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THE ECONOMICS OF DAIRY NUTRIENT MANAGEMENT

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Preamble – Getting Help To Design a Nutrient Management System

This publication addresses many important physical and economic issues in dairy nutrient management. To assist you in designing a nutrient management system, a set of linked spreadsheets can be downloaded (http://farm.mngt.wsu.edu/PDF-docs/Dairy/EB1948E.pdf and http://farm.mngt.wsu.edu/Excel-docs/EB1948E_DNM.xls) or ordered on compact disk (Windows compatible) from http://farm.mngt.wsu.edu/Software.html, order number A.E.C.S Series 03-1. Neither the bulletin nor the spreadsheets cover all possible alternatives and issues. For additional help, contact your local office of the USDA Natural Resources Conservation Service. Additional spreadsheet software will soon be available from the University of Idaho that will be particularly useful to Northwest dairy producers. It provides economic guidance and additional detail in several aspects of the nutrient management system design. As soon as it is available, ordering information will be included here.

Qinghua Liu is a graduate research assistant; C. Richard Shumway is a professor and chair; and Kelli J. Myers Collins was an undergraduate research assistant in the Department of Agricultural and Resource Economics, Washington State University. This bulletin has drawn extensively from a variety of sources identified in the list of references. While every effort has been made to acknowledge their contributions, it is recognized that the extensive assistance of so many can never be fully credited. In addition to those credited in the list of references, we wish to acknowledge the assistance of Shulin Chen (Department of Biological Systems Engineering, WSU), Sam Marseli (Department of Agricultural Economics and Rural Sociology, University of Idaho), Sharon Baum (Department of Agricultural and Resource Economics, WSU), and several reviewers – Joe Hillers and Joe Harrison (Department of Animal Sciences, WSU), Herb Hinman (Department of Agricultural and Resource Economics, WSU), Ned Zaugg (Cooperative Extension, WSU, Snohomish County), Robert Dyk (Thurston Conservation District), John Gillies (Natural Resources Conservation Service), and Garth Taylor (Department of Agricultural Economics and Rural Sociology, University of Idaho).

Introduction

The loss of nutrients from the manure of large dairy herds to groundwater or surface runoff has caused increasing public concern about water quality in the state of Washington. Because cow manure (feces and urine) entering waterways does not go through municipal treatment system processes, it may contain harmful bacteria and pathogens. Also, nutrients from manure feed oxygen-consuming algae or hydrophytic vegetation, ultimately suffocating fish and aquatic organisms. Dairies may generate negative publicity when incorrectly handled manure pollutes waters of the state.

In addition, increasing herd sizes and high rainfall in western Washington compound the potential for water pollution. The runoff from heavy rains can carry nutrients and bacteria into surface water. Manure can also transfer nutrients to groundwater by leaching through the soil. These factors combine to produce a high likelihood for water contamination unless proper handling facilities are in place (Hansen, 1993).

Washington provides an attractive climate and other conditions conducive both to dairy operations and a growing human population. Good environmental quality, especially water quality, is expected by its citizens. Groundwater is the source of drinking water for two-thirds of Washington residents. Protecting drinking water quality from dairy manure nutrients is a valid concern, as many of the dairies in Washington are located in lowlands with high water tables, thus making contamination of drinking water an even greater possibility.

To protect the quality of both surface and groundwater, Congress enacted the Clean Water Act, or the "Federal Water Pollution Control Act" Amendments of 1972, as amended in 1977. By this act, the Environmental Protection Agency (EPA) is responsible for developing a comprehensive program to eventually eliminate water pollution. In Washington, the Department of Ecology is responsible for implementing the federal Clean Water Act. On April 1, 1998, Governor Gary Locke signed into law the 1998 Dairy Nutrient Management Act. This law significantly changes how water pollution attributed to commercial dairy farms is addressed. "The law requires all dairy farms to develop an approved dairy nutrient management plan by July 1, 2002, and to fully implement the plan by December 31, 2003" (Washington State Department of Ecology, 1999). So, farmers must have nutrient handling systems that meet the requirements of the Dairy Nutrient Management Act in order to stay in operation. However, compliance with pollution laws is expensive for dairy operators. Some farmers have already spent more than $100,000 to store their dairy waste, which commonly is held in large lagoons and then sprayed on fields as fertilizer.

Objectives

This report seeks to help dairy farmers in Washington choose cost-effective methods of nutrient management that comply with the law. In doing so, it is hoped that society will benefit both by better protection of the water supply and by retaining a local food-producing system that contributes economically, aesthetically, socially, and politically to the communities.

A series of worksheets have been developed to help dairy producers compute the costs and benefits of the most common nutrient management alternatives, as well as composting. Investment, operating costs, and net costs are examined for lagoon and liquid tank handling systems. Herd size, interest rate, distribution method, and fertilizer price are also considered. Where operating and environmental conditions make it feasible, the lagoon is a less-expensive method of handling liquid nutrient than the liquid tank. Since a lagoon is not always feasible, economic data are also provided for the liquid tank system. Special attention is given to the economics of composting solid dairy manure and bedding. Since compost is fine textured and has fewer nutrients, it can be stored and applied to land when it is needed and is most convenient. The two keys to making compost a financially viable alternative when other distribution methods are feasible are (1) achieving adequate scale in compost production and (2) effective marketing. This report will address both issues.

Relevant Literature

Before developing our worksheets, we need to mention several studies that have particularly influenced their development. They not only provide economic information on various dairy nutrient management procedures, but also suggest appropriate analytical procedures.

An economic model for analyzing alternative dairy nutrient handling systems was developed by Hansen (1993). The primary objective of his study was to develop a series of worksheets to analyze the economic, financial, risk, and environmental impacts of alternative nutrient management methods for a representative western Washington dairy farmer. He considered total waste that must be handled, facilities and equipment associated with each alternative, transportation of manure to storage, storage procedure, transport to land, and soil incorporation. He examined capital investment required, annual costs, financing, cash flow, nutrient values of the waste, and financial and environmental risks. The dairy selected by Hansen needed a larger nutrient handling system to accommodate expansion for 69 additional mature cows and 42 additional heifers. He considered two alternatives: (1) add a second lagoon, use a solid separator, and purchase a big-gun pumping system for distribution of liquid nutrients on land, or (2) add a second lagoon without a solid separator, and hire a custom service to pump liquid nutrients from the lagoons. Alternative 2 had a lower capital investment, a net annual cost advantage, a lower net annual cash outflow and lower financial risk because of less debt. Alternative 1 had a lower risk of environmental damage because of excess lagoon capacity.

Morgan and Keller (1987) emphasized the need for reliable and complete cost and benefit data in their evaluation of nutrient management systems for Tennessee dairy farms.

Considering alternative herd sizes, they computed direct construction and installment costs, annualized costs, and stability of cost/return relationships of different nutrient systems. They also conducted a sensitivity analysis of nutrient loss rates of different nutrient management systems during storage and varying nutrient values after application to land. They noted the substantial cost of all nutrient management systems and the fact it could be expected to increase significantly should more stringent environmental regulations be applied to the dairy farm sector (as they have now been applied in Washington).

Garsow, Connor and Nott (1992) examined seven liquid handling systems and one solid manure handling system for three Michigan dairy herd sizes ranging from 60 to 250 cows. They found that investment costs for the least expensive system could be less than a fifth of the most expensive system. Yet, more stringent manure handling regulations could cause some producers to leave the industry because the additional costs of improved manure handling systems could force their break-even price above the expected milk price. The likelihood of a producer leaving the industry depended on the farm's current financial position and performance.

Bennett, Osburn, Fulhage, and Pfost (1994) conducted a comparative analysis of two nutrient management systems for Missouri dairies. Annual ownership and operating costs were computed for herd sizes of 100-1,000 cows. A break-even analysis was also provided for irrigation systems used with the lagoon system. Lagoon systems consistently handled dairy nutrient at a lower cost than liquid tank systems for all herd sizes. Even though nutrients from liquid tank systems are more concentrated and valuable than nutrients from lagoon systems, the liquid system's net cost was 1.5 to 2.4 times greater than the lagoon system's net cost, depending on herd size. The liquid tank system also required a 5 to 10 times larger plant filter area than the lagoon system. This can be an important consideration for operations with limited acreage. Dairies with more than 300 cows benefited from purchasing a traveling gun irrigator rather than relying on a custom operator to remove nutrients from lagoon systems.

Cawthon (1999) researched the economics of composting dairy manure using actual installation costs and estimated annual fixed and variable costs. In his study, a 24-cubic-yard in-vessel aerobic composter was modeled from prototype composters, manufactured, and installed on a 400-cow dairy near Como, Texas. Annualized fixed and variable costs totaled $23,650. The 400-cow free-stall dairy produced 6 cubic yards of solid waste per day for composting. A market price of $11 per cubic yard (FOB compost facility) was sufficient for the compost facility to break even in the management of solid waste.

Nutrient Management Systems

There are several different types and combinations of nutrient management systems. Most systems accommodate six basic functions: (1) production, (2) collection, (3) storage, (4) treatment, (5) transfer, and (6) utilization of waste. For a specific system, some of these functions may be combined, repeated, eliminated, or rearranged. Nutrients produced in milking parlors and confinement areas must be collected. Storage is the temporary procedure to contain the nutrients. The storage facility is the tool that gives the manager control over the scheduling and timing of the system functions. Treatment is a process designed to reduce the pollution potential of the nutrients, including physical, biological, and chemical treatment. Transfer refers to the movement and transportation of the nutrients throughout the system. Utilization includes recycling reusable waste products and reintroducing non-reusable waste products into the environment. Agricultural wastes may be used as a source of energy, bedding, animal feed, mulch, organic matter, or plant nutrients. Properly treated, they can be marketable (NRCS, 1999).

Alternative systems are created when different methods are used for any of the waste handling system components or when any of the components are rearranged or modified. Generally, dairy nutrient management can be classified into three systems – solid, slurry, and lagoon.

Solid nutrient management systems are commonly used in smaller operations (less than 100 cows) with bedded loafing barns or stanchion stalls. These systems minimize the volume of manure that is handled. However, a separate facility is required for liquid milking center waste. Manure with 75 to 80 percent moisture content can usually be handled as a solid. Manure at this moisture content has a consistency of peanut butter. Twelve pounds of bedding per 100 pounds of fresh manure (about 4 pounds of dry straw per cow per day) is needed to permit dairy manure to be handled as a solid. These systems require scraping devices, loaders, manure storage, and manure spreaders.

Slurry nutrient management systems maximize recovery of plant nutrients from waste and are often used where geologic conditions are unsuitable for a lagoon system. Compared with solid nutrient management systems, slurry systems increase the volume of manure handled because water content is higher than in solid waste, but they allow the manure to be handled as a fluid. Manure with 90 to 96 percent moisture content can usually be handled as a fluid, but may require special pumps. These systems require slurry storage, earth basins, scraping devices, pumps, and perhaps tank wagons. Slurry systems require more land for application than do lagoon systems because more nitrogen is retained.

Lagoon systems are favored by many dairies because they have lower cost relative to other systems. Solids separators are used to reduce solids buildup in the lagoons and drastically reduce the frequency of lagoon dredging. Lagoons are generally preferred where flushing is desired and where a significant amount of lot runoff must be contained. Lagoon systems handle highly diluted waste (96 percent or more water) that can be pumped through irrigation systems. Waste with 96 to 98 percent water content can be handled with ordinary pumps and flushing equipment if excessive straw or fibrous material is not present. For conventional pumping, two gallons of water must be added to dilute a gallon of fresh manure to 96 percent. Of course, this greatly increases the volume of material to be stored and transported. Most lagoon effluent is more than 99 percent water. These systems require pumps and irrigation equipment. The latter are generally sprinkler systems and may be either stationary, hand-carried, or moving systems.

Most operations with fewer than 100 dairy cows use some form of solid nutrient storage. Use of methods for storing manure in a liquid form increases with herd size. With the slurry method, manure is stored as a thick liquid in a pit under the barn floor or in a tank or earth-basin until it is applied onto land. These are most often used as short-term transfer tanks. With lagoons, either anaerobic or aerobic, manure is diluted with water, often from flush systems and milking parlor wash water. Slurry systems are more common than lagoon systems for herds of fewer than 200 cows. Both systems are equally popular among producers with 200 or more cows. Over 90 percent of herds with 200 or more cows have some type of liquid manure storage. Since evaporation reduces total lagoon volume more than slurry volume, especially in more arid parts of the country, it is not surprising that lagoons are most common in the western United States. Producers with liquid manure systems in the Midwest and Northeast often prefer slurry systems over lagoons (USDA, 1999).

Criteria for Selecting Nutrient System

Since nutrient handling does not generally produce significant revenues, impact on profitability can be measured in terms of net cost. Net cost is the cost of owning and operating the system minus revenues from the sale and/or value of distributed nutrients. The system with the lowest net cost is the most profitable.

In addition to economic considerations, factors such as environmental impacts, animal characteristics, facility investments, and nutrient distribution area must also be considered in selecting an appropriate nutrient-handling alternative. For example, the most economic alternative may not be relevant if soil conditions or limited land area make it infeasible. So, while the following worksheets only address economic aspects of the alternatives, other factors often limit the range of alternatives that can be considered for a particular dairy.

Development and Explanation of Worksheets and Summary Tables

A series of worksheets are included as linked spreadsheets in an appendix. They were developed to help dairy producers choose among alternative systems for managing manure using computation procedures based on the *Agricultural Waste Management Field Handbook* (NRCS, 1999) and the *On-Farm Composting Handbook* (Rynk, 1992).[1] Considering common values for many variables, summary tables were developed using the worksheets to examine costs and benefits of dairy nutrient management for five different herd sizes in Northwest Washington. The appendix and linked spreadsheets can be downloaded from the Web site (http://farm.mngt.wsu.edu/PDF-docs/EB1948E.pdf and http://farm.mngt.wsu.edu/Excel-docs/EB1948E_DNM.xls) or ordered on compact disk (Windows Compatiable) from http://farm.mngt.wsu.edu/Software.html, order A.E.C.S. 03-1. They enable a dairy producer to tailor the data to his/her specific operation in any location.

[1] These handbooks can be examined in many Natural Resources Conservation Service and County Conservation District offices. The most successful dairy waste handling and distribution system is often a combination of several types. The choice depends on herd size, accessible lands, soil types, crops raised, weather, and time of year.

Worksheet I is designed to estimate how much waste is produced during the storage period and then to determine the storage capacity requirement for the farm. Worksheet II estimates capital investment as well as annual investment and operating costs. Worksheet III computes the value of wastes based on their nutrient content, and Worksheet IV calculates net costs. Worksheet V examines the costs and benefits of turning solid manure and bedding into compost either on the farm or at a central composting facility.

Assumptions

We made the following assumptions in our calculations.

Handling system. Dairy operators often use multiple methods to handle their dairy manure. To simplify the analysis for systems most relevant to Washington dairies, this study will focus on two basic alternatives – lagoon-gutter flush systems and liquid storage tank. With the lagoon-gutter flush system, parlor and yard nutrients are removed by flushing with water, solids are separated, and liquid nutrients are stored in the lagoon. The liquid storage tank system is used when a lagoon is not possible due to soil and/or geological conditions. The liquid tank stores all dairy waste.

Cow numbers and size. Cow numbers continue to increase in Washington. The number of cows rose 29 percent between 1987 and 1998 (growing from 201,000 to 260,000 head). Yakima County made the most rapid growth (335 percent) during this period and became the largest dairy county in the state (with 67,900 head) in 1998. The steady immigration of large California dairies to the Sunnyside area contributed greatly to the increase in cow numbers (Hansen, 1993). Whatcom County, the previous leading dairy county, had 62,700 dairy cows in 1998. Many dairies in the state have 250-350 cows and the largest one has 6,000 cows. To provide relevance for the wide range of herd sizes, our analysis will be conducted for five different herd sizes – 50, 500, 1,000, 2,000, and 3,000 cows.

Animal weight. We assume that milking cows weigh 1,400 lbs and dry cows weigh 1,500 lbs. Heifers range in weight from 100 to 1,400 lbs with an average of 750 lbs (Hillers, 1999).

Herd composition. We assume 85 percent of cows in the herd are milking and 15 percent are dry. Heifers equal 85 percent of cow numbers and their ages are evenly spread from birth to 24 months.

Days of storage required. For each dairy nutrient-handling alternative, we assume that dairy manure will be stored up to 180 days.[2]

Manure Production and Storage Requirement

For each nutrient handling system, the first step in estimating the cost of dairy nutrient management is to determine the nutrient storage requirements (see Table I-1). Storage requirements depend on several factors, including the quantity of manure produced, bedding, wash water, slab runoff, and rainfall. The volume of manure produced is determined by the number of animals, their average weight, and the storage period. The daily volume of manure produced per animal unit (1,000-lb animal) is approximately 85 lbs (Grusenmeyer and Peterson, 1995) with a volume of 1.36 cubic feet. Volume of waste from bedding depends both on the housing system and the type of bedding used. Bedding waste in Table I-1 is for shavings in a free-stall barn. Other housing systems and bedding types can produce considerably more waste. Wash water comes from preparing cows for milking as well as from cleaning milking equipment, parlor, and holding area. Slab runoff refers to the precipitation

[2] While 180 days' storage is ideal in much of northwest Washington, it is not a general requirement at present. The required number of manure storage days will depend on type of storage, crops grown or vegetative cover of application area, and physical limitations of application field soils.

Table I-1. Volume Requirements for Lagoon and Liquid Tank Systems, Northwestern Washington[a]

1. Herd size	250	500	1,000	2,000	3,000
2. Animal units (au)	513	1,026	2,053	4,105	6,158
3. Total volume of manure production (180 days) (cf)	125,613	251,226	502,452	1,004,904	1,507,356
4. Total bedding volume (180 days) (cf)	13,854	27,709	55,418	110,835	166,253
5. Separated solids removed, lagoon system (cf)	11,449	22,899	45,797	91,594	137,391
6. Waste water volume (180 days) (cf)	81,528	112,128	173,328	295,728	418,128
7. Slab runoff volume (cf)	25,801	51,602	103,204	206,409	309,613
8. Total waste volume (line3+line4-line5+line6+line7) (cf)	235,347	419,766	788,605	1,526,282	2,263,959
Lagoon volume requirement					
9. Final lagoon depth after adjustment	11.2	10.7	12.7	14.7	14.7
a. Depth for dairy waste (ft)	6	6	8	10	10
b. Add allowance for accumulated solids (ft)	0.5	0.5	0.5	0.5	0.5
c. Add depth for precipitation on lagoon surface (ft)	1.7	1.7	1.7	1.7	1.7
d. Add depth of 25-year, 24-hour rainfall (ft)	0.3	0.3	0.3	0.3	0.3
e. Add depth required to operate emergency outflow	0.7	0.7	0.7	0.7	0.7
f. Add for freeboard (ft)	2	2	2	2	2
10. Total lagoon volume after depth adjustment (cf)	488,006	844,768	1,387,805	2,449,941	3,611,570
Liquid tank volume requirement					
11. Total tank depth (ft)	12.0	12.0	12.0	12.0	12.0
a. Less allowance for accumulated solids (ft)	0.5	0.5	0.5	0.5	0.5
b. Less depth for precipitation on lagoon surface (ft)	0.0	0.0	0.0	0.0	0.0
c. Less depth of 25-year, 24-hour rainfall (ft)	0.0	0.0	0.0	0.0	0.0
d. Less freeboard (ft)	1.0	1.0	1.0	1.0	1.0
e. Effective depth (ft)[b]	10.5	10.5	10.5	10.5	10.5
12. Surface area required (sf)	21,047	37,244	69,638	134,425	199,213
13. Total liquid tank volume (cf)	252,566	446,928	835,656	1,613,100	2,390,556

Notation: cf is cubic feet and sf is square foot.

[a] To tailor volume requirements to a specific operation, use Worksheet I-1 for a lagoon and Worksheet I-2 for a liquid tank.

[b] Precipitation is not considered if the liquid tank is covered.

collected and stored from confinement areas and slabs. When a separator is used with the lagoon system, separated solids do not enter the lagoon. Solids are generally not separated for the liquid tank system or for two-cell holding ponds.

For the lagoon system, total storage requirements must be sufficient for the total volume of waste, solids accumulation, normal precipitation less evaporation on the lagoon surface during the storage period, precipitation on the lagoon surface from a 25-year, 24-hour storm, and a margin for safety (freeboard). Solids separated prior to entering the lagoon must be stored until distributed, composted, and/or sold. Frequently, lagoons are designed to include outside runoff from watersheds. For such, the runoff volume of the 25-year, 24-hour storm must also be included in the storage volume. Rainfall and evaporation in the major dairying areas of northwest Washington vary greatly by location and season. For a half-year storage period, the size of the nutrient storage facility is computed to accommodate winter conditions. During this period about 65 percent of annual rainfall is received. Annual rainfall is presumed to be 40 inches and evaporation is considered to be one inch per month during the winter storage period. A 24-hour, 25-year rainfall of 4 inches is also accounted for. Farmers can obtain more precise estimates of average rainfall and 25-year, 24-hour storms for their farms from the local Natural Resources Conservation Service (NRCS).

Volume requirements computed in Table I-1 are for lagoons with a dairy waste depth of 6 feet for herd sizes up to 500 cows, 8 feet for 1,000-cow herds, and 10 feet for larger herds. Final depth ranges from 11.2 to 14.7 feet, depending on herd size. Sides of the lagoon typically are sloped 2 to 1 and allow for 2 feet of freeboard. Total volume in the lagoon ranges from about 11.2 acre feet (af) for a 250-cow herd to about 82.9 af for a 3,000-cow herd (488,000 to 3,612,000 cubic feet).

For the liquid tank system, volume requirements noted in the table are for tanks with a total depth of 12 feet. If the tank is covered, it is not necessary to provide storage capacity for precipitation. In this case, the total liquid tank volume requirement ranges from about 5.8 af for a 250-cow herd to about 54.9 af for a 3,000-cow herd (252,000 to 2,391,000 cubic feet).

In addition, seepage and runoff, which frequently occur from manure stacks, must be controlled for both systems to prevent pollution of surface or groundwater. One method of control is to channel any seepage into a storage pond. At the same time, uncontaminated runoff, such as that from the roof and outside the animal housing and lot area, should be diverted around the site.

Annual waste volume managed by the lagoon and liquid tank systems is reported in Table I-2. Annual waste volume handled by lagoon systems ranges from 12.1 af for a 250-cow herd to 110.5 af for a 3,000-cow herd. The corresponding volume handled by liquid tank systems ranges from 10.3 to 97.4 af.

Investment Costs

Lagoon System

The storage lagoon is the most basic component of the lagoon nutrient management system. It is a treatment facility for slurry and liquid waste. While it can also be used to temporarily store all forms of nutrients, subsequent removal of solid and semisolid nutrients can be difficult and expensive. Location is important. The lagoon should be located as far as possible from houses and public roads and downwind so that prevailing winds carry odors away. Lagoon odors can be objectionable at distances of 1/2 mile and detectable at distances of a mile or more. The lagoon should be located as close to the nutrient source as possible. If the lagoon is downhill from the nutrient source, gravity can transport the waste (NRCS, 1999).

Where possible, the lagoon should be located over impervious soil so that the bottom and sidewalls don't require sealing. The Natural Resources Conservation Service and Cooperative Extension personnel can help evaluate soils. Lagoons on many soils require sealing with liners,

Table I-2. Annual Waste Production Computation, Northwestern Washington[a]

1. Herd size	250	500	1,000	2,000	3,000
2. Annual rainfall, inches	40	40	40	40	40
3. Pond evaporation, winter storage period, inches/month	1	1	1	1	1
4. Annual manure production, cf	254,715	509,431	1,018,861	2,037,722	3,056,583
5. Annual bedding volume, cf	28,094	56,187	112,374	224,749	337,123
6. Annual separated solids removed, cf	23,217	46,433	92,866	185,732	278,599
7. Annual wastewater volume, cf	165,321	227,371	351,471	599,671	847,871
8. Annual slab runoff volume, cf	39,694	79,388	158,776	317,552	476,328
9. Annual rainfall less evaporation into lagoon, cf	63,034	116,803	162,371	249,698	374,921
10. Average annual waste and runoff in lagoon, cf	527,641	942,747	1,710,987	3,243,660	4,814,227
11. Average annual waste in liquid tank, cf	448,130	792,989	1,482,706	2,862,142	4,241,577

[a] To tailor rainfall and evaporation to a specific operation, use Worksheet I-3.

clay, or soil cement. Sealing may also be accomplished biologically. Animal nutrient solids are a good sealant in many soils, but this process takes time. Clay or soil cement delays leaking while biological sealing is developed. Membrane sealing (plastic, vinyl, rubber, etc.) is positive and effective, but it is expensive and difficult to install.

Common methods for transferring liquid dairy manure to storage include gravity flow, large piston pump, pneumatic pump, and centrifugal chopper pump. A piston-type pump provides convenient transport of manure to a storage structure.

A key factor in the design of any liquid storage structure is provision for agitating the material prior to irrigating or loading the tank spreader. Without complete agitation, solids will accumulate in the structure and reduce storage capacity.

Irrigation equipment has been adapted for application of liquid manure and wash water on cropland. The primary concerns are to apply the nutrients at agronomic rates on cropland that has need of the manure nutrients and to apply them in an environmentally acceptable manner. The use of manure or wash water for "true" irrigation is seldom accomplished because of the relatively small volume applied. Those who desire to irrigate in addition to spreading manure must be certain of an adequate supply of water.

Pipelines used in nutrient management systems can be of the same type and general design of those used in normal irrigation systems. Because of the corrosiveness of the wash water, however, underground pipelines should be constructed of plastic or other non-corrosive material. Flushing pipelines and other nutrient-application equipment with clean water is recommended after each use and definitely before storage (NRCS, 1999).

Dairy farmers face two options when they apply manure to cropland. One is to hire a custom irrigation system, which typically costs about $100-$125/hour. The other (which provides more flexibility in controlling amount, form, timing, and placement of dairy manure nutrients) is to purchase an irrigation system. A traveling gun irrigation system is most often purchased and is the option included in our cost calculations. Injection systems are increasingly being used near urban and environmentally sensitive areas in an effort to reduce odor and nutrient volatilization and to utilize manure nitrogen more efficiently, near the roots of the plants.

Table II-1 reports typical investment costs for the waste storage pond construction and necessary equipment for the various herd sizes. John Gillies (2001), a district conservationist for NRCS, estimates lagoon construction costs in Washington to be $20-$25 per 1,000-gal ($6,500-$8,000 per af) for the first million gallons and $15 per 1,000-gal. ($4,900 per af) for additional storage volume above a million gallons. This estimate includes the cost of fencing, access ramps and dike seeding. In addition, many ponds in northwest Washington require imported fill material for the embankment or the earthen liner. This can add $8 per 1,000 gal ($2,600 per af) to the cost of construction. In this study, we use $9,600 per acre-foot for the first million gallons and $7,500 per af for additional storage volume. It can be somewhat higher if a private engineering firm is used for consultation. However, many farmers rely on help from local NRCS staff rather than hiring an engineering firm. Consequently, depending on herd size, the cost of constructing the lagoon ranges from $90,000 to $628,000 (Table II-1).

The lagoon capital investment includes many expenditures in addition to construction costs. Even if a custom irrigation system is hired, other equipment required for the lagoon system include a storage tank for flushing, tractor, recycling pump and pipe, agitator, and a separator. Generally, the separator is an integral component of the flush systems. In addition, a storage area for the separated solids is required. Larger herd sizes may require multiple separators to adequately handle the volume. A tractor (normally about 100 hp) is typically used to operate the agitator. For smaller dairies, the same tractor may also be used for other dairy and/or farm operations, so only a portion of its cost is charged to the nutrient management operation for such dairies. The typical total investment for farmers who hire a custom irrigation system

Table II-1. Lagoon System Investment, Northwestern Washington[a]

1. Herd size	250	500	1,000	2,000	3,000
Investment if hire custom irrigation system:					
2. Lagoon construction cost	90,323	151,749	245,247	428,122	628,127
3. Storage tank (gutter flush)	7,500	12,000	18,000	30,000	42,000
4. Tractor	6,000	11,000	20,000	36,000	50,000
5. Separator	56,000	64,000	74,000	120,000	164,000
6. Solid storage construction cost	3,828	7,656	15,313	30,626	45,938
7. Recycling pump and pipe	4,200	5,500	7,500	11,500	15,500
8. Agitator or mixing propeller	4,000	7,000	9,000	10,000	10,000
9. Total investment	171,851	258,905	389,060	666,248	955,565
10. Average investment per cow	687	518	389	333	319
Additional investment if purchase own irrigation system:					
11. Big gun sprinkler	28,000	42,000	56,000	64,000	112,000
12. Irrigation pump	10,000	15,000	20,000	30,000	40,000
13. Irrigation pipe	8,750	17,500	35,000	70,000	105,000
14. Total investment	218,601	333,405	500,060	830,248	1,212,565
15. Average investment per cow	874	667	500	415	404

[a] To tailor investment costs to a specific operation for a lagoon system, use Worksheet II-1.

ranges from $172,000 for a 250-cow herd to $956,000 for a 3,000-cow herd. Average investment per cow is less than one-half ($319) for the largest herd than for the smallest ($687).

Additional equipment is needed if the farmer doesn't hire a custom irrigation system. Equipment typically required includes a big gun sprinkler, irrigation pump, and pipe. Such equipment can add 25 percent or more to the nutrient management investment costs.[3] Although expensive, purchasing the irrigation system reduces annual operating costs (to be discussed later) sufficiently to be economical for each of the herd sizes considered in this study. It may also be necessary in areas where custom irrigation systems are not available for hire and where equipment cannot be shared.

Additional equipment is required to load and possibly distribute dairy manure and bedding solids. Many dairies that separate solids develop markets for raw or composted material that fully cover the cost of managing the solids. Consequently, no additional equipment or operating costs are calculated here for managing solids. Costs and returns from composting the solids are developed in a later section.

Liquid Manure Tank System

In locations when a lagoon is not feasible because of geological or other conditions, a liquid tank system is often selected (Table II-2). The liquid tank system considered here is a cast-in-place, in-ground, concrete-covered storage tank with 180-day capacity that is loaded by gravity. Above-ground tanks would need a mechanized pump for loading manure into the tank. The primary investment cost of the liquid tank system is for construction of the manure tank. Typical construction costs are about $120,000 per million gallons of storage capacity

[3] Due to environmental considerations and more effective manure nutrient utilization, direct injection systems are replacing the older big gun systems. Costs for the injection system depend on whether it is custom applied or purchased and whether it is operated with on-farm labor.

Table II-2. Liquid Manure Tank System Investment, Northwestern Washington[a]

1. Herd size	250	500	1,000	2,000	3,000
2. Manure tank	227,310	402,235	752,090	1,451,790	2,151,500
3. Scraper	500	500	1,000	1,500	1,500
4. Tractor	65,000	65,000	65,000	65,000	65,000
5. Tank wagon, 3,000-gallon capacity	15,000	30,000	60,000	75,000	90,000
6. Agitating and loading pump	10,000	10,000	10,000	10,000	10,000
7. Open-impeller	5,500	8,000	10,000	10,000	10,000
8. Irrigation reel	20,000	40,000	0	0	0
9. Manure spreader (injector)	0	0	40,000	60,000	80,000
10. Total investment	343,310	555,735	938,090	1,673,290	2,408,000
11. Average investment per cow	1,373	1,111	938	837	803

[a] To tailor investment costs to a specific operation for a liquid tank system, use Worksheet II-2.

(Dyk, 2001). Liquid tank construction costs are estimated to range from about $227,000 for a 250-cow herd to about $2,152,000 for a 3,000-cow herd.

Equipment requirements include a manure scraper, tractor, and a 3,000-gallon tank wagon pulled by a 100-horsepower tractor. In the table, the number of tank wagons varies by herd size (i.e., one wagon for 250 cows and six wagons for 3,000 cows).[4] This permits nutrients to be distributed within a 10-day period. Other equipment needed includes agitating and loading pumps (used to agitate the slurry in the tank while pumping from storage tank wagons), an open-impeller, and an irrigation reel or manure injector system. The average investment per cow for this nutrient management system is very high ($1,373 for 250-cow herds to $803 for 3,000-cow herds).

Annual Fixed Costs

Table II-3 develops annual fixed costs as a percent of the investment in various parts of the lagoon and liquid tank nutrient management systems. We used an annual nominal interest rate of 8 percent and computed the annual interest charge on the average of the initial investment and salvage value. When calculating depreciation charges, we used the straight-line method and allowed for a 10 percent salvage value for the equipment. We assumed a 30-year life for the slab, a 20-year life for the waste storage facility and separator, and a 10-year life for other equipment. Annual repair and maintenance costs average 2.5 percent of the investment for the separator and 1.5 percent for the storage facility and other equipment associated with the nutrient handling system (Hansen, 1993; Dewaard, 2002). Taxes vary both with the tax rate and the value added to the property. Typical assessments and tax rates are used – 0.8 percent for the storage facility and 1.25 percent for equipment (Hansen, 1993). All facilities and

[4] In practice, many larger dairies use larger equipment (such as 6,000-gallon or larger tankers) rather than adding more 3,000-gallon tank wagons.

Table II-3. Annual Fixed Costs as a Percent of Investment[a]

	Slab	Storage tank	Separator	Other equipment
1. Useful life (years)	30	20	20	10
2. Interest charge[b] (%)	4	4	4	4
3. Depreciation (%)	3.33	5	5	9
4. Repairs & maintenance (%)	1.5	1.5	2.5	1.5
5. Taxes (%)	0.8	0.8	1.25	1.25
6. Insurance (%)	0	0	0.5	0.5
7. Total annual fixed costs (%)	9.63	11.30	12.75	16.25

[a] To tailor annual fixed costs to a specific operation, use Worksheet II-1 for a lagoon system or Worksheet II-2 for a liquid tank system.

[b] Annual interest charge is approximated by using an interest rate of 8% applied to the average of investment cost and salvage value.

equipment in the system, except the storage facility and fencing, are insurable. We assumed a common 0.5 percent insurance rate. Annualized fixed costs range from 9.63 percent of the investment in the storage slab to 16.25 percent for equipment.

Using the information from Tables II-1-II-3, annual total fixed cost and annual fixed cost per cow are computed for different herd sizes in Table II-4. Total annual fixed cost ranges from $22,000 for 250-cow herds to $117,000 for 3,000-cow herds for farmers with a lagoon system who hire custom irrigation. For farmers with a lagoon system who own their irrigation system, the corresponding figures are $30,000 to $161,000. For farmers with a liquid tank system, annual fixed costs range from $45,000 to $287,000. Even for the largest herd size, fixed costs per cow are greater with the liquid tank system than for most herds with a lagoon system.

Annual Operating Costs

Annual operating costs are reported in Table II-5. For the lagoon system, annual operating costs are mainly from recycle pumping, solids separation, and application costs. Recycle pumping costs are determined by the size of the electric pump, daily pumping time, and hourly pumping cost. In this report, we assume the size of the electric recycle pump is 3.0, 5.0, 7.5, 10.0, and 12.5 horsepower for 250-cow, 500-cow, 1,000-cow, 2,000-cow, and 3,000-cow dairies, respectively. Daily recycle pumping time is approximately 5 hours. Operating costs for solids separation include power and labor which vary by herd size. A wage rate of $14/hour and a power rate of $20/hour are figured to compute the annual application cost when the irrigation system is owned. Per cow, these costs range from $47 per cow for 250-cow herds to $32 per cow for 3,000-cow herds. When the irrigation system is custom hired at $100 per hour, they range from $97 per cow for 250-cow herds to $70 per cow for 3,000-cow herds.

Table II-4. Total Annual Fixed Costs, Northwestern Washington[a]

1. Herd size	250	500	1,000	2,000	3,000
2. Lagoon system: (hire custom irrigation system)					
a. Total annual fixed cost	21,775	32,510	48,394	82,323	117,408
b. Annual fixed cost per cow	87.1	65.0	48.4	41.2	39.1
3. Lagoon system: (purchase own irrigation system)					
a. Total annual fixed cost	29,752	45,222	67,333	110,305	161,258
b. Annual fixed cost per cow	119.0	90.4	67.3	55.2	53.8
4. Liquid tank system:					
a. Total annual fixed cost	45,478	71,644	116,722	210,846	286,885
b. Annual fixed cost per cow	181.9	143.3	116.7	105.4	95.6

[a] To tailor annual fixed costs to a specific operation, use Worksheet II-1 for a lagoon system or Worksheet II-2 for a liquid tank system.

Table II-5. Annual Operating Costs for Lagoon and Liquid Tank Systems, Northwestern Washington[a]

1. Herd Size	250	500	1,000	2,000	3,000
Lagoon system (hire custom irrigation system)					
2. Annual recycle pumping cost	383	639	958	1,278	1,597
3. Annual solids separation cost	3,671	7,061	13,281	19,381	24,781
4. Annual application cost					
a. Pumping time required (hours)	188	336	609	1,155	1,715
b. Custom pumping charge ($100/hour)	18,800	33,600	60,900	115,500	171,500
c. Agitation cost	1,295	2,434	4,446	8,460	12,637
5. Total operating cost	24,149	43,734	79,585	144,619	210,515
6. Operating cost per cow	96.6	87.5	79.6	72.3	70.2
Lagoon system (purchase own irrigation system)					
7. Annual recycle pumping cost	383	639	958	1,278	1,597
8. Annual solids separation cost	3,671	7,061	13,281	19,381	24,781
9. Annual application cost					
a. Pumping time required (hours)	188	336	609	1,155	1,715
b. Labor cost ($14/hour)	2,632	4,704	8,526	16,170	24,010
c. Power cost ($20/hour)	3,760	6,720	12,180	23,100	34,300
d. Agitation cost	1,295	2,434	4,446	8,460	12,637
10. Total operating cost	11,741	21,558	39,391	68,389	97,325
11. Operating cost per cow	47.0	43.1	39.4	34.2	32.4
Liquid tank system					
12. Annual scraping and application cost					
a. Total time required	559	989	1,848	3,568	5,288
b. Labor cost ($14/hour)	7,826	13,846	25,872	49,952	74,032
c. Tractor cost ($25/hour)	13,975	24,725	46,200	89,200	132,200
13. Total operating cost	21,801	38,571	72,072	139,152	206,232
14. Operating cost per cow	87.2	77.1	72.1	69.6	68.7

[a] To tailor annual operating costs to a specific operation, use Worksheets II-3 and II-4 for the lagoon and liquid tank systems, respectively.

Annual operating costs for the liquid tank system are a little lower than those for the lagoon system with a hired custom irrigation system. The annual operating cost per cow ranges from $87 for 250-cow herds to $69 for 3,000-cow herds.

Value of Dairy Nutrients for Plant Production

Field Application of Manure

Dairy manure nutrients can help to build and maintain soil fertility. Also, it can improve tilth, increase water-holding capacity, lessen wind and water erosion, improve aeration, and promote beneficial organisms. In addition, when wastes include runoff or dilution water, they can supply moisture as well as nutrients to crops.

Proper manure application to fields is not only an indispensable part of the nutrient management, but also a critical step to prevent surface and groundwater contamination. Once manure is applied, it must remain on the field until it is absorbed by the soil. If manure moves beyond the targeted field, it becomes a pollutant. The extent to which manure is kept on targeted fields depends on the application method. For instance, big gun applicators provide the least control and accuracy for liquid manure application while tank-type spreaders and injector systems give the most control (NRCS, 1999). Proper management, planning and vigilance during application keep manure in the desired target area and out of streams and ditches.

The soil infiltration rate measures the soil's capacity to absorb the liquid when manure is applied to a field. This rate depends on soil type, amount of solid material contained in the manure, speed and duration of application, and soil compaction. Existing soil moisture at the time of application affects the total amount of liquid manure that can be applied. If manure application exceeds the soil's infiltration rate, a portion may run off and pollute adjacent surface waters. Manure solids can also seal the soil surface causing infiltration to slow or stop. Farmers can consult the USDA county soil survey to get information about infiltration rates on specific soils. WSU Cooperative Extension and NRCS Conservation District staff can help interpret soil survey tabulated data.

The timing of application should also be considered when making the application plan. The best time to apply manure for crop fertilizer is spring and early summer when growing crops need the nutrients. Application after September increases the potential for excess nutrients to become pollutants. At soil temperatures above 40°F, some of the applied manure nitrogen converts to leachable nitrate in the soil. When manure is applied to warm (60°F or higher) moist soil, it converts to nitrate in several weeks. Soil temperatures in the fall are still high enough to provide ideal conditions for converting manure nitrogen to nitrate. However, if the nutrients are not used by a growing crop, the nitrate can leach past the root zone to the ground water (NRCS, 1999).

Computation of Dairy Nutrient Value

On most dairies, operators use nutrients to reduce costs, or even achieve an economic return, since dairy manure can generally be used as a fertilizer and soil conditioner. Dairy nutrient applied to land has a value measured by the fertilizer nutrients of replaced commercial fertilizer and/or for the increased production of plant growth. Based on the description in *Animal Waste Management Field Handbook* (NRCS, 1999), Table III gives the results of value of dairy nutrient to plant production for different management systems.

Estimating the value of dairy nutrient requires several steps. Nutrient content of the manure must be estimated. Total nutrients are then adjusted for separated solids removed and for losses during storage and application. The value of the manure for fertilizer is computed based on the prices of fertilizer nutrients. The minimum acreage on which dairy nutrients can be distributed without environmental risk is also computed based on the crop, yield, and limiting nutrient.

Table III. Annual Value of Dairy Waste to Plant Production, Northwestern Washington[a]

1. Herd size	250	500	1,000	2,000	3,000
2. Total nutrients produced (in fertilizer form, lb)					
a. N	76,161	151,225	301,353	601,609	901,865
b. P_2O_5	27,216	53,184	105,121	208,993	312,866
c. K_2O	60,159	118,331	234,677	467,367	700,057
For lagoon system:[b]					
3. Value of fertilizer equivalent ($) (losses during storage & application are adjusted)	21,739	42,807	84,944	169,218	253,491
4. Acres required for waste disposal[c]	230-288	450-562	889-1,112	1,768-2,210	2,647-3,309
For liquid tank system:					
5. Value of fertilizer equivalent ($) (losses during storage & application are adjusted)	25,573	50,398	100,048	199,348	298,649
6. Acres required for waste disposal[c]	245-306	479-598	946-1,183	1,881-2,351	2,816-3,520

[a] To tailor the value of dairy waste to plant production to a specific operation, use Worksheet III.
[b] Value of fertilizer and acres for application do not include separated solids for the lagoon system.
[c] Lower acreage based on orchardgrass production and higher acreage based on corn silage production.

The starting point for all calculations is to estimate the total nutrient content of the manure. Nitrogen, phosphorus and potassium are the major nutrients in dairy manure that are considered in computing an economic value. It is important to determine the predominant nutrient(s) that control planning and implementation of dairy nutrient application to promote crop production and environmental protection. If herd manure tests are not available, dairy nutrient production values for dairy cow manure as excreted can be approximated from NRCS data. The total production of nitrogen, phosphorus and potassium (in common fertilizer forms) is reported in Table III for different herd sizes. The total amount of these nutrients depends on nutrient production in the excreted manure, wash water production, nutrients in wash water, and storage period. According to NRCS data, daily nitrogen, phosphorus and potassium for milking cows are 0.45, 0.07 and 0.26 pound per day per animal unit in the excreted form, respectively. These figures are greater for high-producing cows (Johnson, Harrison, and Davidson, 2002). For dry cows, the corresponding figures are 0.36, 0.05, and 0.23. For heifers, they are 0.31, 0.04, and 0.24. Nitrogen, phosphorus and potassium in wash water are 1.67, 0.83 and 2.5 pounds per 1,000 gallons, respectively. Daily wash water production is about 10 gal/cow/day. Conversion rates of phosphorus and potassium to phosphate and potash are 2.29 and 1.21, respectively.

Next, nutrient reductions from separated solids not distributed to the land and from storage and application losses are deducted from the total nutrient production. Nutrient losses from dairy waste can be grouped into three general categories – those that occur during storage, during application to the soil, and after incorporation. Here we are interested in determining nutrients available for plant uptake, so we ignore the third category. Nutrient losses from manure during storage and application vary widely and depend on climate and management, including methods used for collection, storage, treatment and application. Farmers should use local climate information to estimate such losses if such information is available. In the absence of local data, NRCS estimates may be used. For the lagoon system, nutrients lost during storage are about 35 percent for N, 10 percent for P, and 10 percent for K. For the liquid tank (covered) system, the corresponding nutrient losses during storage are 15 percent, 10 percent, and 10 percent, respectively.

Timing of nutrient application is critical to conserving the nitrogen in the manure. Volatilization losses increase with time, temperature, and wind, and decrease with humidity. To minimize volatilization losses, manure should be incorporated before it dries. There are additional N losses through volatilization (5-15 percent N loss) and denitrification (10-30 percent N loss) that are dependent on the time and method of application and on the soil drainage class. In this study, we assumed that there is a 15 percent loss of N through volatilization and 30 percent loss of N through denitrification. Little phosphorus or potassium is lost during application.

Using recent representative prices per lb of N, P_2O_5 and K_2O fertilizer of $0.27, $0.31, and $0.14, respectively (Washington Agricultural Statistics Service, 2000) and considering that about 70 percent of nutrients are left in the lagoon after separating, the annual value of fertilizer equivalents for the lagoon system range from $22,000 for 250-cow herds to $253,000 for 3,000-cow herds. Recall that we are not accounting for the value of separated solids that don't go into the lagoon. For the liquid tank system, the value of fertilizer equivalents is about 18 percent higher. It ranges from $26,000 for 250-cow herds to $299,000 for 3,000-cow herds. The difference is due both to separation of solids and the higher rate of volatization in the lagoon system than in the liquid tank system. Because fertilizer prices and application costs change with economic conditions, expected prices should be used. If any nutrient is not needed on the cropland, a zero value should be used for its price.

Although fertilizer value can be obtained by applying dairy nutrient to crops, acreage for nutrient application is often limited. Therefore, it is important to compute the minimum acreage required for safely applying nutrients. Nutrients, especially nitrogen, can be utilized in greater quantities by grasses and cereals than by legumes. Legumes get most of their nitrogen from the air, so additional nitrogen is not usually needed. In order to get the greatest return, dairy nutrients could be applied first to corn and small cereal grains, then to sorghum and forages, and finally to pasture. However, when application acreage is limited, it may be preferable to apply dairy nutrients first to high-yielding forages and silage.

The capacity of plants to utilize each nutrient must be considered in order to determine the minimum acreage required for application. In Table III, a range of minimum acreage in northwest Washington is calculated following NRCS guidelines (Mid West Plan Service, 1993) assuming that dairy nutrients are applied to orchardgrass hay with a target yield of 6 tons per acre and to corn silage with a target yield of 32 tons/acre. The minimum acreage required for application is the largest acreage required for any one of the three nutrients. For both crops, phosphorus is the limiting nutrient. More acres are required for application when producing corn silage than when growing orchardgrass hay. Applying dairy nutrients to at least the acreage listed should avoid undesirable accumulation of plant nutrients in the soil and related environmental risks. The acreage needed to apply dairy nutrients on these crops should meet the requirement for phosphorus, and additional nitrogen and potassium will need to be added from other sources (generally commercial fertilizers) to obtain maximum yields.[5]

Because all dairy nutrients are stored in the liquid tank and fewer nutrients are volatilized from the liquid tank system than from our lagoon system, farms with a liquid tank system need more land area to apply nutrients than do farms with a lagoon system. After estimating crop fertilizer needs and manure nutrient values, the producer can determine how much manure to

[5] Although there is currently no regulation addressing phosphorus overload, it is important to avoid applying excess quantities of any nutrient in sensitive watersheds.

apply per acre and also determine if additional commercial fertilizer is needed for economic crop production.

Net Cost Computation

Tables IV-1 and IV-2 summarize the investment, annual costs, and value of nutrients associated with each nutrient management system. For the lagoon system, no costs are included for managing the separated solid material and no value is included for its application.

The net annual cost of the lagoon system for farms hiring a custom irrigation system ranges from $97/cow for 250-cow herds to $25/cow for 3,000-cow herds (Table IV-1). If dairy farms purchase their own irrigation system rather than hiring equipment to apply manure, the net annual cost is lower for all herd sizes ($79/cow to $2/cow, respectively). Hiring a custom irrigation system may be cost effective for herds somewhat smaller than 250 cows, but given the prices considered here, net costs are reduced by purchasing the irrigation system for all herd sizes within the range we consider.

The net annual cost for the liquid manure tank system is higher than for either lagoon system at all herd sizes (Table IV-2). Net annual cost ranges from $167/cow for the smallest herd to $65/cow for the largest. These figures further document why the lagoon system is preferred unless soil or geological conditions preclude it. This conclusion is not sensitive over a wide range of interest rates. Additionally, since fewer nutrients are lost with the liquid tank system, additional acreage and/or higher crop yields are required to appropriately utilize nutrients.

Composting – An Alternative Solid Manure Management Procedure

A composting system is a modification of a conventional or solid manure handling system in which a composting treatment process is applied to the manure. Composting is becoming

Table IV-1. Summary of Lagoon System Net Annual Cost, Northwestern Washington[a]

Herd Size	250	500	1,000	2,000	3,000
Lagoon system (hire custom irrigation system)					
1. Total investment (II-1, line 9)	171,851	258,905	389,060	666,248	955,565
2. Average investment per cow (II-1, line 10)	687	518	389	333	319
3. Total annual fixed cost (II-4, line 2a)	21,775	32,510	48,394	82,323	117,408
4.Total operating cost (II-5, line 5)	24,149	43,734	79,585	144,619	210,515
5. Total annual cost (lines 3 + 4)	45,924	76,244	127,979	226,942	327,923
6. Total annual cost per cow	184	152	128	113	109
7. Value of wastes (III, line 3)	21,739	42,807	84,944	169,218	253,491
8. Net annual cost (lines 5 - 7)	24,185	33,437	43,035	57,724	74,432
9. Net annual cost per cow	97	67	43	29	25
Lagoon system (purchase own irrigation system)					
10. Total investment (II-1, line 14)	218,601	333,405	500,060	830,248	1,212,565
11. Average investment per cow (II-1, line 15)	874	667	500	415	404
12. Total annual fixed cost (II-4, line 3a)	29,752	45,222	67,333	110,305	161,258
13. Total operating cost (II-5, line 10)	11,741	21,558	39,391	68,389	97,325
14. Total annual cost (lines 12 + 13)	41,493	66,780	106,724	178,694	258,583
15. Total annual cost per cow	166	134	107	89	86
16. Value of wastes (III, line 3)	21,739	42,807	84,944	169,218	253,491
17. Net annual cost (lines 14 - 16)	19,754	23,973	21,780	9,476	5,092
18. Net annual cost per cow	79	48	22	5	2

[a] To tailor the lagoon system net costs to a specific operation, refer to Worksheet IV.

Table IV-2. Summary of Liquid Tank System Net Annual Cost, Western Washington[a]

Herd Size	250	500	1,000	2,000	3,000
1. Total investment (II-2, line 10)	343,310	555,735	938,090	1,673,290	2,408,000
2. Average investment per cow (II-2, line 11)	1,373	1,111	938	837	803
3. Total annual fixed cost (II-4, line 4a)	45,478	71,644	116,722	210,846	286,885
4. Total operating cost (II-5, line 14)	21,801	38,571	72,072	139,152	206,232
5. Total annual cost (lines 3 + 4)	67,279	110,215	188,794	349,998	493,117
6. Total annual cost per cow	269	220	189	175	164
7. Value of wastes (III, line 5)	25,573	50,398	100,048	199,348	298,649
8. Net annual cost (lines 5 - 7)	41,706	59,817	88,746	150,650	194,468
9. Net annual cost per cow	167	120	89	75	65

[a] To tailor the net cost of a liquid tank system for a specific operation, refer to Worksheet IV.

more popular as a method of handling various agricultural wastes. Three factors may induce dairy farmers to consider composting: severe environmental constraints on traditional nutrient management procedures, increasing cost of handling dairy manure, and economic potential of composting. Although these factors encourage consideration of composting, there are several potential tradeoffs farmers must also consider. They include additional equipment and labor costs, land and improvements required to produce compost, composting technique, management required to assure high-quality compost, scale and scope of operation, and market for the final product.

Thus, the objectives of this evaluation of composting include:

1) Identifying alternative methods of composting.
2) Describing economic opportunities for composting solid dairy waste.
3) Determining investment, operating costs, and likely returns from composting.
4) Identifying the market potential for dairy compost.

Composting Methods

Various methods are available to produce compost. They include passive windrow, turned windrow, in-vessel/channel, extended aerated static pile, and vermi-composting. These methods vary greatly in the quality and consistency of compost produced, investment required, and operating costs.

The passive windrow method turns windrows with a loader, is relatively simple and cheap, but produces the lowest and least consistent quality of compost. When implemented on the dairy, this approach may not require any additional equipment or investment unless drying pads, runoff prevention measures, or covered space are needed. The volume of materials this method can handle range from a few hundred to several thousand cubic yards per year. This method of composting minimizes new investment and requires a relatively low level of management intensity (Rynk, 1992).

The turned windrow method requires more capital and labor than the passive windrow method, but the expenditures may still be reasonable because most dairy farmers already own some of the necessary equipment. Farmers may manage windrows at a moderate level of intensity by purchasing a specialized windrow turner. This method requires a moderate amount of labor and may require an investment as small as $10,000. For larger operations, a fully integrated, self-contained windrow turner costing about $200,000 greatly reduces labor costs. Final product quality is high and the composting period is short. For these reasons, the turned windrow method is currently the most popular method for on-farm composting (MacConnell and Chaudiere, 2000).

The in-vessel/channel composting method requires little labor, product quality is high, and space requirements are small. The extended aerated static pile method requires a system of perforated PVC pipe covered with a layer of shavings and topped with about 8 feet of fresh manure solids and then covered with pre-composted solids. Air is forced through the pipes at variable rates essential to maintain consistent composting temperatures. However, these methods are not popular for most on-farm operations since they require investment in very expensive equipment and skilled labor.

Vermi-composting produces the highest quality compost and in some cases, can be the least expensive method. It requires little equipment and labor. The major requirements are a large amount of covered space, the means to move the materials (a turner or front end loader), and screening equipment. This method tends to be used only on a small scale.

Because of their broad potential applicability for handling dairy solids, we will focus on the passive and turned windrow methods.

Composting Merits

Composting converts nutrients to a more stable form, adds humic acid to the soil, increases beneficial soil organisms, improves soil tilth and aeration, reduces raw manure odors, and reduces reliance on synthetic fertilizers. Although compost is not usually marketed as fertilizer, it can add nutrients to the soil. Compost users include home gardeners and landscapers as well as farmers and local governments (Fabian et al., 2000).

Most compost from agricultural waste is currently being used directly by the farm or local government composter (e.g., for easement plantings) or is sold in bulk in many locations for prices near $10 per cubic yard (Fabian et al., 2000). In Washington, final compost is often marketed at $12 or more per cubic yard F.O.B. The price of compost depends on the amount purchased, quality, promotion, packaging, and associated services.

In addition to the potential revenue from compost, it is frequently preferred for environmental reasons. Manure used as compost quickly breaks down, provides slow release of nutrients, has less odor, may require less acreage for application (depending on soil nutrient load), and has excellent benefits for soil. In addition, waste disposal fees of $50 to $100 per ton have become common (Fabian et al., 2000), so revenue can sometimes be generated by charging disposal fees.

Costs of Composting

Depending on the scale of operation and the technology adopted, initial outlays for planning, permits, site preparation, and investment in equipment and the site can vary greatly. Initial outlay can range from a few hundred dollars to hundreds of thousands of dollars (Fabian et al., 2000). To determine net benefits or costs of composting, several factors must be considered –

quantity of waste, land available for the compost facility, market for compost, and transportation costs.

Costs depend on the quantity of manure composted. Many farmers compost several thousand cubic yards of material without significant additional costs (Fabian et al., 2000).

However, when larger volumes of waste are composted, land, labor and capital investment can be substantial.

Land that can be devoted to composting will influence a farmer's decision on whether to compost. At least one acre of unused or underutilized land with suitable slope, drainage, and access is required for the composting facility (Fabian et al., 2000). Concrete slab and cover may be important for efficient composting. Compost leachate must also be contained or filtered to avoid water contamination. Depending on the technology used, one acre can accommodate 2,000-10,000 cubic yards of compostable material per year. Larger investments in equipment or technology can substitute for scarce land.

The market outlet for finished compost is critical. Compost of consistent high quality can generally be sold easily and profitably but requires careful management to assure desired carbon to nitrogen ratio, temperature control, and bacterial content. More capital investment in equipment, such as screens and monitoring equipment, may be needed to improve the quality and consistency of the final product. Marketing costs are also frequently required when farmers sell compost rather than applying it on their own farms. However, if they plan to add all or most of the compost to their own soils, they can simplify their compost systems and avoid much of the expensive extra processing since it adds little value to the compost for farm application (Fabian et al., 2000).

Transportation costs can be substantial and warrant specific consideration. They include the cost of transporting manure to the compost site and then transporting final products to market or to the land where the compost will be applied. Transportation costs may increase substantially if solid manure and bedding from several dairies is transported to a central composting facility to take advantage of economies of size. Carefully balancing transportation costs and economies of size can help minimize costs per ton of composting and make possible the efficient utilization of expensive fixed investments such as specialized composting equipment or land.

Costs of a specific compost system also depend on additional variables, which vary from farm to farm. Such variables include labor cost, fuel price, land value, equipment investment and maintenance cost. Because various combinations of land, labor and equipment can produce desirable compost using different technologies and management systems, the farmer has several options for using existing resources in a cost-effective way (Fabian et al., 2000).

Investment requirements and annual fixed costs for the additional equipment required to convert solid dairy waste to compost are developed for the passive windrow and turned windrow methods in Table V-1. This and subsequent tables include computations for our five herd sizes as well as pertinent information for a centralized facility that handles transported waste from 8,000 cows.

A loader is required for the passive method and a windrow turner and screen are needed for the turned windrow method. A screen is used to separate materials of different sizes and shapes and improves the quality of the compost for sale or use, but it is not necessary if farmers choose to apply compost to their land rather than selling it. In farm composting systems, the screening is nearly always performed following composting (Rynk, 1992).

Annual fixed costs of managing nutrients from the lagoon are taken from Table II-4 assuming the irrigation system is owned. They are reported in Table V-1, line 3. Since a separator was included in the lagoon system, the additional equipment required for passive windrow systems is a loader, tractor, screen, and storage slab. These items are assumed to cost approximately $6,000, $50,000, $40,000, and nearly $8,000, respectively for a 250-cow herd. Although adequate tractor and loader capacity and storage space may be available on smaller dairies to manage a passive-windrow composting system, their full cost is considered here. The additional storage slab for on-farm composting is about twice the area required to store

Table V-1. Composting System Investment and Annual Fixed Cost, Northwestern Washington[a]

1. Herd Size	250	500	1,000	2,000	3,000	8,000[b]
2. Total investment of lagoon system (II-1, line 14)[c]	218,601	333,405	500,060	830,248	1,212,565	
3. Total annual fixed cost of lagoon system (II-4, line 3a)	29,752	45,222	67,333	110,305	161,258	
Passive Windrow						
4. Additional investment	103,656	111,312	126,626	273,251	359,877	
5. Additional annual fixed cost	13,458	14,195	19,510	61,251	65,161	
6. Total investment (lines 2 + 4)	322,257	444,717	626,686	1,103,499	1,572,442	
7. Total annual fixed cost (lines 3 + 5)	43,210	59,417	86,843	171,556	226,419	
Turned Windrow						
8. Additional investment	217,656	225,313	240,626	331,251	361,877	737,507
9. Additional annual fixed cost	28,563	29,300	31,675	43,176	46,126	86,928
10. Total investment (lines 2 + 8)	436,257	558,718	740,686	1,161,499	1,574,442	
11. Total annual fixed cost (lines 3 + 9)	58,315	74,522	99,008	153,481	207,384	

[a] To tailor composting system investment and fixed cost for a specific operation, use Worksheet V-1.
[b] Centralized faciltiy collects and composts waste from 8,000 cows and associated replacement heifers.
[c] Lagoon system with purchased irrigation system.

solid waste without composting. For the centralized composting facility, the full investment in the storage area is included (i.e., three times what would have been required for a single dairy of the same size to store solid waste without composting). Because of the large number of hours required with a passive-windrow system, one tractor and loader is required for every 1,000 cows.

For the turned windrow composting system, the additional equipment required includes a windrow turner, screen, and a tractor. Although various configurations are available, we budget a windrow turner that costs $120,000 and is capable of handling all solid waste even for the large centralized facility of 8,000 cows.

As with most nutrient management equipment, the useful life of each of these items is generally about 10 years. However, with such a wide range in hours required per year, we specified 15 years for the useful life if equipment is used no more than 600 hours per year (150 hours for the windrow turner), 10 years if used up to 1,200 hours (300 hours for the windrow turner), and six years if used more than 1,200 hours per year. We allowed for a 10 percent salvage rate, 1.5 percent annual maintenance charge (2.5 percent for equipment used 2,400 hours per year), 1.25 percent annual tax, and 0.5 percent annual insurance costs, which are generally consistent with previous investment computations.

The additional annual fixed cost from managing the solid material by passive windrow composting ranges from $13,000 for a 250-cow herd to $65,000 for a 3,000-cow herd. The turned windrow system is more capital intensive than is the passive windrow system for smaller dairies but not for the largest dairy. It ranges from $29,000 for a 250-cow herd to $46,000 for a 3,000-cow herd (Table V-1).

The annual operating cost for these composting systems are included in Table V-2. The total volume of solid manure and bedding available for separating is computed from data in Table I-2. Table V-2, line 3 lists operating costs for managing lagoon nutrients. They are

Table V-2. Composting System Annual Operating Costs, Northwestern Washington[a]

1. Herd Size	250	500	1,000	2,000	3,000	8,000
2. Separated solids removed annually, cy (I-2, line 6)	860	1,720	3,439	6,879	10,318	27,516
3. Operating cost for waste in lagoon (II-5, line 10)	11,741	21,558	39,391	68,389	97,325	
Passive Windrow:						
4. Hours required for composting	184	369	738	1,476	2,213	
5. Operating cost for composting	3,873	7,747	15,493	30,986	46,480	
6. Total operating cost (lines 3 + 5)	15,615	29,305	54,884	99,375	143,804	
Turned Windrow:						
7. Hours required for composting	6	11	22	45	67	179
8. Operating cost for composting	224	447	894	1,789	2,683	7,154
9. Total operating cost (lines 3 + 8)	11,965	22,005	40,285	70,177	100,008	

[a] The data in this worksheet is based on Table 10.2 of Rynk (1992). To tailor composting system operating cost for a specific operation, use Worksheet V-2.

calculated from Table II-5 assuming the irrigation system is owned. Planning for weekly turning of compost (NRCS, chapter 10), hours and hourly operating cost for both systems are based on the information in Table 10.2 of the *On-Farm Composting Handbook* (Rynk, 1992). They depend on the composting method applied. Generally, the turned windrow composting system requires far fewer hours and incurs lower operating costs than the passive windrow composting system. While it requires a larger investment, the savings in operating costs is largely responsible for making the turned windrow system more attractive than the passive windrow system for large dairies.

Benefits of Composting

Composting can be introduced for many reasons. It can develop a marketable product from waste, improve manure application management, provide soil conditioning and/or a bedding substitute, and reduce the risk of pollution and nuisance complaints.

Since concerns about traditional manure utilization methods are increasing, both dairy farmers and society in general are searching for alternative manure utilization methods. This could create an opportunity for farmers to collect processing or tipping fees by composting off-farm waste materials, such as municipal ward waste, horse stable bedding, or vegetable processing byproducts. In order for some manures to compost properly, they must have sufficient carbonous materials included. Off-farm waste materials are often ideal for that purpose. Regulations vary, but after meeting those that require on-farm use, sales of the composted material can be lucrative. Economic benefits from composting may also occur due to reduced annual operating costs for manure application and increased revenue from selling compost.

Table V-3 can be used to compare the two composting systems' benefits and costs when the final product can be sold. The volume of compostable waste comes from Table I-2. Waste

Table V-3. Composting System Annual Benefits and Costs, Compost Sold, Northwestern Washington[a]

1. Herd Size	250	500	1,000	2,000	3,000	8,000
2. Compostable dairy waste, cy (V-2, line 2)	860	1,720	3,439	6,879	10,318	27,516
3. Compost volume, cy (.5*line 2)[b]	430	860	1,720	3,439	5,159	13,758
4. Value of fertilizer equivalent of liquid waste (III, line 3)	21,739	42,807	84,944	169,218	253,491	
5. Compost revenue						
a. Passive windrow (sale price $12/cy)	5,159	10,318	20,637	41,274	61,911	
b. Turned windrow (sale price $14/cy)	6,019	12,038	24,076	48,153	72,229	192,612
6. Total value (lines 4 + 5)						
a. Passive windrow	26,898	53,125	105,581	210,492	315,402	
b. Turned windrow	27,758	54,845	109,020	217,371	325,720	
7. Total annual cost for waste management and composting						
a. Passive windrow (V-1, line 7 + V-2, line 6)	58,825	88,722	141,727	270,931	370,223	
b. Turned windrow (V-1, line 11 + V-2, line 9)	70,280	96,527	139,293	223,658	307,392	
8. Total annual profit (net cost) (lines 6 - 7)						
a. Passive windrow	(31,926)	(35,596)	(36,146)	(60,439)	(54,822)	
b. Turned windrow	(42,522)	(41,682)	(30,273)	(6,287)	18,329	

[a] To tailor composting system benefits and costs for a specific operation, use Worksheet V-3.

[b] Manure volume shrinks 50% during composting.

volume typically shrinks by 50 percent during composting (Caldwell, 2000). In Washington, final compost is frequently marketed for $12-$15 per cubic yard F.O.B. Here we use a price of $12 per cubic yard for the passive windrow system and $14 per cubic yard for the turned windrow system in computing expected revenue. Typically, farmers will not get as much homogenization and mixing with the passive system as with the windrow turner, so composting may take longer or require a larger composting area with the former. At the above prices, annual revenue from composting ranges from $5,000 for 250 cows to $62,000 for 3,000 cows using the passive windrow system and from $6,000 to $72,000 using the turned windrow system (Table V-3).

The annual profit (or net cost) for the two composting systems is summarized for the various herd sizes in Table V-3, line 8. For both systems, profit (net cost) increases (decreases) markedly with increased herd size since the equipment can be used to greater capacity. This means that an on-farm composting system is more economical for larger dairies. For the conditions we consider, composting can make the total nutrient management system a profitable part of the dairy enterprise for the largest herd sizes we consider.

Smaller dairies may choose to compost for various reasons. For example, they may face a net cost of disposing of non-composted solid waste or receive processing or tipping fees to compost off-farm waste. If a dairy chooses to compost, the passive windrow is more economical than the turned windrow only for small- to medium-sized dairies. The turned windrow is preferred for dairies with 1,000 or more cows.

Based on the assumptions specified, the break-even price of compost can be computed for a composting system to be preferred to a conventional nutrient management system. For example, unless the dairy has excess tractor and loader capacity and must pay to dispose of non-composted solid waste, it is not economical for a 250-cow dairy to compost solids at a price of $12 per cubic yard (Table V-4, lines 6a-6d). In fact, the break-even price of compost

Table V-4. Annual Profit (Net Cost) Comparision between Lagoon and Composting, Northwestern Washington[a]

1. Herd Size	250	500	1,000	2,000	3,000
2. Total annual fixed cost					
a. Lagoon system hired custom irrigation (II-4, line 2a)	21,775	32,510	48,394	82,323	117,408
b. Lagoon system owned irrigation (II-4, line 3a)	29,752	45,222	67,333	110,305	161,258
c. Lagoon with passive windrow composting (V-1, line 7)	43,210	59,417	86,843	171,556	226,419
d. Lagoon with turned windrow composting (V-1, line 11)	58,315	74,522	99,008	153,481	207,384
3. Total operating cost					
a. Lagoon system hired custom irrigation (II-5, line 5)	24,149	43,734	79,585	144,619	210,515
b. Lagoon system owned irrigation (II-5, line 10)	11,741	21,558	39,391	68,389	97,325
c. Lagoon with passive windrow composting (V-2, line 6)	15,615	29,305	54,884	99,375	143,804
d. Lagoon with turned windrow composting (V-2, line 9)	11,965	22,005	40,285	70,177	100,008
4. Total annual cost (lines 2 + 3)					
a. Lagoon system hired custom irrigation	45,924	76,244	127,979	226,942	327,923
b. Lagoon system owned irrigation	41,493	66,780	106,724	178,694	258,583
c. Lagoon with passive windrow composting	58,825	88,722	141,727	270,931	370,223
d. Lagoon with turned windrow composting	70,280	96,527	139,293	223,658	307,392
5. Total annual revenue and value of fertilizer					
a. Lagoon system hired custom irrigation (III, line 3)	21,739	42,807	84,944	169,218	253,491
b. Lagoon system owned irrigation (III, line 3)	21,739	42,807	84,944	169,218	253,491
c. Lagoon with passive windrow composting (V-3, line 6a)	26,898	53,125	105,581	210,492	315,402
d. Lagoon with turned windrow composting (V-3, line 6b)	27,758	54,845	109,020	217,371	325,720
6. Total annual profit (net cost) (lines 5 - 4)					
a. Lagoon system hired custom irrigation	(24,185)	(33,437)	(43,035)	(57,724)	(74,432)
b. Lagoon system owned irrigation	(19,754)	(23,973)	(21,780)	(9,476)	(5,092)
c. Lagoon with passive windrow composting	(31,926)	(35,596)	(36,146)	(60,439)	(54,822)
d. Lagoon with turned windrow composting	(42,522)	(41,682)	(30,273)	(6,287)	18,329

[a] Costs and revenue for composting systems are computed assuming custom irrigation system hired.

for the 250-cow dairy is nearly $40 per cubic yard using the passive windrow method. Because of equipment capacity (economies of size), the break-even price of compost drops rapidly as more compost is produced. The break-even price per cubic yard of compost produced by the turned-windrow method is $26 for a 500-cow dairy, $19 for a 1,000-cow dairy, $13 for a 2,000-cow dairy, and $9 for a 3,000-cow dairy.

These figures assume that (1) high-quality compost can be produced without being covered, (2) all compost is sold at the same price, and (3) solid material not composted is disposed of without incurring additional cost or revenue. If a roof is required for the compost facility, less compost is sold, quantity discounts are provided, and/or non-composted solid waste generates positive net revenue, the break-even price of marketed compost will be higher. If net costs are incurred in disposing of non-composted solids, if processing or tipping fees can be obtained to compost off-farm waste materials, or if compost can be sold for a higher price through effective packaging and marketing, the break-even price of compost may be lower.

Break-even Mileage Computation

Because a larger composting facility can economically use the turned windrow system and substantially reduce the break-even price for compost because of economies of size, it may be economical for several small dairies to cooperate in creating a composting center. Alternatively, a separate business could be established to receive solid dairy nutrients and produce compost. Which option is preferred depends on the costs of transporting dairy solids to the composting center relative to the savings in fixed and operating costs.

Although there are many benefits to on-farm composting, composting requires equipment, labor and management. Composting may also require additional storage space for raw materials and the final compost product. Weather is an important factor to consider before starting an on-farm composting program. Cold weather and heavy precipitation greatly affect the composting process and facilities required. The same problems must be faced by an individual dairy or a central composting center, but may be more economically dealt with by a larger facility that has its own management, capital, and labor force.

Table V-5 determines break-even mileage for transporting manure to a composting center for dairies that have decided to compost solid waste. To compute break-even mileage, we equate the annual cost of transporting solid waste to the cost saving from composting in an efficient central composting facility rather than creating an on-farm facility. Separated manure weighs about 1,200 lbs per cubic yard. Assuming a transportation cost of $1.20 per ton mile (Jessup, 2002) and a market price of $14 per cubic yard of compost, the break-even mileage varies from 25 miles for 250-cow dairies to two miles for 3,000-cow dairies. Farmers who have decided to compost could consider transporting their manure up to these distances to get to a central composting facility that is cooperatively owned. However, if non-composted solid wastes can be disposed without net cost by dairies with 250-1,000 cows, the maximum economic distance to a centralized facility would drop to five miles.

Marketing Compost

The main challenge farmers must address before starting on-farm composting or cooperating in the organization of a central composting center is to determine whether the final product can be marketed successfully and economically. It is better to examine the potential market for the product before beginning production, especially given the small profit margin estimated here. For most dairies, composting would represent a new enterprise. Accurately assessing the potential market often determines the success or failure of a venture. Thus, the farmer should consider how much of the product can be sold and at what quality and price.

Table V-5. Computation of Compost Break-Even Mileage, Northwestern Washington

1. Herd Size	250	500	1,000	2,000	3,000	8,000
2. Compostable waste, cy (V-3, line 2)	860	1,720	3,439	6,879	10,318	27,516
3. Compost volume, cy (V-3, line 3)	430	860	1,720	3,439	5,159	13,758
4. Compost revenue (V-3, line 5a or 5b)[a]	5,159	12,038	24,076	48,153	72,229	192,612
5. Annual composting cost[a]	17,331	21,942	32,569	44,965	48,809	94,082
a. Annual fixed cost (V-1, line 5 or 9)	13,458	14,195	31,675	43,176	46,126	86,928
b. Annual operating cost (V-2, line 5 or 8)	3,873	7,747	894	1,789	2,683	7,154
6. Annual composting profit (net cost) (lines 4 - 5)	(12,172)	(9,903)	(8,493)	3,188	23,421	98,530
7. Composting profit (net cost) per cy compostable waste (lines 6/2)	(14.16)	(5.76)	(2.47)	0.46	2.27	3.58
8. Difference between profit per cy compostable waste from centralized facility and on-farm composting	17.74	9.34	6.05	3.12	1.31	
9. Break-even Mileage[b]	**25**	**13**	**8**	**4**	**2**	

[a] Based on the passive windrow composting system for 250- and 500-cow herds and the turned windrow system for larger herds.

[b] Break-even mileage is computed by equating the cost per cy of transporting compostable waste to the difference recorded in line 8. It is assumed that separated manure weighs 1,200 lb/cy and is transported by truck at a cost of $1.20 per ton mile.

Selling compost involves marketing. This means searching out potential buyers, advertising, packaging, managing inventory, matching the product to the customers' desires, and maintaining consistent product quality (Rynk, 1992). The potential buyers of compost can be classified into agricultural groups (forage and field-crop growers, fruit and vegetable farmers, homeowners, organic farmers, turf growers), commercial groups (cemeteries, discount stores, supermarkets, garden centers, greenhouses, nurseries), municipal groups (landfills, public works, schools, park and recreation departments), and residential groups (homeowners, apartment buildings, office buildings).

After identifying the potential buyers, the size of market for compost must be determined. In most cases, the market for compost is local, within 25-50 miles of the composting facility, since transportation costs are high in comparison to other production costs (Rynk, 1992).

Next, the customers' preferences must be identified. Providing a variety of compost products may increase success in developing a market. In addition to compost, a composted mulch-topsoil made from a blend of compost and soil could be offered. Different grades of compost such as soil amendment grade, a nutrient-rich fertilizer grade, and/or a potting medium grade may also be marketed (Rynk, 1992).

Finally, the supply of compost available to customers must be reliable. Most compost is used in the spring and early summer, so the product should be stable and suitably dry for delivery at that time.

Conclusions

There are lots of ways to manage dairy nutrients. All are expensive. This bulletin addresses several important issues that must be considered in designing a nutrient management system. All nutrient management systems must comply with governmental regulations to protect water and air quality. The challenge is to determine how to do that in the most cost-effective and socially responsible way. An appendix and linked spreadsheets can help determine tradeoffs between alternatives for specific operations. They are available on the web (http://farm.mngt.wsu.edu/PDF-docs/EB1948E.pdf and http://farm.mngt.wsu.edu/Excel-docs/EB1948E_DNM.xls). They can also be ordered on compact disk (Windows compatible) from http://farm.mngt.wsu.edu/Software.html, order number A.E.C.S Series 03-1.

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