Nutrient management costs

The nutrient management element of a CNMP addresses the requirements for land application of manure nutrients. Land application is the preferred method of utilizing manure since these materials can supply large amounts of nutrients for crop growth, thereby reducing the need to apply commercial fertilizers. CNMP criteria are established to provide for adequate nutrients for crop growth and to minimize the potential for adverse environmental effects.

Costs for nutrient management were developed based on the implementation requirements of a nutrient management plan as defined in the NRCS Nutrient Management Policy (General Manual, Title 190, Part 402) (USDA, NRCS, 1999) and the NRCS Conservation Practice Standard, Nutrient Management (Code 590). The primary criteria within these policy documents are that land application rates of nutrients be based upon Land Grant University nutrient application recommendations. The NRCS criteria for implementing a nutrient management plan include the use of current soil tests, manure testing to determine nutrient content, documented or realistic yield goals, and Land Grant University recommendations for determining nutrient application rates.

Nutrient management plans also address the method and timing of manure and wastewater application to reduce losses of valuable manure nutrients (primarily nitrogen) that occur during and after land application. By reducing these losses, the amount of manure nutrients made available for crop growth is increased and the potential for environmental impacts is decreased. For example, a common management action in a nutrient management plan would be for liquid manure applications by injection into the soil, rather than surface applied. This would minimize nitrogen losses because of volatilization and runoff and reduce the potential for phosphorus losses in runoff or soil erosion. Nutrient management plans also reflect operator decisions to change existing crop rotations to better use manure nutrients produced on the farm. (Erosion control practices, which are part of the land treatment element of a CNMP, further contribute to reducing manure nutrient losses.)

NRCS policy permits manure application rates that are determined using either a nitrogen or phosphorus standard. Manure application rates that are based on a nitrogen standard would supply all the nitrogen recommended for the crop. They also account for the nitrogen volatilization losses and other losses that occur during and after land application. Manure applied at a nitrogen standard usually results in overapplication of phosphorus. NRCS policy permits use of the nitrogen standard on sites for which there is a recommendation to apply phosphorus, or when the use of a risk assessment tool has determined that the site has acceptable risk for off-site transport of phosphorus. (The Phosphorus Index is currently the most widely used risk assessment tool for this purpose.)

Manure application rates that are based on a phosphorus standard supply only the amount of phosphorus that is recommended based on current soil tests or a function of the phosphorus content of plant biomass removed at harvest. Manure applied based on the phosphorus standard will not usually supply the recommended amount of nitrogen, necessitating the application of additional nitrogen from other sources. When using the phosphorus standard, NRCS policy permits an application of phosphorus equal to the amount of phosphorus contained in the biomass of multiple years of crops grown on the site, if the nitrogen recommendation rate for the first year is not exceeded. This allows farms that have enough land to continue to apply manure based on a nitrogen standard, but rotate manure applications to other sites so that a single site receives manure infrequently. Consequently, operations with sufficient land can meet nutrient management criteria without actually applying manure at rates based on a phosphorus standard, which is sometimes difficult to achieve with existing application equipment and is more costly to implement than a nitrogen standard. Operations without sufficient land, however, will eventually need to apply manure based on a phosphorus standard on all available onfarm acres as the phosphorus levels build up in the soil, or else export the manure off-farm for land application or alternative use.

The cost of nutrient management associated with CNMPs was determined by estimating the cost of soil testing, the cost of manure testing, the cost of transporting manure to the application site on the farm, and the cost of onfarm land application. Onfarm land application costs were based on the **additional acres** required to meet nutrient management criteria as producers shift from existing rates of application to lower rates of application. Additional acres will also be required because of the increase in the amount of manure that is recoverable as producers upgrade their manure collection and transfer equipment and practices. Onfarm transport costs were based on the **increase** in the onfarm distance manure is transported when the number of acres receiving manure increases and on the **change** in the amount of manure to be transported on the farm.

Simulating manure application criteria

The first step in estimating nutrient management costs was to estimate the amount of manure produced on each farm that would be available for land application (i.e., recoverable manure.) The second step was to estimate the acres available for manure application on each farm. The third step was to estimate the additional number of acres required to meet nutrient management criteria. The methods used to make these estimates are presented in appendix B. To determine the additional acres required, two land application scenarios were used:

- Baseline scenario, which simulates land application of manure prior to CNMP implementation
- After-CNMP scenario, which simulates land application of manure after CNMP implementation

The baseline scenario simulates manure application practices for about the year 1997, which coincides with the most recent Census of Agriculture data and pre-dates CNMP implementation. Anecdotal evidence and limited information from farmer surveys indicate that manure application practices vary considerably. In general, manure seldom is applied at rates below the nitrogen standard, even when commercial fertilizers also are applied. Application rates exceeding the nitrogen standard are common. In extreme cases manure application rates were reported to be several times greater than the nitrogen standard.

A combination of application rates similar to the nitrogen standard and application rates above the nitrogen standard were used to represent the baseline scenario. The model simulated manure application rates **above** the nitrogen standard for permanent pasture, cropland used as pasture, and nine feed and forage crops. For farms that had enough land for onfarm application, application rates for this group of crops and pastureland were set at one and one-half times the amount of nitrogen taken up and removed at harvest plus an adjustment for nitrogen loss during and after application. For farms that did not have sufficient land at these application rates, application rates were increased to twice the amount of nitrogen taken up and removed at harvest plus the adjustment for losses. Application rates similar to nitrogen-standard application rates were used for other crops. (For details on how the baseline scenario was constructed, see appendix B.)

The after-CNMP scenario simulates manure application practices after all CNMP farms have implemented CNMPs. Manure application rates depend on the amount of acreage available for manure application on each farm and whether nitrogen or phosphorus was the limiting nutrient. If phosphorus was the limiting nutrient, land application on farms **without** enough acres to meet a phosphorus standard was simulated using phosphorus-based application rates for all crops and pastureland. For manure-producing farms that had enough acres to meet a phosphorus standard, land application was simulated using nitrogen-based application rates for all crops and pastureland. For a few CNMP farms (1,379 farms), nitrogen was the limiting nutrient. For these farms, land application was simulated using a nitrogen standard. (For details on how the after-CNMP scenario was constructed, see appendix B.)

Some farms have excess manure (farm-level excess manure), which they will need to export off the farm for land application on surrounding properties or use in alternative ways. To meet CNMP application criteria on farms with excess manure in both land application scenarios, more manure will be exported off the farm after CNMPs are implemented, reducing the amount applied on the farm. Other farms will have enough land in the baseline scenario, but will have excess manure in the after-CNMP scenario. The number of farms with excess manure in the after-CNMP scenario is about 50 percent higher than in the baseline scenario, as shown below and in appendix B.

	Baseline scenario	After-CNMP scenario
Farms with excess manure	47,562	71,999
Farms without excess manure	207,508	183,071
All CNMP farms (excluding farms with specialty livestock types)	255,070	255,070

The majority of CNMP farms (72 percent) had enough acres to meet a phosphorus standard, and so it was assumed they could meet CNMP criteria by applying manure at nitrogen standard rates (table 8). None of these 183,071 farms has excess manure, by definition. The remaining farms—71,999 farms—would need to apply manure at phosphorus-standard rates and will have excess manure after CNMPs are implemented. About two-thirds of the farms with excess manure after CNMPs are implemented (47,562 farms) also had excess manure in the baseline scenario, indicating that they were already exporting some or all of their manure off the farm prior to CNMP implementation. The remaining one-third (24,437 farms) had enough acres for onfarm application at application rates simulated in the baseline scenario, but did not have enough acres to meet CNMP application criteria, and so must export a portion of their manure off the farm after CNMPs are implemented.

Large farms (farms with more than 10 tons of manure phosphorus produced annually) are disproportionately represented in the set of farms with excess manure. About 79 percent of the 19,746 large farms had excess manure after CNMPs were implemented (table 8). Thus, only 21 percent of large farms had enough acres to meet CNMP application criteria. About half of the medium-size farms also had excess manure after CNMPs were implemented. Most of the small farms had enough acres to meet CNMP application criteria (81 percent). Even so, about half of the farms without enough land were small farms.

This approach to simulating application rate criteria for nutrient management plans somewhat understates the onfarm acres required by the 183,071 farms with enough acres to meet a phosphorus standard and somewhat overstates the onfarm acres required by the 71,999 farms without enough acres. Some of the farms without enough acres would be able to meet nutrient

Table 8 Number of CNMP farms in relation to application rate criteria*

Farm group	All CNMP farms #	All CNMP farms %	--Large farms-- #	--Large farms-- %	Medium-size farms #	Medium-size farms %	---Small farms--- #	---Small farms--- %
Farms **with** enough acres to meet CNMP nutrient management criteria (application at nitrogen-standard rates)	183,071	71.8	4,103	20.8	20,469	51.9	158,499	80.9
Farms **without** enough acres to meet CNMP nutrient management criteria (application at phosphorus-standard rates)**	71,999	28.2	15,643	79.2	18,968	48.1	37,388	19.1
Farms **without** excess manure in the baseline scenario	24,437	9.6	4,146	21.8	5,974	15.1	14,317	7.3
Farms **with** excess manure in the baseline scenario	47,562	18.6	11,497	58.2	12,994	32.9	23,071	11.8
Farms with no acres available for application	22,101	8.7	3,907	19.8	4,913	12.5	13,281	6.8
Farms with acres available for application	25,461	9.9	7,590	38.4	8,081	20.5	9,790	5.0

* Excludes CNMP farms with specialty livestock types.
** A small number of farms with nitrogen as the limiting nutrient applied manure at nitrogen-standard rates.

management criteria using nitrogen-standard application rates rather than the phosphorus-standard application rates simulated in the model if a risk assessment tool indicates that the site has acceptable risk for off-site transport of phosphorus. Other farms in this group would be able to apply manure at nitrogen-standard rates for at least a few years until the soil phosphorus level approached the threshold. Conversely, some farms with enough acres to meet a phosphorus standard may have a long history of manure applications and if soil phosphorus tests indicate that phosphorus-standard application rates are needed on most or all of the acres, they would not be able to apply manure at nitrogen-standard rates. In the overall cost assessment, the overestimate of acres required for one group of farms is expected to offset the underestimate of acres required for the other group of farms.

Additional acres required for onfarm land application

Land application costs associated with CNMP implementation are based on the additional acres required for onfarm land application. Acres required for land application were estimated for the baseline scenario and for the after-CNMP scenario. As shown in table 9 and in appendix B, an additional 7.6 million acres on CNMP farms will have manure applied after CNMPs are implemented, averaging about 30 acres per farm. Additional acres with manure applied averaged more than 50 acres per farm for fattened cattle farms, swine farms, turkey farms, and farms with confined heifers or veal (table 10). For the set of farms that needed to apply at phosphorus-standard rates and had acres available, the additional acres with manure applied averaged 156 acres per farm (table 9). Nearly all

Table 9 Summary of onfarm acres required to meet CNMP application criteria*

Farm group	Number of CNMP farms	Total acres on farm	Onfarm acres available for manure application	Onfarm acres with manure applied, baseline scenario	Onfarm acres with manure applied, after-CNMP scenario	Additional onfarm acres with manure applied
All CNMP farms						
Total	255,070	128,884,869	84,843,415	7,187,142	14,814,334	7,627,193
Per-farm		505	333	28	58	30
Farms **with** enough acres to meet CNMP nutrient management criteria						
Total	183,071	112,198,700	77,512,694	3,678,434	7,483,613	3,805,179
Per-farm		613	423	20	41	21
Farms **without** enough acres to meet CNMP nutrient management criteria						
Total	71,999	16,686,169	7,330,722	3,508,708	7,330,722	3,822,014
Per-farm		232	102	49	102	53
Farms **without** excess in baseline scenario						
Total	24,437	9,296,904	5,850,450	2,028,436	5,850,450	3,822,014
Per-farm		380	239	83	239	156
Farms **with** excess in baseline scenario						
Farms with no acres available for application	22,101	0	0	0	0	0
Farms with acres available for application						
Total	25,461	7,389,265	1,480,272	1,480,272	1,480,272	0
Per-farm		290	58	58	58	0

* Excludes CNMP farms with specialty livestock types.

poultry farms (96.5 percent) needed to apply manure at phosphorus-standard rates because they did not have enough onfarm acres to meet the phosphorus standard (table 10). Consequently, nearly all poultry farms also had excess manure in the after-CNMP scenario.

The spatial distribution of additional acres required to meet CNMP application criteria on CNMP farms is shown in figure 14. The number of farms with excess manure in the after-CNMP scenario is shown in figure 15.

Table 10 Onfarm acres required to meet CNMP application criteria and farms with excess manure, by livestock type

Dominant livestock type	Number of CNMP farms	Farms with enough acres to meet CNMP nutrient management criteria	Total acres on farm (avg/farm)	Acres available for manure application (avg/farm)	Onfarm acres with manure applied, baseline scenario (avg/farm)	Onfarm acres with manure applied, after-CNMP scenario (avg/farm)	Additional onfarm acres with manure applied (avg/farm)	Number of farms exporting manure off the farm, baseline scenario	Number of farms exporting manure off the farm, after-CNMP scenario
Fattened cattle	10,159	8,133	2,139	893	50	119	68	1,073	2,026
Milk cows	79,318	65,782	426	325	35	77	42	4,671	13,536
Swine	32,955	20,227	637	507	45	111	66	6,720	12,728
Turkeys	3,213	43	274	172	105	161	57	2,621	3,170
Broilers	16,251	531	170	103	65	88	23	13,700	15,720
Layers/pullets	5,326	305	185	110	60	88	28	3,923	5,021
Confined heifers/veal	4,011	2,204	606	484	28	83	54	1,208	1,807
Small farms with confined livestock types	42,565	30,994	215	165	6	11	5	8,777	11,571
Pastured livestock types	61,272	54,852	590	352	5	10	5	4,869	6,420
All types	255,070	183,071	505	333	28	58	30	47,562	71,999

Figure 14 Additional onfarm acres required to meet CNMP application criteria on CNMP farms (7.6 million acres)

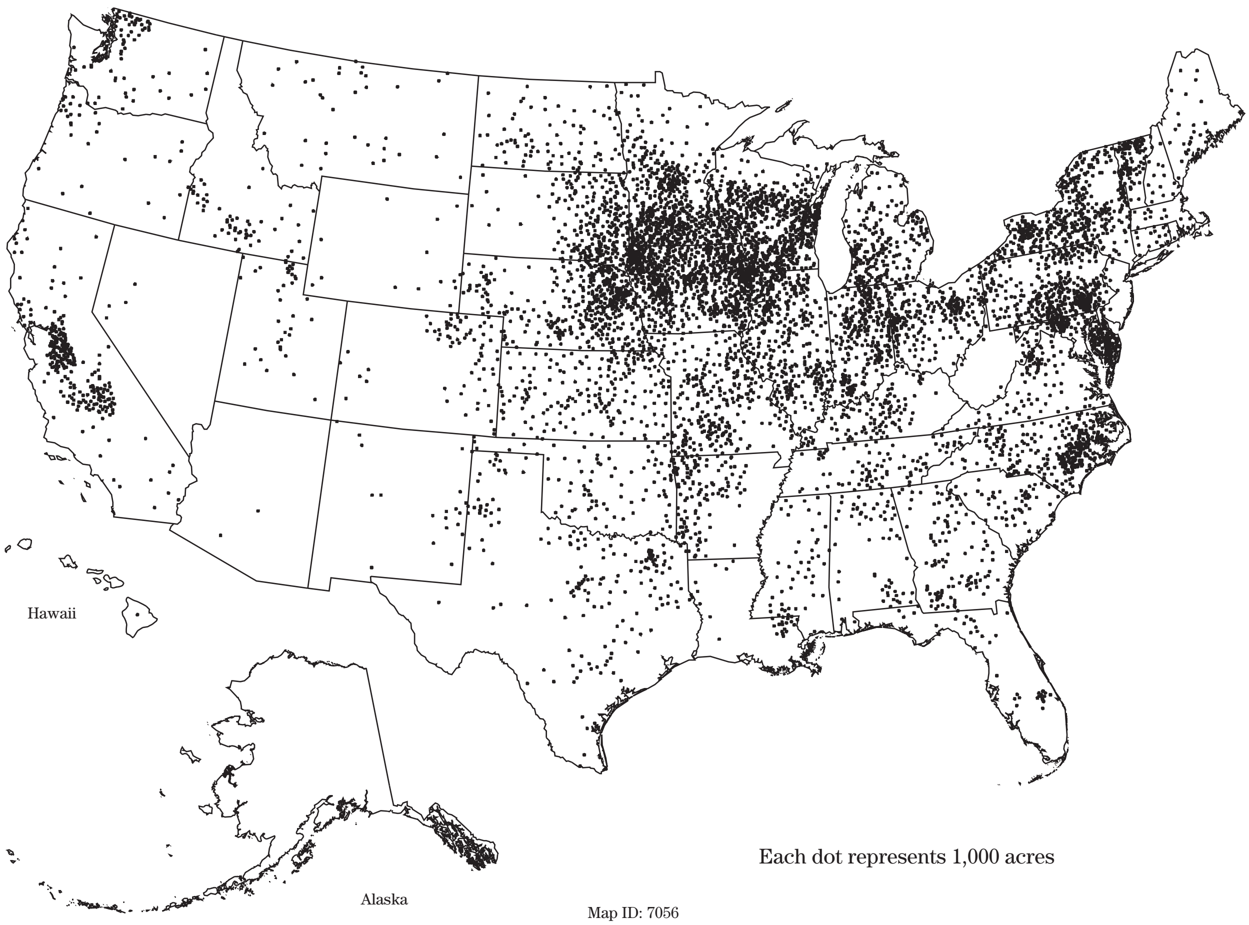
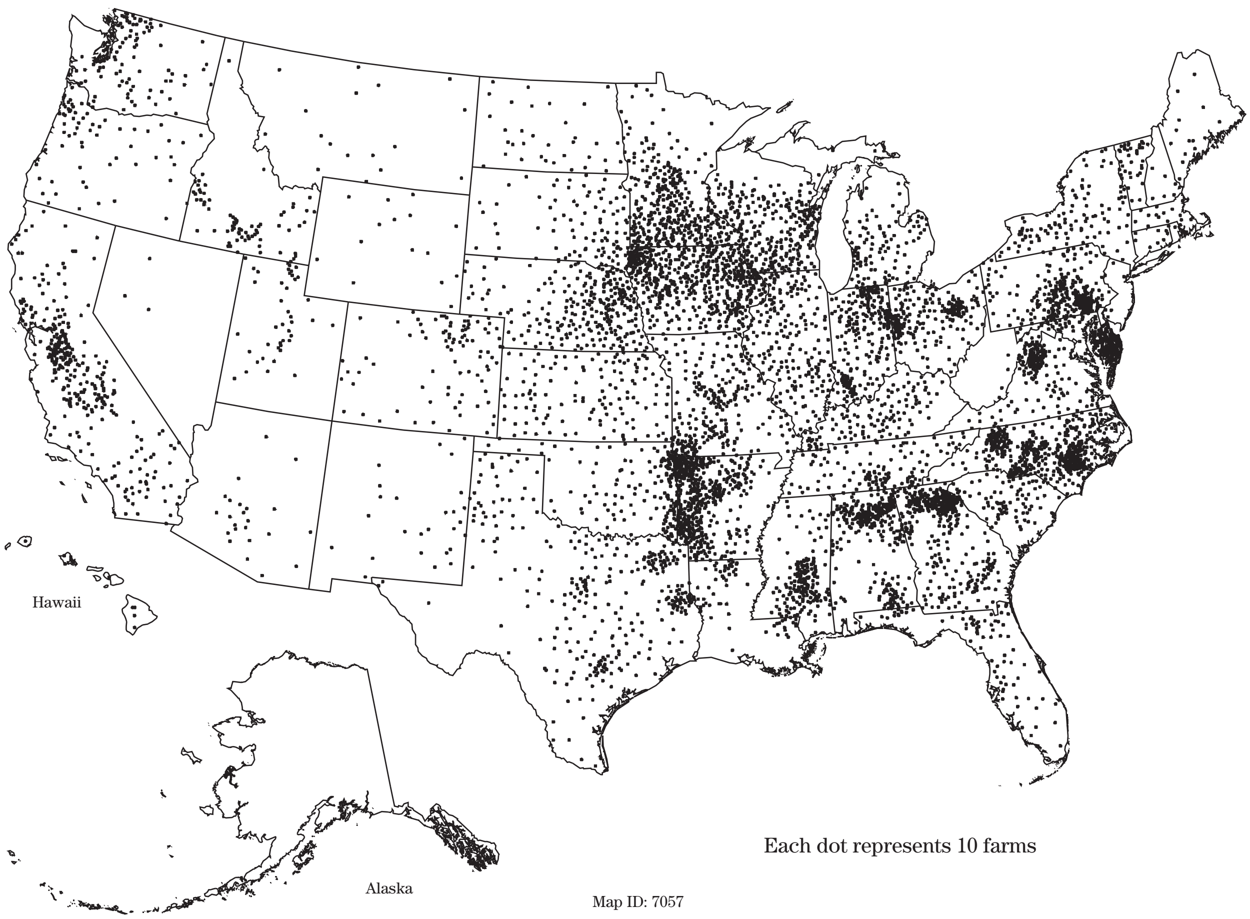


Figure 15 CNMP farms with excess manure after implementing CNMPs (71,999 farms)



Onfarm transport distance

Onfarm transport costs are determined in part by the distance manure is transported. For each CNMP farm, the average onfarm transport distance was estimated for both the baseline scenario and the after-CNMP scenario.

The average onfarm transport distance was calculated for each farm using an approach published by Fleming, Babcock, and Wang (1998). The average transport distance is derived from an estimate of the "searchable area," which is based on the proportion of land on a farm that is available for manure application. Fleming et al. defined the searchable area as a square, contiguous block. Assuming the block was **x** miles on each side, the searchable area would be $\mathbf{x}^2$. Within this block are the fields on which manure would be applied. These fields are assumed to be randomly distributed and of equal size, thus forming a grid of cells. One could calculate the distance from any cell to any other cell, sum up the distances, and divide by the number of cells in the grid to get an average distance. The shortest distance would be zero, and the longest possible distance would be 2**x**. Fleming et al. argues that as the block is divided into smaller and smaller fields, the distribution of possible distances approaches a normal distribution, and thus a median distance could be used to approximate the mean distance. The median distance is the shortest distance plus the longest distance divided by 2, which is equal to **x**. Thus, the average distance is simply the square root of the searchable area.

Fleming et al. defined the searchable area in square miles as:

$$\text{Searchable area} = \text{NM} \times \frac{\text{Q}}{640 \times \alpha \times \beta \times \gamma \times \text{NC}}$$

Where:
- Q = manure volume
- NM = manure nutrient concentration
- NC = crop nutrient uptake, or application rate criteria in quantity of nutrient per acre
- α = proportion of cropland and pastureland
- β = proportion of cropland and pastureland suitable for manure application
- γ = proportion of acres where manure is accepted

The term (NM × Q)/NC is the number of acres required for manure application to meet whatever land application criteria are used. The term 1/640 converts acres to square miles. The term $1/(\alpha \times \beta \times \gamma)$ adjusts the searchable area upward to account for the diversity of land use on the farm and the willingness of the farmer to accept manure. For CNMP farms, the willingness to accept manure was set equal to one, so this term reduces to $1/(\alpha \times \beta)$. If all of the land on the farm was either cropland or pastureland that was available for land application of manure, then $\alpha \times \beta$ would be 1 and the searchable area would simply be the acres required for manure application, and the average transport distance would be the square root of that area. In the case of a similar farm that also had a wooded area, α would be less than one and the searchable area would be larger than the area of land required for manure application; thus the average transport distance would be longer. Similarly, the average transport distance would be longer if some of the cropland and pastureland were not suitable for land application of manure (such as vegetable crops or fruit orchards) because β would be less than one. Thus, the more diverse the land use on a farm, the longer the onfarm transport distance.

This is not an ideal estimate of transport distance because the underlying assumptions would not hold for most livestock operations. Most operations would apply manure to fields that were closest to the confinement facility, rather than randomly throughout the farm. Moreover, estimating the average distance as the square root of the searchable area is strictly appropriate only when the number of fields is large. Since the function implicitly assumes that the size of a field cannot be smaller than the area where manure is applied on each trip, the number of fields will not be large for all farms. For these reasons, this function overstates the onfarm transport distance for farms that are largely contiguous and square. For farms that are not contiguous, or that are more rectangular, the function may understate the transport distance. Nevertheless, the function is readily solved with data from the Census of Agriculture and provides a consistent basis for estimating average transport distance for each farm.

For the baseline scenario, the term (NM × Q)/NC was replaced by the acres on which manure was applied on each farm. For the after-CNMP scenario, the term (NM × Q)/NC was replaced by the acres required to meet nutrient management criteria on each farm. The $\alpha \times \beta$ term was the ratio of acres available for manure application to the total acres on each farm, which is the same for both scenarios for a given farm. (See appendix B for criteria used to determine acres available for manure application.) The average transport distance is a one-way distance in miles and does not include distance traveled on the field while applying the manure. In this study, costs per mile were set to a one-way distance basis so that they would be compatible with this measure of transport distance.

The onfarm transport distance is summarized in table 11 according to groups of farms that differ significantly in onfarm transport costs. For farms with excess manure in the baseline scenario, the median distance hauled was the same in both land use scenarios because all the available land for onfarm manure application was already in use in the baseline scenario. These farms thus will not have any increased cost associated with transport distance. For all other farms, however, the average distance in the after-CNMP scenario was more than in the baseline scenario because of the increase in the number of onfarm acres receiving manure. The median onfarm transport distance for farms with enough acres to meet CNMP application criteria was 0.16 mile for the baseline scenario, which increased to 0.23 mile for the after-CNMP scenario. Onfarm transport distance for this group of farms ranged from 0.04 mile to 0.59 mile in the baseline scenario and 0.05 mile to 0.82 mile in the after-CNMP scenario, where the range is represented by the 1 percentile to the 99th percentile. The greatest increase in onfarm transport distance was for farms without excess manure in the baseline scenario, but without enough acres to meet CNMP application criteria.

Table 11 Onfarm transport distance*

Farm group	Number of farms	Baseline scenario, median transport distance (mi)	Baseline scenario, range of transport distance (mi)	After-CNMP scenario, median transport distance (mi)	After-CNMP scenario, range of transport distance (mi)	Increase in median transport distance (mi)
Farms **with** enough acres to meet CNMP nutrient management criteria (application at nitrogen-standard rates)	183,071	0.16	0.04–0.59	0.23	0.05–0.82	0.07
Farms **without** enough acres to meet CNMP nutrient management criteria (application at phosphorus-standard rates)**						
Farms **without** excess manure in the baseline scenario	24,437	0.33	0.07–1.49	0.54	0.10–2.34	0.21
Farms **with** excess manure in the baseline scenario						
Farms with no acres available for application	22,101	0	0	0	0	0
Farms with acres available for application	25,461	0.33	0.04–1.71	0.33	0.04–1.71	0

* Excludes CNMP farms with specialty livestock types.
** A few farms with nitrogen as the limiting nutrient applied manure at nitrogen-standard rates.
Note: Range is 1 percentile to 99th percentile.

Amount of manure to be transported on the farm

In addition to the transport distance, onfarm transport costs are also determined by the amount of manure transported for onfarm application. Separate estimates were made for solids and for manure handled as a liquid or slurry. Estimates were made by converting tons of recoverable manure to tons at hauling weight for solids and to tons of manure and wastewater for farms with liquid or slurry systems. The amount of wastewater collected in runoff storage ponds was also estimated, allowing for regional differences in precipitation. The hauling weight for solids includes the weight of bedding. The methods used to make these estimates are presented in appendix B.

For farms without enough acres available to apply all of the manure produced, only a portion of the recoverable manure was transported on the farm. The remaining manure and wastewater were transported off the farm. (Costs associated with off-farm transport are addressed in the next section.) The quantity of manure to be applied on each farm was determined based on the percentage of manure nutrients that was applied on the farm to meet the criteria established for each of the two land application scenarios.

The amount of manure for onfarm transport and application is shown in table 12. For farms that did not have enough acres to meet application criteria in the after-CNMP scenario, the amount of manure transported on farm was less in the after-CNMP scenario than in the baseline scenario. To meet nutrient management criteria, these farms were applying manure at lower rates in the after-CNMP scenario than in the baseline scenario, and since onfarm acres were limited, had to export more of their manure off the farm. (A decrease in the amount of solids for onfarm transport and application also occurred because of a change in the consistency of manure for some dairies as a result of CNMP implementation. See the section Manure and Wastewater Handling and Storage and appendix B for details about the calculation of recoverable manure for model farms.)

Manure testing costs

Land application of manure should be based on manure testing to make sure the appropriate amount of nutrients are applied and the need for supplemental commercial fertilizer applications is identified. Testing provides a nutrient analysis of the manure, thus allowing producers to make the best use of onfarm acreage for land application and minimize off-farm export. If manure is exported to manure receiving farms, the recipients will most likely require a nutrient analysis. Producers employing feed management practices to reduce manure nutrients also would benefit from manure testing. Calculations of manure nutrients using standard conversion factors or table values are suitable for design and planning, but manure testing is expected to be a component of most CNMPs. The need for accurate information for farms with small amounts of manure, however, is not critical, and use of table values generally would be acceptable. Thus, it was assumed that all farms with more than 35 animal units would conduct manure testing. Smaller farms would use table values, and thus would have no manure testing costs.

The need for manure testing is determined by the timing of manure application to the land, which is in turn influenced by manure storage capacity. The frequency of manure sampling varies according to the type of manure handling system on the farm. Poultry farms that handle manure as a solid would generally have a 365-day storage capacity under CNMP guidelines, and thus would be expected to land apply manure only once a year. Thus, manure testing for nutrient content would be done only once per year for these farms. For most other farms that primarily handle manure as a solid, manure application is assumed to occur twice per year (180 days of storage), and thus manure testing would be done twice per year. Because of the potential for year-round cropping in the Southeast, minimum storage capacity needs were assumed to be 90 days, and manure testing would be expected four times a year. For liquid systems and operations with runoff collection ponds, minimum storage capacity was assumed to be 180 days, and manure sampling would coincide with the land application of the collected wastewater twice per year. Slurry systems were generally defined as having storage equivalent to 120 days, resulting in manure sampling three times per year.

For each sampling event, a single composite sample consisting of several grab samples from different areas within the manure storage facility was assumed to be adequate. Based on costs found in typical university laboratory price lists, the total cost was assumed to be $50 per composite manure sample, which included a $40 analysis cost and a $10 collection and transfer cost (1 hour labor at $10/hour). Thus, the total annual cost was $200 for farms sampling four times per year, $150 for farms sampling three times per year, $100 for farms sampling two times per year, and $50 per year for poultry farms handling manure as a solid.

While some operations already are testing manure for nutrient content, most do not take manure samples, and of those who do, most do not sample frequently enough. It was judged that about 90 percent of CNMP farms would need to take additional manure samples to meet the CNMP guidelines.

Table 12 Amount of manure for onfarm transport and application*

	Number of farms	Tons of manure for transport onfarm, solids			Tons of manure for transport onfarm, liquid and slurry systems		
		baseline scenario	after-CNMP scenario	change	baseline scenario	after-CNMP scenario**	change
All CNMP farms							
Total	255,070	35,269,938	30,883,243	–4,386,694	312,256,067	751,660,965	439,404,898
Per farm		808	455	-353	7,712	11,642	3,930
Farms with enough acres to meet CNMP nutrient management criteria							
Total	183,071	20,640,269	23,866,400	3,226,131	162,131,411	556,491,110	394,359,699
Per farm		113	130	18	886	3,040	2,154
Farms without enough acres to meet CNMP nutrient management criteria							
Farms **without** excess manure in the baseline scenario							
Total	24,437	9,723,418	5,444,511	–4,278,907	113,452,758	173,549,846	60,097,089
Per farm		398	223	-175	4,643	7,102	2,459
Farms **with** excess manure in the baseline scenario							
Farms with no acres available for application	22,101	0	0	0	0	0	0
Farms with acres available for application							
Total	25,461	4,906,251	1,572,332	–3,333,919	36,671,899	21,620,009	–15,051,890
Per farm		193	62	–131	1,440	849	–591

* Excludes CNMP farms with specialty livestock types.
** Includes additional tons of wastewater from runoff storage ponds.
Note: Manure for off-farm transport is presented in table 17. Total manure production is presented in appendix B, table B–8.

Soil testing costs

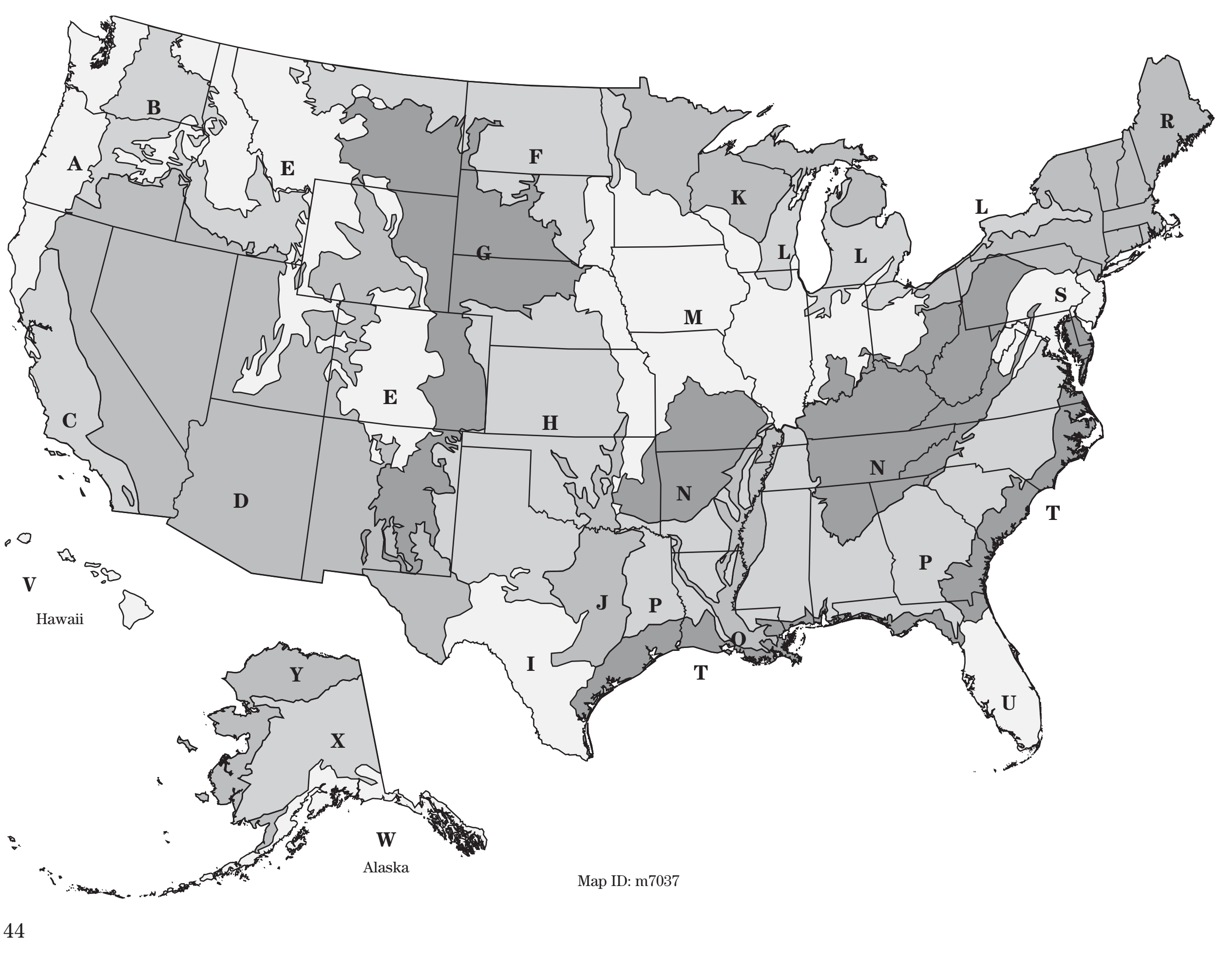
Soil testing is necessary to determine whether a nitrogen standard or phosphorus standard should be used and to determine the need for supplemental commercial fertilizer applications. Soil testing costs are determined by:

- Frequency of sampling over time.
- The number of soil samples needed per acre.
- The number of acres receiving manure.

Nutrient management plans require that application rates be based on current soil tests, which are soil tests that are no older than 5 years. To determine CNMP costs, it was thus assumed that the frequency of soil testing would be once every 5 years. It is recognized, however, that some situations will require more frequent sampling, and some States currently require annual samples.

The number of soil samples required per acre depends on the diversity of soil types and topography and on the history of previous nutrient applications. More samples per acre are needed in fields where soil types are diverse and/or previous applications were variable. To account for the diversity of soil types and topography, the number of acres per soil test was based on the Land Resource Region (LRR) where the farm is located. LRRs are geographic areas made up of an aggregation of Major Land Resource Areas (MLRA) that are characterized by a particular pattern of soils, climate, water resources, land uses, and type of farming (USDA, SCS, 1981). There are 25 LRRs in the United States (fig. 16). LRRs that tend to have more homogeneous soil types had a higher number of acres per sample (less sampling), whereas LRRs that tend to be more heterogeneous had a lower number of acres per sample (more sampling). The number of acres per soil test for each LRR was determined with the assistance

Figure 16 Land resource regions



of The Fertilizer Institute (TFI), the national trade association for the fertilizer industry, and is shown in table 13.

The total number of soil samples needed was determined by dividing the acres with manure applied by the number of acres per soil sample for each farm. All of the additional acres receiving manure applications in the after-CNMP scenario would require soil samples. Although many farmers currently take soil samples, few do so in the context of a nutrient management plan where more systematic sampling is needed. It was therefore judged that about 80 percent of the acres already receiving manure (baseline scenario acres) would also need soil tests to meet CNMP criteria.

Based on costs found in typical university laboratory price lists, the cost per soil sample was assumed to be $20, consisting of $10 per sample for analysis and $10 per sample for sample collection and handling (1 hr labor at $10/hr). The annual cost per farm for soil testing was obtained by multiplying the $20 per sample cost times the total number of samples needed times 0.2 to account for the 1-in-5 year sampling frequency.

Table 13 Number of acres per soil test according to Land Resource Region

Land resource region	Acres per soil test	Land resource region	Acres per soil test
A	20	N	10
B	50	O	10
C	10	P	10
D	50	R	10
E	50	S	10
F	50	T	10
G	50	U	10
H	50	V	5
I	50	W	10
J	10	X	50
K	10	Y	10
L	10	Z	5
M	20		

Onfarm transport costs

CNMP related onfarm transport costs include only the costs associated with the additional acres required for manure application. Costs were estimated for the baseline scenario and for the after-CNMP scenario, and the difference was used to represent expected onfarm transport costs associated with CNMP implementation. As noted above, farms that do not have enough acres to meet CNMP application criteria export a portion of their manure and wastewater off the farm. Most of these farms will transport less manure on the farm after CNMP implementation as producers shift from current application rates in the baseline scenario to lower rates of application in the after-CNMP scenario, as shown in table 12. Consequently, the onfarm transport costs will be lower after CNMP implementation, resulting in a negative cost estimate (i.e., an apparent savings). This "savings" is offset, however, by increased off-farm transport costs, which are presented in the next section.

Separate cost estimates were made for solids and for manure and wastewater handled as a liquid or slurry, including wastewater from runoff storage ponds.

Solids

Onfarm transport costs for solids were determined for each CNMP farm as follows:

Onfarm transport costs = loading cost
+ (ton-miles)(cost per ton-mile)

Where:
ton-miles = average onfarm transport distance in miles multiplied times the tons of manure for onfarm transport for solids.

Transport costs for solids were based on two generalized application systems, one for small farms (less than 750 tons annually of manure for transport) where a manure spreader is used to transport the manure to the field, and another for the largest farms (more than 7,000 tons annually of manure for transport) where a semi-tractor and trailer is used to transport manure to the field. Assuming a linear relationship between cost per ton per mile and the quantity of manure to be hauled, an equation was developed from these two cases to generate estimates of cost per ton per mile for other size farms.

Capital costs for the small farm system were based on a 138-bushel (4.1 ton) manure spreader with an annual cost of $2,344 and a 105-horsepower (hp) tractor used 10 percent of the time for manure transport with an annual cost of $655, amortizing the total cost over 10 years with an 8 percent interest rate. The total annual capital cost is thus $2,999 per year. Operating costs were based on a study by Oregon State University Extension Service (1982), which reported annual operating costs of $2,277 for this kind of system, including 123 hours of operator time per year to transfer the manure from the farm to the field. Operating costs reported in that study were converted to 2000 costs using a suitable price index. The total annual capital and operating cost converts to $42.89 per hour. Assuming a typical travel speed for onfarm hauling of 10 miles per hour, the cost is $1.03 per ton per mile.

Capital and operating costs for the large farm system were based on contract transport using a large semi-truck. The contract cost for this system was reported by Wimberly and Goodwin (2000) to be $0.24 per ton per mile.

The following function was used to estimate the cost per ton per mile for solids transport as a function of the amount of solids to be hauled on the farm.

x = tons of solids hauled on farm
a = $ per ton per mile

If x < 750, then a = $1.03
If x > 7,000, then a = $0.24
If 750 < x < 7,000, then

$$a=1.03-\left[\frac{(x\text{-}750)}{(7{,}000\text{-}750)}\times(1.03\text{-}0.24)\right]$$

In addition to the cost per ton per mile, solids systems also have a cost associated with loading, which is a function of the tons hauled. The loading cost used for all sizes of operations was $1.00 per ton, which was also taken from Wimberley and Goodwin (2000).

Manure and wastewater handled as a liquid or slurry

Cost estimates for the transport of manure and wastewater as a liquid or slurry (including wastewater from runoff storage ponds) were based on two generalized application systems: for farms with less than 1,000 tons of liquid or slurry manure to be transported annually, and for farms with more than 1,000 tons. The small farm system is based on using a tank wagon to transport the manure and wastewater, which was also used for land application. The system for larger farms assumes the wastewater would be pumped through pipes to the application site and applied using an irrigation system.

Onfarm transport costs for the small farms were determined for each CNMP farm as follows:

Onfarm transport costs = ton-miles × cost per ton-mile

where ton-miles is the average onfarm transport distance in miles multiplied times the tons of wastewater for onfarm transport in a tank wagon.

For the larger farms where pumping is used to transport liquids, onfarm transport costs are estimated as the cost per mile of pipe multiplied by the maximum distance that the wastewater is transported on the farm.

A pump is needed to transfer the wastewater from the storage pond to the tank wagon for the smaller farms, and to transport the wastewater to the field application site for the larger farms. The cost of the pump is included in the transfer component of the manure and wastewater handling and storage element, and so is not included here.

Capital costs for the small farm system (<1,000 tons) were based on a 3,200-gallon (12 ton) tank wagon with an annual cost of $2,780 and a 105-hp tractor used 20 percent of the time for manure transport with an annual cost of $1,309, amortizing the total cost over 10 years with an 8 percent interest rate. Total annual capital cost is thus $4,089. Operating costs were based on the study by Oregon State University Extension Service (1982), which reported annual operating costs of $5,344 for this kind of system (after converting to 2000 costs). Based on the 314 hours of operation per year reported in the study, total capital and operating costs convert to $30.03 per hour. Assuming a typical travel speed for onfarm hauling of 10 miles per hour, the cost is $0.23 per ton per mile.

For the larger farms, transport cost was based on the length of installed pipe needed to transport wastes to the furthest point of application. The distance to the furthest point of application on each farm, following from the modeling assumptions used to estimate the average transport distance, is two times the average transport distance. (The maximum possible distance, assuming the farm is square-shaped with a distance of **x** on each side, would be 2**x**, where **x** is estimated as the square root of the searchable area.)

Pipe and installation costs were taken from the NRCS Field Office Technical Guide, average cost lists. The pipe was assumed to be polyvinyl chloride (PVC) pipe 6 inches in diameter, which costs about $1.50 per foot. The installation cost (including trenching, bedding, fitting, backfilling, and concrete thrust blocks) was estimated to be $2.34 per foot. A contingency factor of 20 percent was applied to account for variations in pipe size, added costs for road crossings, and more difficult installation sites. (Most NRCS planning engineering cost estimates of this nature include a 20 percent contingency factor to cover unforeseen items not identified in the preliminary investigations.) Thus, the average cost per foot is expected to be about $4.61. One mile of installed pipe (5,280 feet) thus costs $24,340. The annual cost (amortized over 10 years at 8 percent interest) is $3,626 per mile.

Land application costs

Land application costs associated with CNMP implementation are determined by:

- Acres required for land application
- Cost per acre for land application
- Loading costs for application of solids on large farms
- Calibration costs for land application equipment

Costs were estimated for the baseline scenario and for the after-CNMP scenario, and the difference was used to represent expected onfarm land application costs related to CNMP implementation. Separate cost estimates were made for solids and for manure and wastewater handled as a liquid or slurry, including wastewater from runoff storage ponds.

Solids

The cost per acre for land application of solids was based on two generalized application systems: for small farms (less than 750 tons annually of manure for transport) where a small manure spreader is used (the same system used for onfarm transport costs), and for the larger farms with more than 7,000 tons annually of manure for transport where a large manure spreader is used. Assuming a linear relationship between cost per acre and the volume of manure to be applied, an equation was developed from these two cases to generate estimates of cost per acre for other size farms.

Capital and operating costs for the small farm system (<750 tons) are the same as those reported above for the small farm system used to estimate transport costs (138 bushel manure spreader), which were $42.89 per hour. Assuming a travel speed for application of 4 miles per hour and a 15-foot spread width provides a cost estimate of $5.90 per acre.

Capital costs for the large farm system (>7,000 tons) were based on a 510-bushel (15.3 ton) manure spreader with an annual cost of $3,708 and a 105-hp tractor used 10 percent of the time for transport of manure with an annual cost of $655, amortizing the total cost over 10 years with an 8 percent interest rate. The total annual capital cost is thus $4,363. Operating costs were based on the study by Oregon State University Extension Service (1982), which reported annual operating costs of $4,720 for this kind of system after converting to 2000 costs. Operating costs included 255 operating hours per year, as well as fuel, oil, and other costs. Based on 255 hours of operation per year, total capital and operating costs are $35.62 per hour. Assuming a travel speed for application of 4 miles per hour and a 20-foot spread width provides a cost estimate of $3.67 per acre.

The following function was used to estimate the cost per acre for solids according to the amount of solids to be applied on the farm:

x=tons of solids applied on the farm
a= $ per acre

If x < 750, then a= $5.90
If x > 7,000, then a=$3.67
If 750 < x < 7,000, then

$$a = 5.90 - \left[\left(\frac{x\text{-}750}{(7{,}000\text{-}750)}\right)\times(5.90\text{-}3.67)\right]$$

In addition to the costs per acre, solids systems also have a cost associated with calibration of the manure spreader. Sometimes these services can be obtained free from local extension services or other programs. It was therefore assumed that 10 percent of the farms either were obtaining this service free or had already incorporated the practice into their routine. For the remaining 90 percent of the farms, an annual cost of $190 per farm was assigned to cover manure calibration. This cost assumes the purchase of two wheel scales for $1,000, which converts to $150 annual capital cost, and two calibration events per year each requiring 2 hours at $10 per hour, which results in $40 annual operating cost.

For farms with less than 7,000 tons of solids to be land applied annually, it was assumed that the manure spreader would be used to transport the manure from the farm to the field, requiring no additional handling. For farms with more than 7,000 tons of solids, however, it was assumed that a large semi-truck would be used to transport the manure (see previous section on onfarm transport costs) because of the greater capacity of the semi-truck and thus the lower transport cost. In this case the manure would be off-loaded at the edge of the field and then re-loaded into a manure spreader for application. Thus, for farms with more than 7,000 tons of solids, an additional re-loading cost of $1.00 per ton would be incurred.

Manure and wastewater handled as a liquid or slurry

Cost estimates for land application of manure and wastewater as a liquid or slurry (including wastewater form runoff storage ponds) were based on the same two generalized application systems used to estimate onfarm transport costs—one for farms with less than 1,000 tons of liquid or slurry manure to be transported annually and one for farms with more than 1,000 tons. The small farm system is based on using a tank wagon to transport and apply the manure and wastewater. The system for larger farms assumes the wastewater would be pumped through pipes to the application site and applied using an irrigation system.

Capital and operating costs for the small farm system (<1,000 tons) are the same as those reported above for the small farm system used to estimate transport costs (3,200 gallon tank wagon), which were $30.03 per hour. Assuming a travel speed for application of 4 miles per hour and a 10-foot spread width provides a cost of $6.19 per acre.

In addition to the costs per acre, small liquid systems also have a cost associated with calibration of the liquid manure spreader. It is assumed calibration takes 1 hour per calibration and two calibration events per year. At an operator cost of $10 per hour, the calibration cost is $20 per farm.

The cost estimate for larger farms (>1,000 tons) was based on a study by Bennett, Osburn, Fulhage, and Pfost (1994) on waste handling and application costs for pumped irrigation systems. Costs reported in that study were converted to 2000 costs using a suitable price index. The cost of the pump is included in the transfer component of the manure and wastewater handling and storage element, and so is not included here. Capital costs were based on the costs of a traveling fixed spray gun with 500 gallon per minute capacity. The annual cost for this spray gun is $2,969 after amortizing the total cost over 10 years with an 8 percent interest rate. To convert this cost to a cost per acre basis, the capacity of the system was assumed to be 2,000 acres per year (assuming the application rate of the traveling gun was 500 gallons per minute and the gun could be used 180 days per year at 16 hours per day). The capital costs were thus $1.48 per acre.

Operating costs were computed based on information reported in table 17 by Bennett, Osburn, Fulhage, and Pfost for a 100-cow herd. The following table values were used: 57 acre-inches pumped per year, 22 acres used for land application, and 16 hours annually for set up times. These values were used to calculate a set time of 0.73 hour per acre. Pipe laying and check time were 25 percent and 12.5 percent, respectively, of the set-up time. Total labor time was thus 22 hours, or 1 hour per acre. Using a labor rate of $10 per hour, the total operating cost for a 100-cow herd was $10 per acre.

Bennett, Osburn, Fulhage, and Pfost also reported significant per unit operating cost reductions as the scale of the operation increased. The relationship they found between farm size and total operating costs of the irrigation system is shown below.

Cows per farm	Acres w/manure applied per farm	Total operating cost	Operating cost per head	Size adjustment factor
100	22	1,098	10.98	1.000
200	33	1,683	8.42	0.766
300	41	2,156	7.19	0.655
500	61	3,213	6.43	0.585
750	80	4,316	5.75	0.524
1,000	100	5,515	5.52	0.502

(This information includes some operating costs we included in transport costs and in the manure and wastewater handling and storage element.)

This relationship was used to adjust the $10 per acre cost estimate for a small farm applying wastewater on 22 acres (100-cow herd) to a medium-size farm applying wastewater on 41 acres (300-cow herd) and a larger farm applying wastewater on 100 acres (1,000-cow herd). The per-acre estimate for the medium size farm is $6.55, and the per-acre estimate for the larger farm is $5.02. Using these three estimates of per-acre costs, the following function was derived for use in estimating the operating cost per acre according to the number of acres with manure applied on the farm:

x = acres with manure applied on the farm

a = operating cost per acre

If x < 22, then a= $10

If 22< x <41, then $a=10-\left[\frac{(x-22)}{(41-22)}\times(10-6.55)\right]$

If 41< x< 100, then $a=6.55-\left[\frac{(x-41)}{(100-41)}\times(6.55-5.02)\right]$

If x > 100, then a=$5.02

Calibration costs for the larger farms that use a big gun application method were assumed incidental to the cost of the big gun. It was assumed that a flow meter on the gun or pump would be used to determine the amount of application. Calculating wastewater applied over a measured area is a simple calibration. No calibration costs were assigned to the larger farms that apply their liquid using a big gun.

Summary of CNMP costs for nutrient management

The annual average cost for the nutrient management element of a CNMP was estimated to be $1,043 per farm (table 14). This breaks down into an average of $15 per farm for soil testing costs, $54 per farm for manure testing costs, $636 per farm for onfarm transport costs, and $338 per farm for land application costs on additional onfarm acres needed to meet CNMP criteria. The highest per-farm cost was for dairies, which averaged $2,101 per farm per year. Fattened cattle farms and swine farms were also high, averaging $1,655 and $1,601 per farm respectively. Confined heifer farms and veal farms were the next highest, averaging $1,153 per farm. The relatively high nutrient management cost for confined heifers and veal is not unexpected because one of the criteria used to identify a confined heifer or veal farm in the census was few pastureland or rangeland acres (see appendix A.) The remaining farms had low nutrient management costs ranging from $180 to $248 per farm. These estimates are deceptive for poultry farms and large farms generally, however, because many have negative costs (i.e., "savings") for onfarm transport that will be offset by higher off-farm transport costs.

Differences in nutrient management costs according to farm size were not pronounced (table 14). Large farms had the highest average cost, but small farms averaged within $100 of the cost for medium-size farms. Onfarm transport costs for small farms actually averaged more than for large farms, reflecting the "savings" that occurs for large farms with few acres available for land application. Differences by farm size were pronounced for land application costs, as would be expected.

On a per-farm basis, nutrient management costs were highest in the Northeast and lowest in the Delta States (table 15). Most regional differences in costs reflect differences in onfarm transport costs, which in turn are heavily influenced by the proportion of large farms and poultry farms in the region. Land application costs were about the same for all regions, varying by less than $150 per farm among the 10 regions.

Overall, annual nutrient management costs totaled $268 million. Costs in the Corn Belt region, the Lake States, and the Northeast region comprised about three-fourths of this total cost.

Table 14 Annual nutrient management costs per farm, by livestock type and farm size

Dominant livestock type or farm size class	Number of farms	Soil testing costs	Manure testing costs	Onfarm transport costs, baseline scenario	Onfarm transport costs, after-CNMP scenario	CNMP-related onfarm transport costs	Onfarm land application costs, baseline scenario	Onfarm land application costs, after-CNMP scenario	CNMP-related onfarm land application costs	Total cost for nutrient mgt. element
Fattened cattle	10,159	18	94	866	1,953	1,088	406	860	455	1,655
Milk cows	79,318	24	94	1,152	2,712	1,560	223	646	423	2,101
Swine	32,955	24	117	1,558	2,461	903	303	860	557	1,601
Turkeys	3,213	45	45	811	478	–333	606	1,080	474	230
Broilers	16,251	30	45	298	196	–102	382	657	276	248
Layers/Pullets	5,326	27	51	950	745	–204	377	647	270	144
Confined heifers/ veal	4,011	14	100	551	1,151	600	185	623	438	1,153
Small farms with confined live-stock types	42,565	3	0	37	41	4	37	232	196	203
Pastured live-stock types	61,272	2	0	34	38	3	31	236	205	211
Specialty live-stock types*	2,131	14	0	96	64	–32	167	365	198	180
Large farms (>10 tons P)	19,746	59	67	2,130	2,755	625	793	1,567	775	1,526
Medium-size farms (4-10 tons P)	39,437	24	67	1,133	1,683	549	265	710	444	1,085
Small farms (<4 tons P)	198,018	10	50	421	1,075	654	103	377	274	987
All CNMP farms	257,201	15	54	662	1,297	636	181	519	338	1,043

* Cost estimates were based on average costs for small broiler farms (35–60 broiler AU).

Table 15 Annual nutrient management costs per farm, by farm production region

Farm production region	Number of farms	Soil testing costs	Manure testing costs	Onfarm transport costs, baseline scenario	Onfarm transport costs, after-CNMP scenario	CNMP-related onfarm transport costs	Onfarm land application costs, baseline scenario	Onfarm land application costs, after-CNMP scenario	CNMP-related onfarm land application costs	Total cost for nutrient mgt. element
Appalachian	22,899	20	39	768	995	227	195	515	320	607
Corn Belt	71,540	12	54	597	1,162	565	148	491	343	973
Delta States	12,352	22	40	609	682	73	300	552	252	387
Lake States	52,817	14	67	556	1,564	1,007	135	476	341	1,430
Mountain	7,964	5	41	999	1,362	363	214	518	304	713
Northeast	31,598	25	68	644	1,864	1,220	180	579	400	1,713
Northern Plains	26,309	8	47	581	1,180	599	200	548	348	1,000
Pacific	7,974	23	48	1,421	1,772	351	230	621	391	813
Southeast	12,807	21	40	627	712	84	246	521	275	420
Southern Plains	10,941	17	44	914	1,158	245	273	564	291	597
All CNMP farms	257,201	15	54	662	1,297	636	181	519	338	1,043