Manure and wastewater handling and storage costs

Manure and wastewater storage and handling includes components and activities associated with the production facility, feedlot, manure and wastewater storage and treatment structures and areas, and any areas or mechanisms used to facilitate transfer of manure and wastewater. For most CNMPs, addressing this element requires a combination of conservation practices, management activities, and facility upgrades designed to meet the production needs of the livestock operation while addressing environmental concerns specific to each operation. Manure and wastewater storage and handling needs are highly specific to the condition and location of each facility, and differ from farm to farm.

This study adopts a generalized approach to estimating needs and costs for this element by identifying major cost items and making broad assumptions about CNMP needs. There are many types of CNMP-related costs on specific farms, and it is impractical to simulate the full array of potential cost items. This analysis focuses on the needs and costs that generally would be representative of the industry. Needs and costs were identified so that they would reasonably represent alternatives. For example, composting was selected as the basis for estimating the costs of managing mortality on poultry and swine farms. There are acceptable alternatives to composting, but the costs generally are about the same. The needs and costs assigned to a specific farm in the model simulation may differ from those that would be identified for a specific farm in an actual CNMP. However, it is expected that the overall estimates derived from the model simulation will be representative of the total CNMP costs for this element.

The analytical framework used to derive CNMP needs and costs for the manure and wastewater handling and storage element is based on the model farms described previously (see tables 2–5). Components of the manure and wastewater storage and handling element were identified for each model farm. Not every model farm has every component. The objective was to define adequate components to meet the criteria established in the NRCS CNMP Technical Guidance and applicable NRCS conservation practice standards.

The team was guided by the NRCS Agricultural Waste Management Field Handbook (AWMFH) (NRCS, 1992). The appropriate components of a typical manure management system for each model farm were based on chapter 9 of the AWMFH. Major cost items for manure and wastewater storage and handling are broken down into the following components:

- Mortality management (poultry and swine)
- Lot upgrades
- Clean water diversions (including roof runoff management, earthen berms, and grassed waterways)
- Liquid treatment (small dairies)
- Collection and transfer (including solids, liquid, contaminated runoff, and pumping)
- Settling basins
- Solids storage
- Liquid storage
- Slurry storage
- Runoff storage ponds

In all but one case, it was assumed that farms would not switch from one production system to another (i.e., switch from one representative farm to another) because of implementing a CNMP. An exception was made, however, for large dairies in the Dairy Belt that reported a solids-based manure handling system in the farmer surveys. The team felt that these large dairies would find it too labor intensive to continue to handle manure as a solid and meet CNMP criteria, and would convert to a liquid system with a waste storage pond.

Cost estimates for conservation practices for pastured livestock are included in the manure and wastewater handling and storage element. Components for farms with pastured livestock types include:

- Fencing
- Water well
- Watering facility
- Heavy use area protection
- Windbreak or shelter break establishment
- Solids storage
- Filter strip

Manure and wastewater handling and storage costs were estimated for the system associated with the dominant livestock type on each farm. Many of these farms, however, have other confined livestock types on the farm. The assumption was made that costs associated with addressing CNMP needs for the secondary livestock types on the farm, for the most part,

could be incorporated into the system costs for the dominant livestock type. Any additional costs were assumed minor and were not estimated. For several components, however, costs were based on the amount of recoverable manure produced on the farm (handling and transport weight), which included recoverable manure from all livestock types on the farm. (See appendix B for details on the calculation of recoverable manure and the amount for handling and transport.)

CNMP costs for the manure and wastewater storage and handling element were estimated for each farm. Costs were defined on a per-animal or per-animal-unit basis wherever possible so that the final cost estimate would more closely represent the existing production capacity of each individual operation. For poultry, costs were estimated on a per-house basis. For this purpose it was assumed a broiler house would hold 25,000 birds, a layer or pullet house would hold 50,000 birds, and a turkey house would hold 5,000 birds for slaughter or 8,000 birds for breeding.

To obtain estimates of CNMP-related costs for manure and wastewater handling and storage components, information is needed on per-unit costs and on CNMP needs for each component. Most per-unit cost estimates were based on literature values or values taken from the NRCS Field Office Technical Guide.

However, no data are available on CNMP needs for this element, nor can CNMP needs be derived from other databases, as was done for nutrient management costs, land treatment costs, and off-farm export costs. CNMP needs for manure and wastewater handling and storage components were estimated by a team of experts using a consensus approach to approximate what the needs might be. The team of experts consisted of agricultural engineers, environmental engineers, economists, and agronomists with extensive experience working with livestock producers and government technical assistance programs. Team members also consulted with other experts who had knowledge about specific industries or areas of the country.

To simplify the process of estimating CNMP needs for this element, three groups of "virtual" farms were established: the 25 percent of farms with the lowest needs, the 25 percent of farms with the highest needs, and the 50 percent of farms with average needs. For each of the three groups, the percentage of farms needing upgrades was estimated by the team. The final estimate of CNMP needs for each component was then obtained as a weighted total. CNMP needs were estimated as percentages that can be interpreted in two ways:

- The percentage of the total cost that the average farm would incur in upgrading facilities to meet CNMP guidelines.
- The percentage of farms in a group that would need to add a component, incurring the full cost.

These two interpretations of the needs percentages are analytically equivalent. However, one of these two interpretations may be more appropriate than the other for specific components.

Separate cost estimates were made for capital expenditures (equipment and structures), operating costs, and maintenance costs. All costs are presented as annual costs. Capital costs are converted to annual costs by amortizing the total cost over 10 years with an 8 percent interest rate. Operating costs are largely labor costs, but also include fuel and other costs where appropriate. The standard wage rate used for labor was $10 per hour. Maintenance costs were estimated as 3 percent of the capital costs.

Specific estimates of CNMP needs and costs for each component were made for farms with more than 35 AU of confined livestock types. Farms with less than 35 AU where confined livestock types were dominant (42,565 farms) were judged to be too diverse with respect to the type of production technologies employed in producing livestock to apply the standard set of representative farms. Small farms tend to use small lots and pastured environments to a greater extent than the larger farms for which the set of representative farms were derived. Furthermore, CNMPs for these smaller farms would most likely address only a subset of the components that would be addressed for larger farms, focusing on situations and practices associated with environmental impacts. (Pastured livestock farms with less than 35 AU were not explicitly excluded, but few were included in the set of farms that may need a CNMP because of the small quantities of recoverable manure produced.)

Manure and wastewater handling and storage costs for farms with **less** than 35 AU of confined livestock types (and where pastured livestock were not dominant)

were estimated based on costs derived for small dairies. (Most of these farms either had milk cows or swine as the dominant livestock type. See appendix A, table A–5.) Operating costs per AU were estimated using the average capital cost for dairies with 35 to 60 AU. Capital costs per AU were estimated as 50 percent of the average capital cost for dairies with 35 to 60 AU. The total manure and wastewater handling and storage costs for these small farms were obtained by multiplying the per-AU costs times the number of AU for confined livestock types on the farm.

A description of each component and how the costs were derived follows. The per-unit costs and assumptions of CNMP needs derived by the team of experts for each model farm are summarized in appendix E. The overall cost estimates for manure and wastewater handling and storage are presented in the last part of this section.

Mortality management

The cost of mortality management is included for all poultry and swine farms. For dairy and fattened cattle, it was assumed that existing mortality management practices would be adequate in most cases. Various acceptable methods are used to manage poultry and swine mortality, such as composting, incineration, burial pits, and freezing. Composting was selected as the representative technology for assessing CNMP costs.

Poultry

The cost of mortality management for poultry was determined on a per-house basis. A concrete slab covered with a timber structure comprised the composting facility. Capital and operating costs of the structure were based on costs reported by the North Carolina Cooperative Extension (1999) for a 100,000-bird broiler flock. The cost of the timber structure and concrete floor was $3,600, and the cost of water service for the facility was $150, resulting in an annual capital cost of $559. Operating costs included labor (27.5 hours per flock at $10 per hour) and machinery rental ($20 per hour at 51 hours per year), for a total of $2,533 per year. For the 25,000-bird broiler house used as the standard house size in this study, annual costs were $140 for capital and $633 for operating costs.

Costs for the other poultry livestock types were estimated by prorating the cost for broilers based on capacity needed for the other poultry types. The capacity needed was estimated using a method published by the North Carolina Cooperative Extension (1996). Maximum capacity was estimated by multiplying the expected daily death rate by the market weight (maximum weight), and then multiplying by the number of birds per house. Although mortality takes place throughout the production cycle with birds at various weights, for most operations the majority of the mass that must be dealt with occurs near the end of the production cycle when birds are closest to their market weight. To ensure adequate composter space, capacity needed is based on the greatest demand in order to handle the larger bird mortality. Calculations are shown in the chart that follows:

Poultry type	Birds per house	Market weight (lb/bird)	Mortality rate (%)	Mortality rate (lb/d)	Ann. capital cost per house ($)	Ann. operating cost per house ($)
Broilers	25,000	4.5	0.1	113	140	633
Layers & pullets	50,000	4.0	0.033	66	82	371
Turkeys for slaughter	5,000	19.2	0.080	77	96	433
Turkeys for breeding	8,000	18.8	0.100	150	187	846

CNMP needs for mortality management for poultry were judged to be lower for the larger operations and higher for turkey operations. CNMP needs were assigned as follows:

- 45 percent for broiler and pullet farms with less than 220 AU
- 15 percent for broiler and pullet farms with more than 220 AU
- 45 percent for layer farms with less than 400 AU
- 15 percent for layer farms with more than 400 AU
- 60 percent for turkey farms with less than 220 AU
- 30 percent for turkey farms with more than 220 AU

Swine
Estimates of mortality management costs for swine were based on a composting facility consisting of a concrete pad with walls constructed of large round bales and covered with a tarp, and a fence to keep animals out. Included in the system are a carcass cutter and grinder. (Costs for this system are described by Ken Foster in *Cost Analysis of Swine Mortality Composting*, Purdue University.)

The annual cost of the cutter and grinder is $1,248, which would need to be incurred only once per operation regardless of the size of the operation. Other capital costs (concrete slab, fence, tarp, bales) were reported by Foster for a farrow-to-finish operation with a maximum capacity of about 250 animal units to be $549 per year. Annual operating costs (labor, sawdust, fuel, and utilities) for this system were reported to be $350 per year. On an animal unit basis, these costs convert to $2.20 per animal unit for the additional capital costs and $1.40 per animal unit for operating costs.

Because swine operations have only recently begun to address mortality management practices as an integral part of their operation, CNMP needs were set at 70 percent for all sizes and types of swine operations.

Feedlot upgrades

The cost of feedlot upgrades was applied only to cattle on feed (fattened cattle and confined heifers) and consists of improving the open lot area where cattle are held to ensure the proper functioning of collection systems. It includes grading to enhance drainage and a concrete pad to protect drainage collection and diversion areas during manure collection activities. (These lot upgrades exclude the costs of berm construction for diverting contaminated water into the storage pond, which are costed separately.)

A 750-head fattened cattle operation was used as a basis for deriving representative costs for this component. Costs were estimated assuming installation of 111 cubic yards of concrete (6,000 square feet) at $200 per cubic yard, and 1,700 cubic yards of earthmoving and shaping at $2.00 per cubic yard. (These costs were taken from the Iowa State Beef Feedlot System Manual—PM 1867, January 2001.) The total capital cost is thus $25,600 per 750-head operation, or $34 per head. The amortized annual cost is $5.09 per head.

Most operations typically have addressed this component as a part of their existing management systems, so needs were judged to be comparatively low, as follows:

- 15 percent for fattened cattle farms with a scrape and stack operation
- 30 percent for confined heifer farms with a scrape and stack operation
- 30 percent for the smaller fattened cattle farms with manure pack
- 5 percent for the larger fattened cattle farms with manure pack

Clean water diversions

Clean water diversions are used to minimize the amount of rainfall runoff that can come in contact with areas of the animal production operation where manure and wastewater are present, primarily the open lot areas. The types of clean water diversions used in this study were roof runoff management, earthen berms with a surface outlet, earthen berms with underground pipe outlets, and grassed waterways. Because diversions were only essential for operations with an open lot, clean water diversions were not applied to operations that only confined animals in buildings.

Roof runoff management
Gutters and downspouts were used to capture rainfall on the roofs of buildings to route the water from the production area. This kind of clean water diversion was applied to dairy, turkey, and swine operations that provided outside access to animals. Fattened cattle operations were not included because typically these animals are raised in a feedlot without any buildings or structures within the confinement area.

The per-unit costs used were taken from the NRCS Field Office Technical Guide, Section 1, Annual Cost List. The installation cost for a standard gutter and downspout used in most areas of the United States is $2.25 per foot. In areas of higher rainfall, such as the Southeast, a larger gutter is needed at a cost of $4.50 per foot. Since downspouts are often damaged by animals and machinery, repairs and maintenance were assumed to be an additional 7 percent of the

installation cost. (This 7 percent is in addition to the maintenance costs estimated as 3 percent of all capital costs, bringing the total percentage for maintenance cost for this component to 10 percent.) The estimated quantities of gutters and downspouts used per type and location of facility were based on average building size and typical building capacities. Dairy costs were based on 200 feet of gutters and 40 feet of downspouts for a 100-cow dairy, and converted to a per-head basis. The annual capital cost for dairies, including maintenance and repair, was $2.37 per head in the Southeast and $1.18 per head for other regions. For turkey ranches, the annual capital cost was $473 per house, assuming 800 feet of gutter and 160 feet of downspouts per house. For swine farms with buildings and outside access, the annual capital cost was $0.85 per animal unit, based on 200 feet of gutter and 40 feet of downspouts for a 140-AU operation.

Roof runoff management has been a neglected component on some systems, but is commonly present on other systems. Larger operations are expected to have fewer needs than smaller operations. CNMP needs were assigned as follows:

- 30 percent for swine farms with buildings and outside access
- 90 percent for turkey ranches
- 80 percent for Dairy Belt dairies #1 and #2 (solids systems) with up to 270 AU
- 45 percent for Dairy Belt dairies #1 and #2 with more than 270 AU
- 40 percent for all other dairies

Earthen berms with underground pipe outlets

This type of clean water diversion was used for fattened cattle operations with a manure pack method of managing waste as well as for all dairy operations. These operations generally take advantage of the relief of the land to provide drainage within the lot. Often, these operations have dry or intermittent streams (swales) that run through the feedlot areas. To control clean water upgradient of the lot, a small earthen berm is installed across the swale above the feedlot or lot to catch the clean runoff and then outlet the water through an underground pipe to some point downstream of the feedlot area.

The cost of installing the earthen berm associated with this system addressed the cost of hauling and shaping activities. The berm used for this type of system is considerably shorter than those for other diversion practices because its only function is to create a temporary pool that will drain out through the underground pipe. Although the berm length is considerably shorter than the other berms described in this section, it is usually higher to create sufficient hydraulic pressure to discharge through a long pipeline. The assumed dimensions of the berm were based on a trapezoidal shape with an 8-foot top width, 3 horizontal to 1 vertical side slopes, and 3 feet of average height (1.9 cubic yards per foot of length) for a length of 30 feet per berm. The cost per cubic yard was $2 installed, or $115 per berm. The estimate for the underground outlet pipe was based on a 12-inch diameter corrugated metal pipe, and unit costs reflect the cost of pipe and installation activities, such as excavation, laying the pipe, and backfill. Lengths were estimated based on professional judgment of a typical distance through a feedlot based on a particular size of operation. Larger operations could require more than one berm and pipe outlet per feedlot. Per-unit costs were taken from the NRCS Field Office Technical Guide, Section 1, Annual Cost List. Cost estimates were developed for three different-sized operations as follows.

Number of animals	Linear feet of pipe	Pipe cost per foot ($)	Number of 30-foot berms	Berm cost ($)	Total cost installed ($)	Cost per animal ($)	Annual cost per animal ($)
75	200	12	1	115	2,515	34	5.07
150	360	12	1	115	4,435	30	4.47
600	1,200	12	3	345	14,745	25	3.58

Using these three cost estimates, the following rules were established for assigning costs to farms on a per-head basis:

- If the number of head is less than 100, then the cost per head is $5.07.
- If the number of head is between 100 and 300, then the cost per head is $4.47.
- If the number of head is more than 300, then the cost per head is $3.58.

Most of these operations already have this practice in place or do not need it because of the characteristics of the terrain near the facility. Some systems in some regions of the country, however, were judged to have relatively high needs. CNMP needs were assigned as follows:

- 20 percent for the smaller fattened cattle farms
- 10 percent for the larger fattened cattle farms

- 50 percent for dairy representative farm #1 (Dairy Belt)
- 50 percent for dairy representative farm #2 in Dairy Belt with <270 AU
- 30 percent for dairy representative farm #2 in Dairy Belt with >270 AU
- 20 percent for dairy representative farm #2 in West and Southeast
- 30 percent for dairy representative farm #3
- 40 percent for dairy representative farm #4
- 20 percent for dairy representative farm #5 in Southeast and in West with <270 AU
- 10 percent for dairy representative farm #5 in West with >270 AU

Grassed waterways
Grassed waterways are shaped channels that are seeded to establish vegetation. They are used for clean water diversion in areas that receive sufficient annual rainfall that vegetation can be maintained naturally and where the runoff-contributing watershed is relatively small. These waterways are more efficient than an earthen berm because they can handle larger flows without concern of erosion. This is a typical practice used east of the Mississippi River. This practice was used to represent the clean water diversion treatment needs for fattened cattle operations and confined heifer operations that utilize a stack and scrape manure management system. Only 15 percent of these operations were assumed to need to install this practice because of its common use.

All grassed waterways were assumed to be 30 feet wide. The length varies by the size of the operation. Per-unit costs were taken from the NRCS Field Office Technical Guide, Section 1, Annual Cost List. The cost of installing a grassed waterway involves grading and shaping the channel, which costs $115 per acre, and seeding, which costs $125 per acre. The total cost is $240 an acre or $36 per acre annually. Lengths were estimated based on professional judgment of a typical distance to bypass a feedlot for two sizes of farms and then converted to a per-head cost, as follows:

Number of animals	Linear feet of waterway	Acres	Total cost installed ($)	Annual cost ($)	Annual cost per animal ($)
150	1,200	0.83	199	30	0.20
600	1,800	1.24	298	44	0.08

The $0.20 cost per head was assigned to all operations with less than 500 head, and the $0.08 cost per head was assigned to operations with more than 500 head.

Earthen berms with surface outlet
Earthen berms with a surface outlet are shaped mounds of uniform cross section made of soil to serve as an intercept upslope of an open lot to divert clean water around the lot to a stable natural outlet. This clean water diversion practice was used only on turkey and swine operations that have an open lot as part of the production area. Per-unit costs were taken from the NRCS Field Office Technical Guide, Section 1, Annual Cost List.

All open lots were assumed to have a diversion along two sides. Installation involved primarily earth hauling and shaping activities. The assumed dimensions of the berm were based on a trapezoidal shape with an 8-foot top width, 3 horizontal to 1 vertical side slopes, and 2 feet of height for a running volume of 1 cubic yard of diversion per foot of length. The cost per linear foot was $2.00 installed.

For a swine operation with open lot access and 900 animals (100 animal units), typically 460 square feet of loafing area is provided per animal unit, or 46,000 square feet. Assuming a square lot, the dimension of a side would be 214 feet. Assuming the diversion would be wrapped around two sides, the total length would be 428 feet for a total cost of $856. The amortized annual cost would be $128 per year or $1.28 per animal unit per year. CNMP needs for these operations were judged to be 20 percent for swine representative farm #4 (building with outside access) and 50 percent for swine farm #5 (pasture or lot).

A typical turkey operation would raise approximately 5,000 birds per house. One house is equivalent to 75 animal units. Assuming the lot area provided 460 square feet per animal unit (the same as the proportional area per animal unit provided for swine) the area of a turkey lot would be 34,500 square feet, or a lot with sides measuring 185 feet. The total length of the berm would be 370 feet and would cost $740. The amortized annual cost would be $111 per year per house. CNMP needs were judged to be 40 percent for turkey ranches.

Liquid treatment

Small dairy operations that remove solids daily or weekly would continue to handle their manure as a solid and use a liquid treatment approach to handle the liquid component. Generally, cows on these operations are kept on pasture most of the day. However, they are brought in to be milked, and as a result spend some time in an open lot. During storms, runoff from the open lot would contain manure and related wastes, but this would normally be a small volume. Milk-house washings would also generate small amounts of wastewater. For these operations it was assumed that the runoff and milk-house washings could be handled with a biofilter. A biofilter is a small, vegetated area that functions similar to a wetland by capturing the runoff and bioprocessing it through infiltration of nutrients into the soil for use by the vegetation. Use of a biofilter for liquid treatment precludes the need for collection, transfer, or storage of liquid wastes on these farms.

For the purposes of this simulation, the biofilter was assumed to be a vegetated filter strip of 12,000 square feet, at $0.25 per square foot for a cost of $3,000. The construction of the filter would be accomplished by land grading equipment. Based on an average size operation of 75 milk cows, the capital cost is $6.00 per cow annually.

A liquid treatment component was included for dairy representative farms #1 and #2 with less than 135 AU per farm. CNMP needs were judged to be high for this component; 65 percent for farm #1 and 75 percent for farm #2.

Collection and transfer

The collection and transfer component addresses the installation and operation of practices associated with handling the manure and wastewater within the production area. The type of collection used depends on the type of animal feeding operation, consistency of the manure handled, and the type of management system used. Management systems for animals raised in buildings address a single manure consistency, either a liquid/slurry or a solid. Operations that use open lots generally need to address both solids and liquids because manure and contaminated runoff are generally handled separately.

CNMP costs were determined for three types of collection systems: solids collection, liquid collection with flush systems, and contaminated runoff collection. For the last two types of collection systems, a liquid pumping system is needed to transfer the wastewater to a storage structure and/or from the storage structure to land application equipment. For solids, manure is transferred to a solids storage facility during collection.

Almost all model farms include either a collection or a transfer component, or both. Representative farms that predominantly handle manure as a slurry, however, have storage pits either under the building or adjacent to the housing facility, requiring only rinsing to collect the manure. For these representative farms, it was assumed that the collection structures would be adequate and that only a transfer component may be needed. These farms include veal, swine representative farms #2 and #3, dairy representative farms #1 and #2 with more than 135 AU, and dairy representative farm #3. Dairy representative farms #1 and #2 with less than 135 AU have a liquid treatment component (filter strip for milk-house washings) and so would not need a collection or transfer component.

Solids collection

Solids collection is a component for all operations **except** for swine and dairy farms with complete liquid or slurry systems, layer farms with liquid systems, and veal farms. Generally, most operations have an adequate collection system already in place, so CNMP needs are expected to be low. CNMP needs were judged to be 10 percent for all but the cases listed below:

- 2 percent for broiler farms
- 15 percent for turkey farms (representative farms #1 and #2)

Solids collection for dairy, fattened cattle, confined heifers, and for swine raised in a building with outside access or in a pasture or lot was assumed to consist of a tractor scraper used to collect and pile the manure on a concrete slab. Costs are based on the amount of manure to be handled, which is estimated in appendix B. The scrape operation costs are based on a 37-hp tractor with scraper at a purchase price of $22,000. Assuming this equipment is dedicated 80 percent to this function, the annual cost is $3,591. Conventional guidelines for estimating annual operating costs—fuel, oil, and labor—for equipment used on an intermittent

basis, as in this case, is 15 percent of the purchase price (Tilmon and German, 1997). Thus, the annual operating costs were estimated to be $3,300 per year. The cost per ton was determined for a 150-head dairy operation, which was then used for all dairy, fattened cattle, confined heifer, and swine farms that had a solids collection component. A 150-head dairy operation has about 200 animal units and produces about 580 tons of manure at transport and handling weight (assuming about 2.2 tons of manure as excreted at oven-dry weight, converting to a handling weight by multiplying by 2, and adjusting for recoverability with a 0.65 recovery factor). Thus, capital costs are $6.20 per ton of solids and operating costs are $5.70 per ton.

The cost of solids collection for broilers, pullets, turkeys, and layers with a high-rise or shallow pit production system that raise poultry in confinement buildings was based on the assumption that the buildings are partly cleaned out after each flock and completely cleaned out once per year. A custom rate was used, and since most of the cost is labor, it was categorized as an operating cost, even though a portion of the cost covers the cost of the equipment. The custom rate used was determined based on several sources of information obtained from University Extension Service and private industry sources. The rates varied from $0.02 to $0.07 per square foot depending on the size of the house and regional location. However, the predominant price range was from $0.04 to $0.065 (including both annual cleanout and four to five cakeouts per year.) Averaging the costs from the sources considered provided a custom rate of $0.053 cents per square foot of house. An average size broiler and turkey house is about 20,000 square feet, producing an annual cleanout cost estimate of $1,060 per house. The average size of a layer or pullet house with a 50,000-bird capacity is about 24,000 square feet, producing an annual cleanout cost of $1,272 per house.

For layer operations that use a mechanical belt system installed beneath the layer cages, manure falls directly onto the belt, and periodically the belt empties itself onto a stacking area. For layer operations that use a scraper type system, the litter produced is removed from the building by mechanical scrapers and deposited in a stacking area. Solids collection for these two types of operations was viewed as the activity to move the litter deposited in the stacking areas at the ends of buildings to a central storage area or directly into trucks for transport off-farm. Cost was based on equipment rental rates for a 150-hp front-end loader (3 yard bucket) at $15.08 per hour and an operator cost of $10.00 per hour. Based on a weekly manure production of about 42 tons of litter per house (50,000 birds), the time needed to move the litter is approximately 1.5 hours per week per house for 78 hours per year, or $1,956 per house annually.

Liquid collection with flush systems

The flush system is used commonly by dairy, swine, and layer operations that handle their wastes as a liquid. Waste is collected by the flushing of floor gutters within the barn to move waste and water to a collection tank, where it is transferred to a holding pond or lagoon by gravity or a transfer pump. Existing flush operations are assumed to have most of the system in place. Therefore, systems would only need to be upgraded to be consistent with any modifications in the storage and handling systems. Components assumed to be needed were a flush tank, collection tank, transfer pipe, and a pit agitation pump. CNMP needs were judged to be comparatively low for the following representative farms with flush systems:

- 10 percent for swine representative farm #1 (liquid system with lagoon or storage pond)
- 10 percent for layer representative farm #2 (flush to lagoon)
- 30 percent for dairy representative farm #4 (liquid system with lagoon or storage pond) with less than 270 AU
- 40 percent for dairy representative farm #5 (liquid system with lagoon or storage pond) with less than 270 AU
- 20 percent for dairy representative farm #4 or #5 with more than 270 AU

Costs for three sizes of dairy farms were used as the basis for flush cost systems. The base system for the smallest operations included two collection tanks (10 feet wide by 20 feet long and 8 feet deep); a transfer pipe (50 feet of 100-lb/in^2 PVC); and an agitation pump (PTO driven impeller). Costs for larger systems would account for the increased size needed to handle more animals. Operating costs cover fuel, oil, electricity, and pump maintenance. For these systems, the cost of the pipe used to transfer the waste to the field for application was treated as a hauling cost, and the cost of pumping to the field for irrigation is covered under the pumping transfer system costs. The dairy liquid collection costs are summarized in table 26.

The costs shown in table 26 were applied to dairy representative farms #4 and #5. Dairies with less than 150 head were assigned a capital cost of $28.99 per head. Dairies with 150 to 250 head were assigned a capital cost of $24.57 per head. Dairies with more than 250 head were assigned a capital cost of $23.10 per head. Operating costs for all size farms were $11.84 per head.

The same components are also needed for swine operations with liquid wastes (swine representative farm #1) and layer farms with liquid wastes (layer representative farm #2). The costs above were converted to an animal unit basis for these swine farms and to a per-house basis for the layer farms. The annual capital cost was $20.70 per AU for swine farms with less than 200 animal units, $17.55 per AU for farms with 200 to 400AU, $16.50 per AU for farms with more than 400 AU, and annual operating costs were $8.46 per AU for all size groups. For layers, the annual capital cost was $3,157 per house, and the annual operating cost was $1,291 per house.

Contaminated runoff collection

Earthen berms are used to divert rainfall runoff that has come in contact with manure in the production area to a storage pond. These contaminated water divisions would be located on the down-gradient end of the production area. The types of contaminated water diversions typically used are earthen berms with a surface outlet and earthen berms with pipe outlets.

Table 26 Cost estimates for liquid collection with flush systems for dairy farms

Cost component	Operation		
	100-head ($)	200-head ($)	300-head ($)
Flush tank	7,801	15,602	23,403
Collection tanks	5,721	11,442	17,163
Collection pipe	562	562	562
PTO impeller	5,367	5,367	5,367
Total capital cost	19,451	32,973	46,495
Annual capital cost	2,899	4,914	6,929
Annual operating cost	1,185	2,369	3,554
Annual capital cost/head	28.99	24.57	23.10
Annual operating cost/head	11.84	11.84	11.84

Contaminated water diversions are necessary components for all fattened cattle and confined heifer representative farms as well as turkey ranches and swine farms with a pasture or lot (swine farm #5). It was assumed that lots on dairy farms and swine farms with a building and open access would be small enough that contaminated water diversions would not be needed or would be incorporated into the structure of the runoff storage pond.

Typically, turkey operations and swine raised in a pasture or lot would use an earthen berm with a surface outlet that diverts the runoff to a small storage pond. The construction is similar to earthen berms with surface outlets used for clean water diversion. Based on costs used for the clean water diversion berms presented previously, the annual capital cost would be $111 per house for turkey ranches and $1.28 per animal unit for swine. CNMP needs were judged to be comparatively high for these farms, as follows:

- 50 percent for swine representative farm #5
- 90 percent for turkey ranches

Fattened cattle and confined heifer operations use a similar system; however, they would generally outlet the captured contaminated runoff through a pipe into a holding pond. These types of operations generally take advantage of the relief of the land to provide drainage within the lot. On the downslope end of the lot, an earthen berm is constructed that channels all lot rainfall runoff to a pipe outlet that conveys the contaminated runoff water to a holding pond or lagoon.

The cost of the earthen berm was calculated based on the following assumptions: the shape was trapezoidal with an 8-foot top width, the side slopes were 3 horizontal to 1 vertical, and the height was 2 feet. The unit cost of the berm is $2.00 per linear foot, taken from the NRCS Field Office Technical Guide, Section 1, Annual Cost List. The length of the berm was equal to the downslope width of the lot. The following approach was used to determine the length of berm: first it was assumed that each animal unit was provided 460 square feet of lot space, then the total lot size was computed by multiplying the number of animal units by 460, and then the square root of the area was taken to represent the berm length. The outlet pipe was assumed to be a 12-inch diameter corrugated metal pipe (CMP). The unit cost for pipe, $12 per foot, reflects the cost of the pipe and installation activities, such as excavation, laying the pipe, and backfill. The

length of pipe needed on any particular site varies depending on the distance from the berm to the storage pond. To simulate this variation, it was assumed the length of pipe was 20 percent of the length of diversion.

Three size categories were used for assigning costs to the fattened cattle and heifer farms:

	Size 1	Size 2	Size 3
Animal number (head)	116	308	616
Area of lot (ft^2)	53,130	141,080	283,360
Length of berm (ft)	230	376	532
Cost of berm ($)	460	752	1,064
Cost of berm per head ($)	3.96	2.44	1.72
Linear feet of pipe	46	75	106
CMP cost per foot ($)	12	12	12
Cost of pipe installed per head ($)	4.76	2.93	2.07
Annual cost per head ($)	1.31	0.80	0.56

Using these three cost estimates, the following rules were established for assigning capital costs to farms on a per-head basis:

- If the number of head is less than 200 then the cost per head is $1.31.
- If the number of head is between 200 and 450 then the cost per head is $0.80.
- If the number of head is more than 450 then the cost per head is $0.56.

It was judged that the majority of fattened cattle and confined heifer operations would need contaminated water diversions. CNMP needs were assigned as follows:

- 55 percent for confined heifer and fattened cattle farms with a scrape and stack manure handling system in the South and West
- 40 percent for confined heifer and fattened cattle farms with a scrape and stack manure handling system in the Midwest and the Northeast
- 60 percent of the smaller fattened cattle operations with manure pack
- 50 percent of the larger fattened cattle operations with manure pack

Pumping transfer system

All model farms that must handle waste or wastewater in a liquid or slurry form will need to facilitate the transfer of that liquid or slurry from the storage structure (storage pit, holding pond, lagoon, or runoff storage pond) to the appropriate conveyance for land application. Some operations will own a pump for this purpose, but the smaller operations would likely rent the equipment. Costs were therefore estimated on a per-ton basis using a standard rental rate. Several rental rates were obtained from the literature. Rental rates varied depending on the geographic location, but the rates were all within about 15 percent of each other. The average rate was $140 per 8-hour day, or $17.50 per hour. The pumping rate used in the land application section was 500 gallons per minute, which converts to about 1.5 tons per minute (267 gallons per ton), or 90 tons per hour, after allowing for about 20 percent down time for setup or for moving the pump. Thus, the capital cost of the pump would be about $0.20 per ton. Operating costs would be minimal, consisting primarily of fuel costs. An operating cost of $0.06 per ton was based on the cost of 3 gallons of fuel ($1.65 per gallon) per hour.

These costs would be appropriate for operations that use irrigation systems to land apply the wastewater. However, for smaller operations that use a tank truck and sprayer to land apply wastes, additional down time needs to be factored into the costs to account for the multiple trips to the field needed to empty the liquid storage facility. During these trips, the operator would still pay a rental charge but the pump would be idle. In the section on nutrient management costs, we assumed that operations with less than 1,000 tons of liquid wastes per year would use a tank truck and sprayer for land application. Assuming the pump would only be operated 40 percent of the time for these smaller operations, the pumping rate would be about 45 tons per hour and thus capital costs would be $0.40 per ton. Operating costs would remain the same at $0.06 per ton.

CNMP needs for pumping transfer systems were assumed to be the same as the needs for storage (i.e., runoff storage pond, slurry storage, or liquid storage ponds or lagoons).

Storage of solid wastes

The part of the manure that can be handled as a solid, including bedding material, is collected from production areas and stored until it can be land applied. To efficiently use manure nutrients to fertilize crops, the window of opportunity to land apply manure is limited. Therefore, an essential part of a CNMP is manure storage facilities that have enough capacity to hold manure until the proper time for land application.

Solids storage is included as a CNMP component for dairy representative farms #1 and #2, fattened cattle and confined heifer farms with a scrape and stack system for manure handling, swine representative farm #4 (building with outside access), and for all poultry except layer farms with a flush to lagoon system. Fattened cattle farms and dairy farms in the West with a manure pack system do not need a separate solids storage component, since the manure pack is the method of storage. Similarly, swine farm #5 does not need a storage component because the solids can be collected from the lot or pasture at the time of application.

Conservation practice standards used in CNMP development do not require a minimum period of storage because the storage requirements would vary depending on the crop growing season, the crops being grown, climate, and type of management system in place. These factors determine what the storage capacity should be on a particular farm. For purposes of this assessment, however, general minimum storage capacities were established so that cost estimates could be made. Consistent with typical management practices used in the poultry industry, the storage capacity is assumed to be 1 year of litter production for all poultry types. For other animal sectors the storage period is generally less than 1 year because the solids can be handled more frequently and the limiting period of storage would be dictated by availability of cropland to receive the manure. For most of the country, it was assumed that 180 days (50 percent of the storage period for poultry) represented the typical length of storage because it would allow storage of manure through the winter and wet months of the year. Model farms in the Southeast, in most cases, can produce some type of crop year around, so would not need a 180-day storage capacity. In the Southeast storage time was set at 90 days. (For this purpose, the Southeast States are Texas, Louisiana, Mississippi, Alabama, Georgia, Florida, and South Carolina.)

Storage costs were determined as the cost per ton of solids using the hauling weight to approximate the tons to be stored. The cost per ton was determined using a typical storage facility for a broiler operation. This cost per ton was then applied to all livestock types after adjusting for storage time needed. For example, the cost per ton, which was based on a 365-day storage capacity, was multiplied by 0.5 to estimate the cost per ton for operations that only needed a 180-day storage capacity.

The solid storage structure for a typical broiler house was used as the basis for calculating the costs of storage needs for all model farms. The storage cost for broilers was based on a 1,600-square-foot timber shed with end bays, push walls, and a concrete floor. The shed cost $12,403, or $1,863 per year per house. Using the information presented in appendix B, table B–7, on tons of manure at transport weight, it was determined that the average amount of manure per poultry house was about 267 tons per year, including bedding. Thus, the cost per ton is about $7 for all poultry farms. For other livestock types except the Southeast, the cost per ton is $3.50 after adjusting for the needed storage capacity. Similarly, the cost per ton in the Southeast is $1.75 per ton. The total storage cost for each operation was determined by multiplying these cost per ton values times the total tons of recoverable solid manure (at hauling weight) produced in a year.

Generally, the majority of operations are expected to have an adequate solids storage system already in place. The major exception is dairy farms in the Dairy Belt that reported no solids storage in the NAHMS farmer survey. CNMP needs for solids storage were judged to be as follows:

- 100 percent for dairy farm #1 in the Dairy Belt
- 20 percent for dairy farm #2 with 35 to 135 AU and all sizes in the West
- 40 percent for dairy farm #2 in the Dairy Belt with 135 to 270 AU
- 10 percent for dairy farm #2 in the Southeast with more than 135 AU
- 25 percent for fattened cattle and confined heifer farms with a scrape and stack system
- 40 percent for confined heifers in confinement barns
- 60 percent for swine representative farm #4

- 55 percent for layer farms in the Southeast, West, and South Central regions with less than 400 AU
- 30 percent for layer farms in the Southeast, West, and South Central regions with more than 400 AU
- 40 percent for layer farms in the North Central and Northeast region with less than 400 AU
- 20 percent for layer farms in the North Central and Northeast region with more than 400 AU
- 40 percent for broiler farms in the East and pullet farms in the North with less than 440 AU
- 50 percent for broiler farms in the West and turkey farms with less than 440 AU
- 60 percent for pullet farms in the South and West with less than 440 AU
- 25 percent for all broiler farms, pullet farms, and turkey farms with more than 440 AU

Storage of slurry wastes, liquid wastes, and contaminated runoff

Slurry wastes, liquid wastes, and contaminated runoff are normally stored in earthen or fabricated structures. Earthen structures are also used to treat manure in an anaerobic, aerobic, or aerated lagoon. While lagoons and earthen storages look similar, the design process for each is different.

In this study, the nonsolid storage facilities were designated as liquid storage, slurry storage, and runoff storage ponds. Liquid and slurry systems are differentiated by the consistency of the material being stored as determined by the livestock type and the total solids content of the manure. The breakpoint between liquid and slurry manure varies by livestock type. Liquid storages and runoff storage ponds are identical in appearance. Liquid storage ponds as described here generally store more wash water than runoff water, while the runoff storage ponds generally store more runoff water than wash water. Thus, a runoff storage pond for a small dairy will capture wash water as well.

Liquid storage

The category of liquid storage includes both liquid storage and treatment lagoons. Most treatment lagoons provide a storage function as well as a treatment function. The design concept for anaerobic lagoons is to size the structure based on the treatment volume needed to degrade the organic material. Additional volume is added for long-term storage of sludge (decay residuals) and storage volumes.

Liquid storage in ponds or lagoons is a component of manure management systems for some swine, dairy, and layer model farms. These typically are flush systems where wastewater is gravity fed or pumped to storage ponds or lagoons. Most of these operations are assumed to have adequate liquid storage or treatment systems in place. However, some may be in disrepair, under-capacity, or may need to be replaced entirely. CNMP needs for liquid storage, with the exception noted below, were judged to be the following:

- 20 percent for dairy farm #4 in the Dairy Belt with 35 to 135 AU
- 30 percent for dairy farm #4 in the Dairy Belt with135 to 270 AU
- 40 percent for dairy farm #4 in the Dairy Belt with more than 270 AU
- 30 percent for dairy farm #5 in the Southeast
- 30 percent for dairy farm #5 in the West with less than 270 AU
- 20 percent for dairy farm #5 in the West with more than 270 AU
- 40 percent for layer farm #3 (flush to lagoon)
- 20 percent for swine farm #1 for all sizes and regions

It was recognized that a portion of the operations would choose to convert from one method of handling manure to another method as long as improvements are being made to the operation. Changes that will take place cannot be predicted, so the general assumption was that the method of handling manure would remain the same after CNMP implementation. In the case of representative farm #2 for the largest dairies in the Dairy Belt, however, labor costs associated with properly handling the manure as a solid would be too high, and the operator would most likely convert to a liquid system. Thus, CNMP needs are 100 percent for the liquid storage component on these farms.

The cost of constructing a pond or lagoon was estimated for each model farm using a representative number of animals per farm for each model farm. For dairy farms, the representative number of animals was estimated as 137 percent of the number of milk cows, which accounts for the dairy herd plus dry cows (17 percent) and calves and heifers (20 percent). Storage capacity was assumed to be 180 days for all systems. The calculated annual cost was then converted to a per head basis (dairy), a per animal-unit basis (fattened cattle), or a per house basis (layers).

Pond or lagoon sizes were developed using the NRCS Animal Waste Management (AWM) engineering design program. AWM integrates all aspects of the sizing process to meet current NRCS conservation practice standard criteria for Waste Storage Facility and Waste Treatment Lagoon. Where appropriate, a treatment component was included in the design. Categories were further defined to reflect regional differences. A typical set of climate data (monthly precipitation and evaporation) was selected for each region representative of the model farm. AWM then calculated manure volume for 180-day storage, 180-day normal rainfall on the pond surface, the rainfall on the pond surface from a 25-year 24-hour storm event, and as appropriate, the 180-day runoff volume, for the most critical 6-month period of the year based on location. Where the liquid is recycled for flushing, AWM allows the designer to reduce inputs. The AWM program also adjusted volumes for evaporation. The results from AWM gave pond/lagoon dimensions and final volume in gallons.

The installation costs were based on actual cost data for equivalent systems. The costs per gallon were calculated from the total cost of an installed pond/lagoon by the design storage volume. Costs were obtained from various locations across the country from NRCS engineers that had first-hand knowledge of an actual system. The costs used in this assessment reflect averages of the information received from across the country. Various systems were included in the development of costs that included partially excavated ponds, complete earthen fill ponds, and flexible membrane lined ponds. Installation costs per gallon were: 2.2 cents per gallon for pond/lagoons with a capacity of less than 1 million gallons, 1.8 cents per gallon for capacities from 1 million to 3 million gallons, and 1.5 cents per gallon for greater than 3 million gallons.

Costs associated with liquid storage are shown in table 27 for each model farm.

Slurry storage

Slurry storage in earthen pits, concrete tanks, or small storage ponds is a component of manure management systems for some swine, dairy, and veal model farms. These often are storage facilities beneath a slatted floor. Storage facilities were designed for 120 days of storage to reflect common practice in the industry. Most of the dairy operations for representative farm number 3 and veal farms originally were slurry systems, so most are assumed to already have adequate storage systems. For swine farms with slurry systems, it was assumed that the majority would need extensive upgrades to meet the 120-day storage requirement. CNMP needs for slurry storage were judged to be as follows:

- 20 percent for dairy farm #3 in the Dairy Belt with 35 to 135 AU
- 30 percent for dairy farm #3 in the Dairy Belt with 135 to 270 AU
- 40 percent for dairy farm #3 in the Dairy Belt with more than 270 AU
- 30 percent for veal farms
- 50 percent for swine farm #3
- 60 percent for swine farm #2

Slurry storage facility costs were estimated in the same manner as liquid storage ponds and lagoons, using the same approach and the same costs per gallon. Costs associated with slurry storage are shown in table 28 for each model farm.

Table 27 Per-unit cost estimates for liquid storage

Livestock type	Represent-ative farm	Region	Number animals per farm used to design pond	Storage unit size (gal)	Total installation cost ($)	Annual installation cost ($)	Cost per unit ($)
Dairy	2,4	Dairy Belt	300	4,342,477	65,137	9,707	32.36 per head
Dairy	4	Dairy Belt	200	2,893,414	52,081	7,762	38.81 per head
Dairy	4	Dairy Belt	100	1,321,828	23,793	3,546	35.46 per head
Dairy	5	SE	100	1,580,733	28,453	4,240	42.40 per head
Dairy	5	SE	300	4,573,781	68,607	10,224	34.08 per head
Dairy	5	West	100	1,607,863	28,942	4,313	43.13 per head
Dairy	5	West	200	3,130,253	46,954	6,997	34.99 per head
Dairy	5	West	300	5,216,732	78,251	11,662	38.87 per head
Layers	2	SE	50,000	7,054,470	105,817	15,770	15,770 per house
Layers	2	SE	200,000	26,515,403	397,731	59,274	14,818 per house
Layers	2	SC	200,000	25,387,588	380,814	56,752	14,188 per house
Swine	1	SE	83 AU	1,165,377	17,481	2,605	31.39 per AU
Swine	1	SE	248 AU	3,222,244	48,334	7,203	29.04 per AU
Swine	1	NC-NE	415 AU	5,384,140	80,762	12,036	29.00 per AU
Swine	1	NC-NE	2,075 AU	26,408,062	396,121	59,034	28.45 per AU
Swine	1	West	415 AU	6,577,275	98,659	14,703	35.43 per AU
Swine	1	West	2,075 AU	32,348,499	485,227	72,313	34.85 per AU

Table 28 Per-unit cost estimate for slurry storage

Livestock type	Represent-ative farm	Region	Number AU per farm used to design storage unit	Storage unit size (gal)	Total installation cost ($)	Annual installation cost ($)	Cost per unit ($)
Dairy	3	Dairy Belt	200 Head	1,122,000	20,196	3,010	15.05 per head
Dairy	3	Dairy Belt	300 Head	1,683,000	30,294	4,515	15.05 per head
Dairy	3	Dairy Belt	100 Head	561,000	12,342	1,839	18.39 per head
Swine	2	SE	83	287,363	6,322	942	11.35 per AU
Swine	2	SE	248	708,225	15,581	2,322	9.36 per AU
Swine	2	NC-NE	415	1,101,176	19,821	2,954	7.12 per AU
Swine	2	NC-NE	2,075	5,245,933	78,689	11,727	5.65 per AU
Swine	2	West	415	1,068,808	19,239	2,867	6.91 per AU
Swine	2	West	2,075	5,037,143	75,557	11,260	5.43 per AU
Swine	3	NC-NE	450	2,148,585	32,229	4,803	10.67 per AU
Veal	1	All	415	1,101,176	19,821	2,954	7.12 per AU

Runoff storage ponds

Open lots where animals are held produce contaminated water during rainfall events in the form of runoff. Runoff storage ponds are constructed to capture and store this contaminated water. They are needed for pasture-based swine operations (swine farm #5) and swine operations with a lot (swine farm #4), turkey ranches, dairy farms #1 and #2, fattened cattle and confined heifer farms with a scrape and stack manure management system, and fattened cattle feedlots with manure pack. These ponds will also collect the wash water used around dairies.

A majority of these farms do not have runoff storage ponds, or the existing pond is inadequate. CNMP needs for these farms were judged to be high, as follows:

- 80 percent for dairy farms #1 and #2
- 90 percent for turkey ranches
- 70 percent for fattened cattle farm #2
- 40 percent for fattened cattle farm #1 and confined heifer farm #2 (scrape and stack) in the Northeast and Midwest.
- 50 percent for fattened cattle farm #1 and confined heifer farm #2 (scrape and stack) in the Southeast and West.
- 50 percent for swine farms #4 and #5

Costs for runoff storage ponds for dairy, fattened cattle, swine farms, and confined heifer farms were estimated in the same manner as liquid storage ponds and lagoons, using the same approach and the same costs per gallon. Costs associated with runoff storage ponds are shown in table 29 for each model farm.

Settling basins

Settling basins are expected to be a component for all farms with runoff storage ponds. Runoff from open lots generally carries manure solids and sometimes soil particles with it. If these solids are allowed to reach the runoff storage ponds, the operator of the system is faced with the problem of handling a primarily liquid wastewater that contains some solids, making land application of the liquid more difficult because of plugging of irrigation or spray nozzles. The operator also must address the removal of residual solids from the liquid holding pond periodically to ensure design capacity is maintained, which is another cost to the operator. Because animal operations that use open lots must already handle both solids and liquids, most operations would prefer to separate solids from the lot runoff before it can enter the runoff storage pond. By separating the solids from the runoff, the solids can be managed more effectively and the storage pond can be sized and operated more efficiently. While it is recognized that some operations would continue to handle the runoff as a composite mixture, the added costs of dealing with the solids in the runoff storage pond would easily offset the cost of installing a settling basin. CNMP needs for settling basins were the same as those for runoff storage ponds.

A settling basin consists of a small holding pond with a concrete floor and an outlet structure to allow the liquid to pass through the basin. The outlet structure is a pipe that has a perforated riser at the inlet that allows water level control to enhance settlement of solids. Before entering the storage pond, runoff passes through the settling basin where the solids are settled out and the liquid is outlet to the storage pond. Solids are periodically removed and land applied or stored with other manure solids on the farm.

The sizing of settling basins was based on a typical open lot area size for a given animal operation size and the expected routed rainfall runoff volume associated with a 10 year-24 hour rainfall event on the open lot. Four size classes of operations—100 AU, 200 AU, 500 AU, and 1,000 AU—were used to calculate costs on a per AU basis. The cost of the basin construction (land grading, excavation, placing of earthen fill) would be about $0.04 per gallon of temporary storage volume. The concrete bottom was assumed to be 6 inches thick, with wire mesh reinforcement, at a cost of $200 per cubic yard ($3.70 per square foot) installed. The outlet structure was cost at $780. The costs per AU follow:

AUs used for sizing	Storage volume (gal)	Size of concrete bottom (ft^2)	Total cost ($)	Annual cost per AU ($)
100	17,000	600	3,682	5.49
200	50,000	800	5,743	4.28
500	108,600	1,000	8,828	2.63
1,000	206,700	1,200	13,492	2.01

These costs were assigned to CNMP farms based on the size of operation, as follows:

- $5.49 per AU for farms with less than 135 AU
- $4.28 per AU for farms with 135 to 300 AU
- $2.63 per AU for farms with 300 to 1,000 AU
- $2.01 per AU for farms with more than 1,000 AU

Table 29 Per-unit cost estimates for runoff storage ponds

Livestock type	Represent-ative farm	Region	Number AU per farm used to design pond	Pond size (gal)	Total installation cost ($)	Annual installation cost ($)	Cost per unit ($)
Dairy	1,2	Dairy Belt	200 head	1,355,750	24,404	3,637	18.18 per head
Dairy	2	Southeast	200 head	1,337,331	24,072	3,587	17.94 per head
Dairy	2	West	200 head	731,983	16,104	2,400	12.00 per head
Swine	5	Southeast	83	241,281	5,308	791	9.53 per AU
Swine	5	West	450	632,799	13,922	2,075	4.61 per AU
Swine	4	Midwest	450	1,398,349	25,170	3,751	8.34 per AU
Confined heifers	1	Northeast	50	395,232	8,695	1,296	25.92 per AU
Confined heifers	1	Southeast	50	400,076	8,802	1,312	26.23 per AU
Confined heifers	1	Midwest	50	308,505	6,787	1,011	20.23 per AU
Fattened cattle	1	Northeast	50	395,232	8,695	1,296	25.92 per AU
Fattened cattle	1	Southeast	50	400,076	8,802	1,312	26.23 per AU
Fattened cattle	1	Midwest	50	308,505	6,787	1,011	20.23 per AU
Fattened cattle	2	Southeast	100	535,736	11,786	1,756	17.56 per AU
Fattened cattle	2	Midwest	50	234,919	5,168	770	15.40 per AU
Fattened cattle	2	Midwest	100	399,713	8,794	1,311	13.11 per AU
Fattened cattle	2	Northern Plains	350	791,552	17,414	2,595	7.41 per AU
Fattened cattle	2	Northern Plains	750	1,608,964	28,961	4,316	5.75 per AU
Fattened cattle	2	Central Plains	750	1,673,838	30,129	4,490	5.99 per AU
Fattened cattle	2	Central Plains	1,500	3,321,639	49,825	7,425	4.95 per AU
Fattened cattle	2	West	250	317,391	6,983	1,041	4.16 per AU
Fattened cattle	2	West	750	1,136,631	20,459	3,049	4.07 per AU
Turkeys	2	East	500	1,350,897	24,316	3,624	540.87 per house
Turkeys	2	Midwest	500	1,167,101	21,008	3,131	467.28 per house
Turkeys	2	California	1100	2,285,140	41,133	6,130	415.87 per house
Turkeys	2	West other than California	600	1,374,213	24,736	3,686	458.50 per house

Conservation practices for pastured livestock

Pastured livestock operations differ from conventional feeding operations in that the animals are raised primarily on pasture or range, rather than in a confined environment. However, pastured and range animals sometimes are confined in the more conventional sense to provide for ease of management. For example, in areas of the country where winter is severe, a common practice is to keep pastured or range animals in a confined area with a dependable water supply and access by the farmer to provide supplemental feed. As a result, concentrations of manure are accumulated in these confined areas, generally near feed bunks and watering sources. Sometimes these confinement areas are located adjacent to streams and watercourses. The focus of a CNMP for these types of operations is to ensure a dependable source of water away from the streams to eliminate direct contact with watercourses and provide for collection and handling of recoverable manure generated in these concentrated areas.

Costs associated with conservation practices for pastured livestock are grouped under the manure and wastewater storage and handling element, although they include some costs associated with pasture management that would be expected to be included in a CNMP for these farms. As shown in appendix A, 24,697 farms with pastured livestock and few other livestock qualified as farms that may need a CNMP because of the amount of recoverable manure that would potentially be produced on these farms. An additional 36,575 farms had less than 35 AU of confined livestock types, but had beef cattle as the dominant livestock type on the farm. These two groups of farms comprise the set of farms for which CNMP components for pastured livestock are applied.

CNMP needs and costs associated with conservation practices for pastured livestock were derived using the same approach as used for the manure and wastewater storage and handling element. The methods used to estimate CNMP-related costs are presented in the following sections for each component. All costs, except where noted otherwise, were based on the Natural Resources Conservation Service's Field Office Technical Guide's average cost lists for individual components or practices. All capital costs were amortized over 10 years at 8 percent interest. Cost and needs assumptions are summarized in appendix E, table E–1.

Fencing

To properly control the access of animals to water, feed, and loafing areas, a planned system of fencing is needed that is consistent with each individual animal feeding operation's management strategy. Often the need is primarily focused to exclude animals from direct access to a stream. However, with exclusion from the stream, alternative water sources need to be provided, and generally, additional fencing is needed to control the movement of animals relative to the new water sources. It was judged that about a third of the pastured livestock operations would need additional fencing.

The amount of fencing needed is dependant on the particular operation. For a typical 150-AU cattle operation, it was assumed that about a mile of fence would be needed to supplement existing fencing and replace fencing in disrepair, or 35.2 feet per AU. Based on NRCS Conservation Practice Standard *Fence* (Code 382), the cost of fencing was $0.80 per foot of fence for a total cost of $28.16 per AU, or $4.20 annually per AU.

Water well

An alternative water source needs to be provided if livestock are excluded from direct access to streams and watercourses. Numerous methods are used to provide this alternative water source, with no consistency of method demonstrated in any particular region of the country. Methods include the installation of water wells dedicated to providing water for the pasture confinement area, utilizing instream pumps to transfer water from the immediate stream corridor, developing natural spring areas that are located away from the stream corridor, and pumping and piping water from an existing water system. For this assessment, it was assumed that a new well would be installed. The use of a dedicated well is generally the method of choice because of its reliability in providing a consistent quantity and quality of water (springs go dry, stream flows and quality fluctuate). Costs were based on criteria for well development in NRCS Conservation Practice Standard *Water Well* (Code 642). The depth of the well was assumed to be 250 feet. (Actual depths vary from 100 feet to over 1,000 feet around the country; however, most wells used for

livestock watering are installed near riparian areas where the depth to a reliable, potable water table is relatively shallow.) Using $22 per foot as the cost of installing a well, the average cost of a well 250 feet deep is $5,500, or $820 annually per farm. It was judged that representative farms #3 and #4 would not need to construct a well, as an alternative water source will most likely be readily available. For representative farms #1 and #2, it was judged that about 40 percent of the operations would need to implement this practice.

Watering facility
Along with the need to provide an additional source of water is the need to provide temporary water storage and a watering facility for the animals. The amount of water storage needed is dependant on the source and reliability of water and the size of the herd. Watering facility design is based on the criteria established in NRCS Conservation Practice Standard *Watering Facility* (Code 614). In most situations the watering facility consists of a corrugated metal trough with a concrete bottom and pad that stores the equivalent of 1 day of water needs. Storage needs were based on 30 gallons per animal unit. For this assessment, costs per animal unit were based on storage requirements for a 150-AU herd, which would be 4,500 gallons. The watering facility would consist of a circular corrugated metal tank 1.5 feet deep and 23 feet in diameter. The cost is $0.75 per gallon for a total cost per AU of $22.50, or an annual cost of $3.35 per AU.

In the Northern Plains and Mountain States where winter confinement areas tend to be located a considerable distance from the operations' headquarters and where winter temperatures can drop and remain below freezing, special "frost free" watering facilities are needed. This type of facility is an enclosed fiberglass, insulated tank with a small drinking area for cow access. The need for more than 1 day of storage would depend on how remote and accessible the confinement site is. For the purposes of this assessment, 1 day of storage was used to calculate the cost. Based on a per-unit cost of $3 per gallon, the total cost per AU is $90, or $13.41 per AU annually.

In some areas of the upper Midwest or New England, winter temperatures also drop to below freezing; however, because of the close proximity of the headquarters area to the confinement areas, more cost-effective alternative methods are available to ensure the water does not freeze (such as manual clearing of ice, electric heaters).

CNMP needs for watering facilities are the same as those for water wells.

Heavy use area protection
The purpose of heavy use area protection is to stabilize areas of high traffic or use by equipment and animals. Associated with a CNMP for pastured livestock, this generally would address the area surrounding the watering facility. The practice would not only protect the integrity of the watering facility, but also provide an area for easier recoverability of manure. For the purposes of this assessment, heavy use area protection will consist of a concrete pad surrounding the watering facility. Costs per animal unit were based on a 150-AU herd. The heavy use area would be a square pad, 43 feet on a side or 1,815 square feet, 6 inches thick. Subtracting out the area of the tank, the required installation is 1,414 square feet, or 26.2 cubic yards of concrete. Based on an installation cost of $120 per cubic yard (which includes the minor grading and shaping required, forming, cost of concrete, and labor), the cost of the pad for the 150-AU herd would be $3,141, or $3.12 per AU annually. Using the same approach, per-AU costs would be $6.35 for a 50-AU herd and $2.32 for a 250-AU herd. The following function was derived for use in estimating the cost per AU:

x = herd size
a = annual cost per AU

If $x \leq 50$, then a=$6.35
If $x \geq 250$, then a=$2.32

If $50 < x < 150$, then $a=6.35-\left[\frac{(x-50)}{(150-50)}\times(6.35-3.12)\right]$

If $150 < x < 250$, then $a=3.12-\left[\frac{(x-150)}{(250-150)}\times(3.12-2.32)\right]$

Heavy use area protection is needed only for representative farm #1. CNMP needs were judged to be 50 percent for these operations.

Windbreak or shelterbelt establishment
One of the primary reasons that pastured livestock have been wintered in riparian areas is to provide shelter from the wind and weather. In moving pastured

livestock directly out of the immediate stream corridor, certain regions of the country will be moving their animals away from natural cover and protection from the elements. Replacement of the needed protection is essential in implementing a CNMP. The windbreaks or shelterbelts are installed along the edge of the confinement area on the side of the prevailing winds expected in the winter. The windbreaks or shelterbelts generally consist of from three to seven parallel rows of trees of varying species. This is primarily a concern in the West, Northern Plains, and Mountain States.

The criteria used to determine the size and type of protection needed were based on NRCS Conservation Practice Standard *Windbreak/Shelterbelt Establishment* (Code 380). Cost estimates were estimated for three herd size categories: 50, 150, and 250 AU. For these herd sizes, the length of the windbreak or shelter break would be 600, 1,200, and 1,800 feet, respectively. Installation cost is $4.20 per foot. Thus, the annual cost per AU is $7.51 per AU for a 50-AU herd, $5.01 per AU for a 150-AU herd, and $4.51 per AU for a 250-AU herd. The following function was derived for use in estimating the cost per AU:

x = herd size
a = annual cost per head

If x <= 50, then a=$7.51
If x >=250, then a=$4.51

If $50 < x < 150$, then $a=7.51-\left[\frac{(x-50)}{(150-50)}\times(7.51-5.01)\right]$

If $150 < x < 250$, then $a=5.01-\left[\frac{(x-150)}{(250-150)}\times(5.01-4.51)\right]$

Windbreak or shelter break establishment is only needed for representative farm #2. CNMP needs were judged to be 50 percent for these operations.

Solids storage

Most pasture operations would allow manure to accumulate through the period of temporary confinement, periodically removing the manure as it accumulates. A designated storage area is generally not needed to manage the manure produced. However, in regions such as the Midwest, Lake States, and the Northeast, manure cannot be periodically spread because of frozen and snow covered ground. In these regions temporary storage is needed for about 2 to 3 months while the animals are temporarily confined. Because the period of storage is during the winter when the only precipitation expected is in the form of snow, a cover for the storage area is not considered essential. Therefore, a concrete slab 6 inches thick was used for estimation. For a 150-AU herd, the relative size of a solid storage pad would be 1,600 square feet. A 1,600 square foot pad 6 inches thick would require 29.6 cubic yards of concrete. Based on a per-unit cost of $120 per cubic yard (which includes the minor grading and shaping required, forming, cost of concrete, and labor), the total cost of the storage pad would be $3,556, which equates to about $1.85 per ton of recoverable solids. CNMP needs were judged to be 50 percent for operations in the Midwest, Northeast, and Lake States.

Filter strip

For pasture operations in the Midwest, Lake, and Northeast States, filter strips on the downslope edge of the temporary confinement area would be needed to prevent removal of solids and dissolved nutrients from the lot with the runoff from snowmelt and spring rains. Costs per AU were based on a 50-AU herd size. It was assumed that the filter strip would need to be 30 feet wide by 400 feet long, resulting in a treatment area of 12,000 square feet, or 0.28 acres. The average cost of shaping and seeding is $1,500 per acre. Thus, the total cost of the filter strip is $413, which is equivalent to an annual cost of $1.23 per AU. Because the typical location of these pasture operations is near stream corridors, vegetated areas are often already in place, assuming the lot areas have been set back from the stream. CNMP needs were therefore judged to be only 30 percent for representative farms #3 and #4.

Summary of CNMP costs for manure and wastewater handling and storage

Estimates of CNMP costs for each model farm were used to calculate estimates for each CNMP farm in the Census of Agriculture in the same way as cost estimates were calculated for recoverable manure estimates in appendix B. For farms with more than one representative farm assigned to it, the probabilities associated with each representative farm were used as weights to obtain a weighted total. The probabilities associated with each model farm are presented in tables 2 through 5.

The average annual per-farm cost estimates for each of the manure and wastewater handling and storage components are presented in table 30 according to livestock type. Manure storage components (solids, liquid, slurry, and runoff ponds) had the highest cost per farm for all but pastured livestock and swine farms. Liquid transfer costs were slightly higher than storage costs for swine farms. For dairies, liquid transfer costs were nearly as high as storage costs. Collection costs were a significant portion of the total costs for fattened cattle and turkey farms, and mortality management costs were a significant portion for swine, broiler, and turkey farms.

The annual average cost for the manure and wastewater handling and storage element was estimated to be $2,509 per farm (table 31). Capital costs were nearly 75 percent of the total cost, overall. The highest cost was for fattened cattle farms at $9,112 per farm and for turkey farms at $7,940 per farm, reflecting the larger number of animal units per farm for these two types of farms. Dairy farms had the highest cost per animal unit at $22 per milk cow animal unit. Swine farms had the next highest cost per animal unit at $18 per swine animal unit.

Table 30 Annual cost per farm for each manure and wastewater handling and storage component

Dominant livestock type	Number of farms	Mortality mgt.		Lot upgrades	Clean water diversions			Collection					Liquid treatment
					Grassed waterway	Earthen berm	Roof runoff	Contaminated water diversions	Solids		Liquid or slurry		
		capital ($)	operating ($)	capital ($)	capital ($)	capital ($)	capital ($)	capital ($)	capital ($)	operating ($)	operating ($)	capital ($)	capital ($)
Fattened cattle	10,159	0	0	405	1	399	0	304	1,216	1,118	0	0	0
Milk cows	79,318	0	0	0	0	159	75	0	157	144	218	458	128
Swine	32,955	1,236	231	0	0	4	4	0	2	2	82	165	0
Turkeys	3,213	256	1,155	0	0	36	346	81	0	1,320	0	0	0
Broilers	16,251	128	577	0	0	0	0	0	0	58	0	0	0
Layers/pullets	5,326	26	119	0	0	0	0	0	0	163	21	52	0
Confined heifers/veal	4,011	0	0	327	4	0	0	46	402	370	0	0	0
Small farms w/ confined livestock types	42,565	0	0	0	0	19	7	0	16	29	13	15	27
Pastured livestock types	61,272	0	0	0	0	0	0	0	0	0	0	0	0
Specialty livestock types	2,131	54	245	0	0	0	0	0	0	18	0	0	0

Costs differed most by farm size (table 31). Large farms (producing more than 10 tons of phosphorus annually) had an average annual cost of $15,167 per farm, compared to an average annual cost of $3,397 per farm for medium-size farms and $1,070 per farm for small farms. The cost per animal unit on large farms, however, was lower than for medium-size and small farms because of the economies of scale embodied in the assignment of per unit costs and the lower CNMP needs expected for the largest farms.

Per-farm costs were highest in the Pacific, Mountain, and Southern Plains regions (table 32) and lowest in the Lake States and the Corn Belt regions. Total costs were highest in the Corn Belt, the Lake States, and the Northern Plains, which together represented about 45 percent of the total costs for manure and wastewater handling and storage.

Overall, annual manure and wastewater handling and storage costs totaled $645 million.

Table 30 Annual cost per farm for each manure and wastewater handling and storage component—Continued

Dominant livestock type	Solids storage	Liquid storage	Slurry storage	Liquid transfer		Runoff storage pond	Settling basin	Fence	Heavy use area	Well	Watering facility	Wind-break	Filter strip
	capital ($)	capital ($)	capital ($)	capital ($)	operating ($)	capital ($)	capital ($)	($)	($)	($)	($)	($)	($)
Fattened cattle	31	0	0	484	136	3,457	1,332	0	0	0	0	0	0
Milk cows	223	606	21	630	189	125	38	0	0	0	0	0	0
Swine	8	568	511	904	270	31	16	0	0	0	0	0	0
Turkeys	4,085	0	0	7	1	354	140	0	0	0	0	0	0
Broilers	1,539	0	0	0	0	0	0	0	0	0	0	0	0
Layers/pullets	2,490	663	0	288	86	0	0	0	0	0	0	0	0
Confined heifers/veal	632	10	0	120	31	934	236	0	0	0	0	0	0
Small farms w/ confined livestock types	41	13	2	7	4	0	0	0	0	0	0	0	0
Pastured livestock types	11	0	0	0	0	0	0	147	80	203	263	109	10
Specialty livestock types	509	0	0	0	0	0	0	0	0	0	0	0	0

Table 31 Annual manure and wastewater handling and storage cost per farm, by livestock type and farm size

Dominant livestock type or farm size class	Number of farms	AU for dominant livestock type	AU for other livestock types*	Capital cost** ($)	Operating cost** ($)	Maintenance cost** ($)	Total cost ($)	Cost per AU of dominant livestock type ($)
Fattened cattle	10,159	858	440	7,629	1,254	229	9,112	11
Milk cows	79,318	149	46	2,620	551	79	3,249	22
Swine	32,955	236	40	3,451	585	104	4,139	18
Turkeys	3,213	638	49	5,305	2,476	159	7,940	12
Broilers	16,251	150	33	1,666	635	50	2,351	16
Layers/pullets	5,326	258	39	3,519	390	106	4,015	16
Confined heifers/veal	4,011	237	64	2,710	401	81	3,192	13
Small farms with confined livestock types	42,565	18	7	149	46	4	199	11
Pastured livestock types	61,272	107	10	NA	NA	NA	823	8
Specialty livestock types	2,131	NA	17	563	263	17	843	NA
Large farms	19,746	1,129	290	11,627	2,721	349	15,167	13
Medium-size farms	39,437	191	61	2,477	543	74	3,397	18
Small farms	198,018	63	17	773	126	23	1,070	17
All types	257,201	165	45	1,867	389	56	2,509	15

NA Not available.
* Includes pastured livestock types.
** Costs for farms with pastured livestock types dominant were not broken down into capital and operating costs. Costs for these farms are presented in the Total cost column.

Table 32 Annual manure and wastewater handling and storage cost per farm, by farm production region

Farm production region	Number of farms	Capital cost ($)	Operating cost ($)	Maintenance cost ($)	Total cost ($)
Appalachian	22,899	2,155	545	65	2,987
Corn Belt	71,540	1,312	214	39	1,647
Delta States	12,352	1,468	436	44	2,181
Lake States	52,817	1,363	250	41	1,669
Mountain	7,964	4,184	980	126	6,177
Northeast	31,598	1,595	303	48	1,976
Northern Plains	26,309	2,012	345	60	3,088
Pacific	7,974	5,684	1,479	171	7,731
Southeast	12,807	2,074	549	62	2,901
Southern Plains	10,941	3,508	775	105	4,776
All types	257,201	1,867	389	56	2,509