could reach surface water and cause eutrophication and consequently, algae blooms (Neal and Storm, 1999).

Detailed monitoring of Lake Eucha in 1997 showed that the algae balance was typical of eutrophic lakes. In addition, although the lake was free of harmful bacteria (an indicator of possible impacts from animal waste), excessive bacteria were found in the tributaries. This study, by the Oklahoma Conservation Commission, linked phosphorus from poultry waste runoff to excessive algae growth in the lake (Wagner and Woodruff, 1997; Lassek, 1998a). The algae causes taste and odor problems in the water, costing Tulsa thousands of dollars for treatment (Lassek, 1998a; Front, 2000).

The Oklahoma legislature has announced that drinking water contamination due to CAFOs is a priority issue to be addressed. Studies are being conducted at Oklahoma State University and Texas A&M University to determine limiting nutrients in Lake Eucha tributaries. These studies will be used in combination with other ongoing research to develop a total maximum daily load (TMDL) for Lake Eucha (Keyworth et al., 2000). In addition, the city of Tulsa is working to design a land conservation plan to address the problem (Front, 2000). Tulsa has also begun to buy land around Lake Eucha in an effort to create a buffer zone for the city's drinking water supply (Lassek, 1998b).

4.4.2 The Chino Basin

The Santa Ana River watershed has the highest density of dairy cows in the nation, averaging 25-30 cows per acre. Currently, 270 dairies operate on 25,000 acres within the Chino Basin portion of the watershed, with over 336,000 animals. Although the number of dairies continues to decrease, the number of animals is increasing, and the resulting impact on water quality is enormous. The 1998 California 303(d) List and Total Maximum Daily Load (TMDL) Priority Schedule issued by the EPA for the Chino Basin area cites agriculture and the dairies as the source of significant impairment to surface waterbodies due to nutrients, pathogens, suspended solids, salinity, total dissolved solids (TDS), and chlorides (OCWD, 2000).

Accumulation of salts and nitrates in the Chino Basin is occurring as a result of stockpiling manure and runoff from dairy waste. The Santa Ana River and the ground water basin it recharges supply over 2 million residents with approximately 75 percent of their water. The impact of large-scale dairies on recharge water quality is a critical issue in protecting Orange

County's primary drinking water supply. The Orange County Water District (OCWD), along with other concerned water agencies, has dedicated considerable resources to remove salts and nitrates from the Orange County ground water basin in order to improve the quality of water. Projects completed or in the construction phase that are directed at the removal of salts and nitrates include:

- Santa Ana River Interceptor (SARI) - $100 million
- SARI Extension to Lake Elsinore - $25 million
- Arlington Desalter (Riverside) - $13.5 million
- Water Factory 21 (Fountain Valley) - $20 million
- Chino Desalter - $39 million
- 7th Street Desalter (Tustin) - $7 million
- Prospect Desalter (Tustin) - $3 million
- Garden Grove Nitrate Reduction - $2 million

Efforts are currently underway at OCWD on two additional projects aimed at reduction of salts and nitrates. The proposed Ground Water Replenishment System (GWRS) is a $350 million proposed project that will utilize microfiltration and reverse osmosis to desalt treated wastewater, which will be transported to ground water recharge basins to significantly lower the basin's salt levels. The Irvine Desalter is a $30 million project to extract and remove salts from ground water for use in the Irvine area (OCWD, 2000).

4.4.3 Lake Waco and the Bosque River Watershed

Lake Waco is located in the Bosque River watershed in Texas. It is the public water supply for the city of Waco and several adjoining communities. In 1996, 23 river or lake segments caused concern or possible concern for six different criteria, including over 40 percent (19 instances) caused by nutrients (Texas Office of Water Resource Management, 1997). In 2000, water quality testing showed high levels of nutrients in the North Bosque River (Segment 1226) and in the Upper North Bosque River (Segment 1255). These high levels have contributed to excessive growths of algae and other aquatic plants, which can cause taste and odor problems in drinking water and result in fish kills under certain circumstances. High levels were also found for chloride, sulfate, total dissolved solids, and occasionally, bacteria (TNRCC, 2000a). The elevated level of bacteria was found to correlate with dairy waste application fields and herd density (TIAER, 1998).

The Upper North Bosque River (Segment 1255) is located in Erath County. Erath County is home to a large dairy industry, which has become increasingly concentrated over the last few decades. These dairy operations produce over 1.5 million tons of waste per year (PEER, 2000). A judge in upstream Erath County requested a waste management study for the county's dairy industry, which generates over 1 million cubic yards of dry-state dairy manure per year. The application of dairy waste to fields resulted in non-point nutrient runoff into the Bosque River during storm events, resulting in degraded water quality (Brazos River Authority, 1998). The state of Texas has a TMDL goal of reducing annual average soluble phosphorus loading by about 50 percent. The draft TMDL for the North Bosque River is due to be published this fall (TNRCC, 2000a).

In public comment on the 2000 Texas Clean Water Act Section 303(d) List, a representative of the National Wildlife Federation contended that there were taste and odor problems in Lake Waco and that these are due to algae. The Texas Natural Resource Conservation Commission (TNRCC) response to the comment notes that the TMDL currently being developed for the North Bosque River is expected to significantly reduce nutrient loading to Lake Waco. This may address the periodic taste and odor problem in Lake Waco if it is caused by algae (TNRCC, 2000b).

4.5 CASE STUDY SUMMARY

Over 100 case studies were compiled and presented in a summary report titled “Case Study Summary: Manure Application” (USEPA, 2000b). This report is included in the public record.

5. EFFECTS OF THE PROPOSED REGULATIONS

5.1 POTENTIAL BENEFITS FROM POLLUTANT REDUCTIONS

The main sources of pollution from CAFOs include:

- waste, runoff, and leachate from confinement facilities and manure storage piles;
- runoff and leachate from land application sites;
- discharges and leachate from storage lagoons; and
- airborne emissions from confinement facilities, land application sites, and storage.

The practical impacts of implementing the proposed regulations are a function of the following: (1) the location and characteristics of affected facilities; (2) current waste and runoff management practices; and (3) the contribution of pollutants from other sources.

In general, increased treatment and management practices can reduce environmental impacts and subsequent human health effects from animal waste. They can also maximize the use of animal waste as a fertilizer. Exhibit 5-1 presents the main environmental benefits that could arise from the treatment and management of animal waste.

The EPA is not currently able to quantitatively evaluate all human health and ecosystem benefits associated with water quality improvements from reduced releases of CAFO wastes. The EPA is even more limited in its ability to assign monetary values to those benefits. The economic benefit analysis can be found in the benefit report, titled "Environmental and Economic Benefits of the NPDES/ELG CAFO Rules" and located in section 9.5 of the public record.

In some cases, animal waste releases to the environment result in direct monetary costs. Many of these costs are associated with additional requirements for drinking water treatment. For example, in California's Chino Basin, it could cost over $1 million per year to remove the nitrates from drinking water due to loadings from local dairies (USEPA, 1993b). In Iowa, Des Moines Water Works planned to spend approximately $5 million to install a treatment system to remove nitrates from their main sources of drinking water, the Raccoon and Des Moines Rivers (Hubert, 1991). Agriculture was cited as a major source of the nitrate contamination, although the portion attributable to animal waste is unknown. In Wisconsin, the city of Oshkosh has spent an extra $30,000 per year on copper sulfate to kill the algae in the water it draws from Lake Winnebago (Behm, 1989). The thick mats of algae in the lake have been attributed to excess nutrients from manure, commercial fertilizers, and soil.

EXHIBIT 5-1
Anticipated Benefits of the CAFO Proposed Regulations

Category	Benefit	Origin of Impact	Population/Resources Affected	Notes
Human Health	Reduced risk of methemoglobinemia ("blue baby syndrome")	Nitrates in drinking water in excess of the MCL (Maximum Contaminant Level) of 10 mg/L	Primarily infants drinking water not treated by public treatment facilities (private rural wells; ground water is more susceptible than surface water)	Nitrate is extremely mobile in the environment, and nitrate contamination of ground water is a well-recognized historical problem in the agricultural community. According to the EPA's *National Survey of Pesticides in Drinking Water Wells* (1990), nitrate is the most widespread agricultural contaminant in drinking water wells. The EPA estimates that 4.5 million people are exposed to nitrate levels in excess of the MCL.
Human Health	Avoided illness from pathogenic organisms (e.g., gastrointestinal illness; infections of the skin, eye, ear, nose, or throat)	Pathogens in drinking and recreational waters	People drinking or swimming in contaminated water. Surface waters, and ground waters in sandy or fractured soils, are most susceptible to contamination.	Over 150 pathogens in manure are linked to human risk (e.g., *Salmonella*, *Cryptosporidium parvum*, *Giardia lamblia*, *Escherichia coli*). A U.S. General Accounting Office study (1997) of bacterial contamination of ground water over a four-year period found contamination in 3 to 6 percent of community water systems each year, and 15 to 42 percent of private wells. Drinking water disinfection does not eliminate the need for source water protection; source water protection is an integral part of the multiple barrier approach to drinking water treatment. Drinking water disinfection also does not address recreational risks.
Human Health	Avoided illness from toxic aquatic organisms (e.g., red tides, *Pfiesteria piscicida*)	Toxic organisms whose growth is enhanced by eutrophication (nutrient enrichment)	People with significant dermal or inhalation exposure to affected estuarine/marine waters; people consuming affected shellfish (pathways vary by organism)	

EXHIBIT 5-1
Anticipated Benefits of the CAFO Proposed Regulations

Category	Benefit	Origin of Impact	Population/Resources Affected	Notes
Ecological, Recreational	Avoided fish kills and other environmental damage (e.g., fish and wildlife disease, clogged fish gills, benthic habitat destruction, eutrophication) due to discharges of waste directly to surface water	BOD, ammonia, pathogens, solids, nutrients	Surface waters, aquatic organisms, waterfowl, people using the water for recreation	States have documented hundreds of cases of discharges from CAFOs, resulting in the death of millions of fish, over the past decade. Discharges directly to surface water are prohibited by the existing effluent guidelines except in the event of the 25-year, 24-hour storm, but implementation of the guidelines has been problematic. The proposed regulations are likely to call attention to the problem of such discharges and result in improved implementation. The proposed regulations also expand the scope of regulatory coverage and establish operation and maintenance requirements for storage lagoons to reduce the likelihood of discharge.
Ecological, Recreational	Reduced contribution to eutrophication effects (harmful algae blooms, decreased dissolved oxygen, fish kills, reduced biodiversity, reduced abundance of desirable aquatic plants) due to runoff from land application sites	Nutrients	Surface waters, aquatic organisms, people using the water for recreation	The EPA's *National Water Quality Inventory* (1997) indicates that nutrients are the leading cause of impairment of U.S. lakes and rivers and are the fifth leading cause of impairment of U.S. estuaries.
Ecological, Recreational	Reduced contribution to environmental damage due to runoff of other (non-nutrient) pollutants from land application sites	BOD, pathogens, solids, salts, metals	Surface waters, aquatic organisms, waterfowl, people using the water for recreation	The proposed regulations' CNMP requirement focuses on nutrients but would also incidentally address other pollutants.

EXHIBIT 5-1
Anticipated Benefits of the CAFO Proposed Regulations

Category	Benefit	Origin of Impact	Population/Resources Affected	Notes
Commercial	Reduced damage to commercial fishing and shellfish industries	Nutrients, BOD, pathogens, solids	Commercial fishing and shellfish industries	The National Oceanic and Atmospheric Administration (1995) reported that feedlots were a potential or actual contributor to the impairment of 110 shellfish beds (3 percent of all impaired shellfish areas). Outbreaks of *Pfiesteria* have directly impacted menhaden (a commercially harvested fish), and indirectly impacted the commercial fishing industry as a whole. Nutrient enrichment is one of several factors that affect growth of *Pfiesteria*. Reduction in submerged aquatic vegetation (SAV) due to excessive algae and suspended solids is a significant impact because SAV serves as critical habitat for juvenile fish and crabs. The proposed regulations' CNMP requirement focuses on nutrients but would also incidentally address other pollutants.
Other	Avoided costs associated with treatment or replacement of nitrate-contaminated ground water	Nitrates in drinking water in excess of the MCL of 10 mg/L	Public and private drinking water sources (ground water is generally more susceptible than surface water)	By implementing the proposed regulations, the following treatments may be avoided: private well owners needing to drill deeper wells to reach uncontaminated ground water or purchase bottled water, and public water suppliers needing to obtain an uncontaminated source or treat the water to meet the MCL.
Other	Avoided costs associated with treatment to remove algae, odors, and disinfection byproducts from drinking water	Algae growth stimulated by nutrients	Drinking water sources (surface water)	Implementing the proposed regulations may decrease the amount of disinfection byproducts (e.g., trihalomethanes) in drinking water that exceed the MCL. Disinfection byproducts are caused by chlorination of organic matter. The guidelines would also decrease additional or alternative treatment required to avoid or remove excess byproducts.

5.2 REPORTED BENEFITS OF ANIMAL WASTE MANAGEMENT AND RELATED NON-POINT SOURCE MEASURES IN SELECTED WATERSHEDS

Several states have successfully implemented non-point source pollution programs under Section 319 of the Clean Water Act. Following are descriptions of the reported benefits derived from some of these programs and summaries of other research on specific land application practices. The examples provide anecdotal evidence of the effectiveness of animal waste management measures that might be implemented as a result of the proposed regulations. Several of the examples demonstrate the impact of a single management practice (e.g., dry litter waste management), while others address comprehensive plans that may include several practices.

5.2.1 Benefits of Single Practices

The effects of riparian forest restoration, dry litter waste management, dead bird composting, and land application practices are discussed below. All examples except the land application practices are described in *Section 319 Success Stories Volume II: Highlights of State and Tribal Nonpoint Source Programs* (USEPA, 1997b). Land application practices were investigated by Daniel et al. (1995). Studying the effects of separate practices individually leads to a better understanding of the impact associated with each of these practices and whether each would be a useful component of comprehensive management plans.

Riparian Forest Restoration

In the Suwanee River basin near Tifton, Georgia, in the Southeastern Coastal Plain, a riparian forest (trees, shrubs, and native grasses) was reestablished to ameliorate the water quality impacts of liquid manure application to cropland. Project workers evaluated the effects of the riparian restoration by measuring changes in the surface and subsurface water quality indicators in the field where manure was applied and again after the runoff had moved through the restored riparian area toward the stream. The monitoring results demonstrated that the restored riparian area effectively removed nitrogen, phosphorus, and sediment in the first two years of the project. Furthermore, nitrate levels leaving the area in shallow ground water not exposed to the riparian forest were higher than in mature riparian forest sites.

Dry Litter Waste Management

At a swine farm in Hawaii, a modified dry litter waste management system was implemented to lessen water quality impacts. In the dry system, swine are housed in sloping pens. Dry litter or bedding is used to help push the waste down the slope into a composting or storage pit, rather than using water to transport the waste.

The Hawaiian farm improved the dry system by incorporating pen sizes with slopes ranging from 15:1 to 20:1. Wood chips and grass cuttings were found to be excellent bedding materials, but the farm achieved best results with macadamia nut husks. The swine crush the bedding materials and the manure with their hooves; the mix dries and begins to decompose, and eventually moves down slope into a composting pit. The composted product is a good medium for organic farming, and can be used to generate income for the swine farmer. The product can be sold in

Hawaii for about $30 per cubic yard. A typical pen can convert about 30 cubic yards of green waste into 20 cubic yards of compost annually.

In addition to helping protect water quality by eliminating lagoons, the dry litter waste management system also produces very little odor. Hydrogen sulfide (H_2S) levels recorded throughout the production and storage areas were considerably less than the conventional wash down system. H_2S measurements at the dry litter facility were 10.7 parts per billion (ppb) in the production area and 5.0 ppb in the storage area. By comparison, H_2S levels at the control or conventional wash down facility were 54.3 ppb in the production area and 104.5 ppb at the entry to the waste lagoon.

Dead Bird Composting

In 1993, 62 growers in a six-county area in south central Mississippi handled 7 million birds. By 1997, 150 growers reported a census of 16.2 million birds. Because of this expansion, the state was concerned about potential threats to surface and ground water resources from dead birds, which traditionally were disposed in burial pits or incinerated. Arkansas recently prohibited the use of pits for dead bird disposal, because the carcasses often decay only partially and the leachate from the pits poses a danger to surface water and ground water.

The project promotes composting as a preferred method of dead bird disposal. Approximately 194,400 birds per year will be disposed of by composting in a manner that reduces the chance of ground water contamination. In addition, area farmers are saving up to $25 per ton by using the composted material as a substitute for commercial fertilizer. (When composting is combined with other practices such as soil testing and nutrient management planning, it reduces the risk of nutrient enrichment to nearby surface waters.)

Land Application Practices

Daniel et al. (1995) applied animal manure to constructed plots with established grass and measured the resulting impacts on the quality of runoff and subsurface water. The study investigated the effect of differing application rates and other factors on the runoff of the following animal waste constituents: total Kjeldahl nitrogen, ammonia-nitrogen, nitrate-nitrogen, total phosphorus, orthophosphorus, total suspended solids, and chemical oxygen demand.

The results of the study indicate that lower application rates resulted in lower runoff for all constituents from poultry litter, and lower runoff of all constituents except nitrate-nitrogen from both poultry and swine manure. Lower application rates were also associated with less nitrate leaching into subsurface water.

5.2.2 Benefits of Multiple Practices

The following examples demonstrate the effect of multiple practices available to farmers. These examples are all taken from USEPA (1997b).

Cadron Creek, Arkansas

The Cadron Creek Watershed in Arkansas has a high concentration of poultry and dairy farms. Cadron Creek is widely used for recreation, canoeing, and fishing; Brewer Lake provides drinking water to the cities of Morrilton and Conway. Other land uses in the project area include forestry (41 percent), grasslands (52 percent), and croplands (6 percent).

All waters within the watershed are threatened by bacteria and nutrients from confined animal operations. At least 20 stream miles do not meet their designated uses, and it is likely that most small streams in the watershed do not meet the standard for contact recreation.

To restore the watershed, the Van Buren County Conservation District implemented a portable land application system for liquid animal waste, which collects and redistributes liquid waste from 30 to 40 dairies to return nutrients to pastures and fields in the watershed and reduce pollution in surface waters and ground water. Other key elements of the project include monitoring on two creeks and establishing on-farm waste management systems. Farmers are applying the following best management practices (BMPs):

- dead poultry composting;
- nutrient management planning;
- pasture management;
- proper grazing use;
- waste management systems; and
- waste management ponds.

Water quality monitoring indicates that these systems successfully reduced nutrient and bacteria loading to Ward Creek in this watershed. For example, fecal coliform bacteria levels in the stream decreased by a factor of 10 (from 100,000 to 10,000 colonies per 100 ml). The count is still far higher than the 200 colonies per 100 ml standard for recreational contact; however, with continued efforts, the project is anticipated to restore swimming as a beneficial use of this stream.

Benthic macroinvertebrate communities (aquatic insects) are another indicator of watershed health and in-stream conditions. Species diversity, a standard indicator of benthic community strength, is measured on the Family Biotic Index (FBI): the lower the FBI, the more diverse the community. The FBI in the monitored stream improved from 5.48 (which indicates the probability of substantial organic pollution) to 4.27 (which indicates the probability of slight organic pollution).

Moore's Creek and Beatty Branch Subwatershed, Arkansas

The Moore's Creek and Beatty Branch subwatershed is part of the Muddy Fork Hydrologic Unit Area in northwestern Arkansas. The Muddy Fork Hydrologic Unit Area encompasses 47,122 acres, the tributaries of the Illinois River and Lakes Lincoln, Budd Kidd, and Prairie Grove. These tributaries form Lincoln Lake, a drinking water reservoir serving the city of Lincoln.

The project implemented under Section 319 began with a monitoring project in these waters to help establish the usefulness of nutrient BMPs. Land uses, primarily poultry production and pasture management, are major sources of nutrients and chronic high turbidity. According to the state's *1996 Water Quality Inventory Report*, water in the area only partially supports aquatic life. Pathogen indicators sampled in the Muddy Fork Hydrologic Unit Area also exceed acceptable limits for primary contact recreation. This problem, reported in the 1994 water quality inventory, was traced to extensive poultry, swine, and dairy operations in the Moore's Creek basin. Essentially, all parts of the subwatershed are affected by these activities.

Nitrogen and phosphorus management practices were applied throughout the basin to help control the flow of nutrients from CAFOs. Specifically, BMPs were used on approximately one half of the pasture land along Moore's Creek and two-thirds of the pasture land along Beatty Creek. Five monitoring sites were established on Moore's Creek and Beatty Branch to demonstrate the integrated impact of the nutrient BMPs on water quality. Random samples were collected at all five sites, and storm-event samples were also collected at two sites.

Monitoring during the first three years of the project (1991 to 1994) showed decreasing levels of total Kjeldahl nitrogen, nitrate, chemical oxygen demand, total phosphorus, ammonia, and total suspended solids. Nitrate-nitrogen levels declined by 55 to 66 percent per year, total Kjeldahl nitrogen levels declined by 54 to 67 percent per year, and chemical oxygen demand levels declined by 44 to 67 percent per year.

Lake Shaokatan, Minnesota

Lake Shaokatan is a shallow prairie lake located in western Minnesota on the South Dakota border. The lake's water quality severely deteriorated in the 1980s as a result of excessive nutrient loading associated with watershed land-use practices. Harmful algal blooms dominated the open water season and occasionally produced algal toxins alleged to have resulted in the death of dogs and cattle. Sampling revealed extremely high levels of total phosphorus (average summer value of 270 µg/L). Chlorophyll *a* concentrations were episodic with concentrations noted to exceed 100 µg/L (with summer means of 20 to 30 µg/L). The major source of the phosphorus was attributed to swine and dairy feedlots and drain tile operations.

A complete watershed restoration project was implemented. The goal was to achieve total phosphorus levels of 90 µg/L or less. Since late 1991, the restoration program has included the following practices relevant to animal operations, as well as a variety of other practices (such as repairing septic systems):

- diverting a stream from a swine operation; and
- upgrading a dairy feedlot operation.

The combination of the full range of practices in the watershed reduced phosphorus loading rates by 58 to 90 percent. These practices cost about $3 to $11 per kilogram of reduced phosphorus. The watershed's response to these corrective actions was immediate and significant, as both nutrient and sediment losses were reduced. Average summer total phosphorus concentrations dropped from 270 to 89 µg/L by 1994. Furthermore, the intensity and duration of seasonal algal blooms have been curtailed with all values now less than 20 µg/L.

Tangipahoa River, Mississippi

Animal waste from confined dairy, swine, and poultry waste lagoons is a contributing factor to the high level of nitrogen, phosphorus, and fecal coliform found in some Mississippi streams.

Waste management plans were implemented in southwestern Mississippi to help remedy water quality problems in the Tangipahoa River, which flows southeast across the Mississippi and Louisiana state lines to Lake Pontchartrain, Louisiana. The project then expanded to other districts. The plans included pumping solids from improperly functioning animal waste lagoons and applying them to the land with a traveling gun irrigation system, in accordance with waste management plans at various sites. Approved waste management plans may have also included nutrient management plans. During the project time period, 12 lagoon systems (10 dairy, one swine, and one poultry) were pumped out. The total amount of land used for the applications included 192 acres of cropland and 206 acres of pastureland. In total, the lagoon effluent irrigated onto these acres contained 72,402 pounds of nitrogen, 34,911 pounds of phosphorus, and 82,715 pounds of potassium.

The landowners who participated in the demonstration project were pleased with the outcome and saved money on fertilizer costs. They noted that the demonstration resulted in the following benefits:

- The irrigation system helps alleviate lagoon overflow problems.
- Expensive and time-consuming equipment is not necessary for the adoption of this lagoon management practice. Tank trucks and tractors, which cause soil erosion and compaction, can be eliminated.
- Production costs are significantly lower when nutrients are recycled to crop and pasture systems. The alternative practice, commercial fertilizers, is more expensive.

Crooked, Otter, and North Fork Tributaries, Missouri

This project covered an area of approximately 630 square miles in northeast Missouri, including all of the drainage area of the Crooked, Otter, and North Fork tributaries that empty into Mark Twain Lake. Agricultural land composes 55 percent of the project area’s land use. The land is intensively cropped and is also a major pork producing region. Two counties within the drainage area have over 300 swine facilities and an additional 100 dairy and beef operations.

This project expedited the adoption of innovative BMPs through technical assistance to producers. The project is designed to help farmers:

- develop, implement, and evaluate total resource management (TRM) systems or whole-farm plans that emphasize nutrient and pesticide strategies;
- plan, design, and install animal waste systems; and
- provide assistance to field personnel in the formulation and implementation of TRM systems training.

The TRM plans include such practices as manure and nutrient management, intensive rotational grazing systems, alternative water supplies for livestock, waste production storage and treatment programs, erosion control, dead animal composting, soil and water testing, prairie restoration, woodland and wildlife management, precision farming, crop rotation, farm dump cleanups and alternatives to illegal dumping, insect scouting, weed mapping, pesticide container recycling, and nitrogen-fixing legumes for reduced fertilizer applications.

As a result of TRM plan implementation, the farms and communities reaped benefits, including improved water quality, less field and streambank erosion, more plentiful wildlife and beneficial pests, fewer chemicals and nutrients in runoff, and increased yields and income.

Godfrey Creek, Montana

Several dairy cattle, swine, and beef cattle operations are located immediately adjacent to Godfrey Creek in Montana and are the major sources of impairment to the creek. Improper grazing management, riparian area degradation, and crop farming also contribute to the problem.

A project was initiated in 1989 with two primary objectives: (1) to demonstrate agricultural BMPs that will reduce suspended solids, fecal coliform, and nitrates in runoff from dairy operations, grazing, and farming practices; and (2) to develop an education program for producers in the watershed. Over 80 percent of landowners in the area participated in major efforts such as fencing riparian areas, adopting improved grazing systems, removing livestock from riparian areas, establishing buffer zones, improving manure-handling systems, and improving irrigation water management.

Post-project data, from samples taken in 1995 and 1996, suggest that water in Godfrey Creek watershed improved as a result of project activity. Estimated reductions in mean annual concentrations were 58 percent for total phosphorus and 64 percent for total dissolved solids compared with pre-project conditions. A dramatic decline (82 percent) in fecal coliform also occurred. However, nitrate-plus-nitrite data show an average increase of 24 percent. Although the project has not yet reached its goal of 80 percent reduction in these key indicators (except for fecal coliform), it is successfully helping landowners gain control of factors that influence surface and bank erosion and nutrient runoff. Agricultural practices that help control nitrate include a combination of irrigation and manure disposal methods. Future project activities may need to emphasize these practices to ensure the full realization of Godfrey Creek's potential.

Bush River-Camping Creek Watershed, South Carolina

The Bush River-Camping Creek watershed in Newberry County, South Carolina, drains directly to Lake Murray. This 51,000-acre impoundment is used to generate power, provide a municipal water supply serving approximately 330,000 people, and provide a major recreational resource. More than 175 miles of streams run through the project area, and more than 800 ponds are located along these streams. The ponds are used for livestock watering, irrigation, and recreation.

Although land uses vary, the potential for non-point source pollution is primarily agricultural. The watershed's nearly 130,000 acres support the following uses: about 29,500 acres of cropland, 60,700 acres of forest, 22,900 acres of pasture, and 16,600 acres of development (urban, industrial, and commercial). Over 200 farmsteads are maintained in the watershed, with an average size of 165 acres. The farm industry is quite diversified, although the most prevalent enterprises are confined animal operations, small grain production, and row crop farming. Over 60 confined animal operations have been inventoried in the watershed. The USDA Natural Resources Conservation Service (NRCS) estimates that the watershed produces about 75,000 tons of animal waste annually.

Agricultural activities in the project area are a major influence on the streams and ponds in the watershed, and contribute to nutrient-related water quality problems in the headwaters of Lake Murray. In fact, bacteria, nutrients, and sediment from soil erosion are the primary contaminants affecting these resources. The NRCS has calculated that soil erosion, occurring on over 13,000 acres of cropland in the watershed, ranges from 9.6 to 41.5 tons per acre per year. At times, excessive amounts of nutrients, especially nitrates, are found in the water, primarily as a result of land applying too much manure, sometimes with or in addition to commercial fertilizers. Based on these conditions, the Bush River-Camping Creek watershed was identified in the South Carolina Non-point Source Management Plan as a high priority watershed.

A coordinated multiple agency effort to control these non-point sources began in 1990. Phase one of the project demonstrated agricultural BMPs, provided technical assistance to agricultural landowners implementing non-point source pollution controls, financial assistance to qualifying landowners for BMP installations, and a water quality monitoring program. Simultaneously, the state inventoried and inspected all confined animal facilities in the watershed. Technical assistance was then provided to owners who were not in compliance with regulations. Potential violations include illegal discharge pipes, overflow discharges, high vegetation around lagoons, runoff from animal housing, improper dead animal disposal, and absence of permits. Phase two of the project concentrates on confined animal operations in the watershed. Components include demonstration of innovative BMPs, such as lagoon pump-out/irrigation practices and dead bird composting. Farmers in the project area have access to a mobile nutrient testing service, which helps them calculate the right amount of manure to apply to their fields and pastures, and additional computerized information to help them make prudent decisions about pesticide selection and management. Educational activities include newsletters, workshops, field days, and one-on-one technical assistance to farmers.

Several improvements have been noted since the implementation of this project:

- Ambient water quality samples gathered between May and October 1992 from the headwaters of Lake Murray, which receives water from the Bush River-Camping Creek watershed, indicated statistically significant reductions in nutrients (nitrate-nitrite and total phosphorus) since the start of the project. These decreases might be associated with reduced numbers of nutrients reaching the waterbody from non-point sources. Similar data gathered between 1992 and 1996 indicate continued reductions in nitrate-nitrite.

- Of 48 AFOs that were out of compliance with regulations at the beginning of the project, 26 of these operations were in compliance in 1993. Twenty-two others were working on gaining compliance through coordination with state and local entities.

- Approximately 94,000 tons of soil in the watershed were saved through the use of BMPs. Also, 75,000 tons of animal waste are being properly used annually according to South Carolina guidelines (i.e., application rates, slopes, and time of year).

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