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ECONOMIC ANALYSIS OF WASTE MANAGEMENT SYSTEMS ON TENNESSEE DAIRY FARMS

A Thesis Presented

for the

Master of Science

Degree

The University of Tennessee, Knoxville

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ABSTRACT

The purpose of this research was to make a comparative evaluation of the various waste management systems most commonly found on Tennessee dairy farms. Systems deemed to be most typical were classified as: (1) daily haul (DH); (2) dry stack (DS); (3) earthen pit (EP); (4) above-ground tank (AGT) (steel or concrete); (5) single stage lagoon (SSL); and (6) two stage lagoon (TSL). Storage capacity of 3-months and 6-months was assumed for DS, EP, and AGT systems.

The dairy waste management systems were compared for various sizes of milking herds and alternative confinement systems. The sizes of milking herds modeled were 80, 160, and 320 cows. Alternative confinement systems were defined as partial and total confinement. Seventy-eight distinct dairy waste systems resulted from incorporating the three herd sizes, two confinement systems, and seven waste systems (with associated variation in storage capacity and collection methods) into the analysis.

Based upon technical data synthesized and primary cost data collected, each specific dairy waste management system was modeled with regard to economic parameters of initial investment and annual costs/-returns. It was assumed that quantifiable economic returns from any system were restricted to the fertilizer value of the waste nutrients preserved by that waste system. System comparisons were then made based upon these estimated economic parameters.

With regard to initial investment, DH systems were least cost in each case analyzed. Generally, EP (particularly EP/3) systems were the

next least cost system. AGT systems consistently required the greatest initial investment. Typically, SAGT systems required larger capital outlays than similar CAGT systems.

Definite economies accrued to herd size. Per cow investment costs fell by as much as 70% when herd size was increased from 80 to 320 cows. Additionally, doubling storage capacity on those systems for which this parameter was varied resulted in less than double investment costs.

When compared with respect to net annual costs, DH systems were least cost for modeled dairy herds utilizing partial confinement. However, EP systems (EP/3 and EP/6) tended to be least cost on modeled dairy herds incorporating total confinement. At the very large herd size (320 cows) lagoon systems, especially the SSL/FC system, became quite competitive with EP systems. AGT systems, specifically SAGT systems, were consistently the most costly systems.

Certain critical parameters were varied to test the stability of the performed net annual cost analysis. Parameters deemed to be critical included nutrient loss rates, manurial nutrient values, and labor costs.

Generally, variation of these parameters did not significantly impact on relative net annual costs. Systems remained relatively stable when compared to one another. However, net annual costs for particular dairy waste systems were significantly affected in absolute terms.

Only when nutrient values were increased by 50% did positive returns accrue to any dairy waste management system. Increases of this magnitude in prices of manurial fertilizer nutrients are not anticipated in the near future.

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CHAPTER I

INTRODUCTION

The various systematic methods of collection, storage, and disposal of dairy farm waste have received increased scrutiny during the last two decades. The underlying reasons for this rise in interest are basically fourfold.

First, there has been a significant change in the structure of the dairy farm industry. Increases in milking herd size coupled with a decline in dairy farm numbers have been observed for the past several years. In 1969, 58% of the total number of milk cows on commercial farms in Tennessee were in dairy herds of 30 or more, while almost 39% were on farms with herds of 50 or more (9). By 1982, the number of milk cows in herds of 30 or more had risen to 84% of the milk cow population on commercial farms; over 70% of the total number of milk cows were in herds of 50 cows or more. From 1969 to 1982 the number of commercial farms reporting milk cows dropped from 14,012 to 8,098 (9, 11).

In a survey of Tennessee Grade A dairy producers compiled in 1983, Whipple (72) found that five years prior to the survey, 45% of the respondents operated milking herds of 51-120 cows. For the same time period, 10% and 2% of the survey respondents owned herd sizes of 121-200 and 200 cows or more respectively. In 1983, 50% of the survey respondents had 51-120 cows, 11% had 121-200 cows, and 3% had 200 cow or more herds. The survey results also indicate that five years from

the time of the survey, 48% of the responding Grade A dairymen plan to own milking herds of 51-120 cows. However, 17% and 4% of the respondents plan to own milking herds of 121-200 and 200 cows or more respectively.

Obviously, Tennessee dairymen seem to be following the national trend to fewer and larger dairy farms. One result of these structural changes has been that the quantity of dairy waste handled per dairy farm has increased at a significant rate, hence its rapid rise as a management concern.

Secondly, associated with the increase in milking herd sizes, there has been a general trend toward more confined herds with a reduction (or complete elimination) of large pasture areas. Dale (14) reported that "summer pasture, considered a must some 30 to 35 years ago" has been a substantially reduced. He also notes that the "loafing" areas for dairy herds are becoming smaller.

A significant consequence of the trend toward more confinement (increased time spent on concrete or small, unpaved lots) has been tremendous increase in the quantity of waste that must be collected and removed. The continuous pasture confinement system (essentially no confinement) offered the benefit of a waste management system in which a majority of the dairy waste was effectively discarded automatically. Obviously, waste management systems associated with continuous pasture confinement systems required little actual management i.e. they were essentially self-managed. However, as the level of confinement increased, the relative proportion of a dairy farmer's labor, energy, and investment costs allocated to waste disposal also rose. Significant

labor and capital conflicts developed between the waste management system and the other farm enterprises. Thus, the management requirements of dairy waste systems increased with the level of confinement. "Management" has therefore become the key word in the term "waste management system."

The third reason often cited for the increased attention given dairy waste management systems is the rapid rise in value of the manurial fertilizer nutrients, especially nitrogen, during the 1970's. Historically, animal manures have been used as a source of fertilizer nutrients. Because the manufacture of fertilizer is an energy requiring process, increased energy costs have led to increases in the cost (or value) of the nutrients in fertilizer sources (37). Parker (50) noted that commercial fertilizer prices in Tennessee "almost doubled between 1960 and 1980." A result of this price spiral was a renewed emphasis on dairy waste as a substitute for commercial fertilizer.

The conservation and utilization of these nutrients is not presently as major an issue as during the periods of rapidly rising energy prices. However, the nutrients in dairy waste are a potentially valuable resource and should be considered when analyzing the various manure management systems. Other, non-quantifiable benefits from dairy waste application to cropland include improved soil organic matter and tilth (12, 34). Thus, the economic value of dairy waste is likely to exceed its value measured strictly in nutrient terms.

A heightened environmental awareness is the fourth underlying reason for the increased concern about waste management on dairy farms. Due mainly to the potential of dairy waste as a source of water

pollution (point and nonpoint), dairy farms, as well as all of production agriculture, have been scrutinized with regard to the methods used in waste collection and disposal. As a result, dairy farms have come to be included in the "technology based" effluent limitations for control of pollution sources from all industrial operations. One such statute is the Federal Water Pollution Control Act, PL92-500 of 1972 (3, 13).

Currently, these environmental concerns seem to have lessened somewhat. However, the possibility of stricter enforcement and/or imposition of more stringent guidelines does exist. This creates the risk that forces outside the market may be able to dictate the type of waste management systems that can legally be used on dairy farms; the management techniques of these acceptable systems could likewise be prescribed. The installation of new waste storage facilities and equipment or a significant modification of existing facilities would likely result. The realization of this contingency could result in a tremendous expense to the individual dairy farmer and the dairy industry as a whole (7, 31, 19).

Expansion of dairy waste management research, both technical and economic in nature, has resulted in improved management of existing waste systems which attempt to exploit the fertilizer value of dairy wastes. Newer, more technically advanced systems have also been developed. Examples of these more exotic waste management systems include methane generation (for energy production) from dairy waste and liquids-solids separation of waste. Solids reclaimed could be reused

as a bedding material, a feed ingredient, or in some instances, bagged and sold commercially.

Definition of the Problem

The problem addressed by this study is the need for reliable and complete cost and return data for evaluating and comparing waste management systems used or suitable for use on Tennessee dairy farms. Without adequate data for objective comparison, the choice of a waste management system must rely primarily on subjective evaluations. Although a high value may possibly be placed on individual preferences, the dairy farm manager and others involved need to be aware of the relative costs of these preferences. Continued escalation in amounts and cost of capital and value of labor associated with waste handling systems provides incentive for installing and operating economically more efficient systems.

Obviously, waste management systems cannot be analyzed adequately in isolation from other phases of the dairy farm operation. While a cost and returns study necessarily analyzes the waste management as a separate enterprise, the farm manager integrates this one management aspect into the whole farm plan for a more complete analysis. Coote et. al. (13) state "the dairy farm is a complex system of interacting components or processes, and decisions related to feed purchases, crop selection, herd size, fertilizer applications, building modifications and manure handling must be evaluated for their effects on this total system." This whole farm, integrated analysis is necessary because of

the significant dissimilarities among dairy farms and dairy farm managers.

A general recommendation of a specific dairy waste management system as "best" for all dairy farms therefore is not feasible. However, if sufficient technical and economic data for the various waste management systems are available, the dairy farm manager, and any consultants involved, will be better able to select the system best suited to the specific dairy and its unique parameters. These parameters include such things as available land, topography, meteorology, soil type, financial resources, and other farm enterprises.

Research Purposes and Objectives

The purpose of this study was to make a comparative economic evaluation of the various waste management systems most commonly found on Tennessee dairy farms. Systems determined to be most typical for Tennessee dairy farms were classified as: (1) daily haul; (2) dry stack; (3) earthen pit; (4) above-ground tank (steel or concrete); (5) single stage lagoon; and (6) two stage lagoon. Variation in storage capacity of 3-months and 6-months was assumed for dry stack, earthen pit, and above-ground tank systems.

The waste management systems were compared for various sizes of milking herds and alternative confinement systems. The various sizes of milking herds considered were 80, 160, and 320 cows. The alternative confinement systems were defined as partial and total confinement.

The specific objectives of the study were:

1. To describe the more common waste management systems currently in use on Tennessee dairy farms.

2. To estimate the direct costs of constructing and installing the various waste systems on synthesized dairy farms for two confinement levels, and three sizes of milking herds.

3. To estimate and compare the annualized costs and returns from the various synthesized dairy waste management systems.

4. To analyze the stability of the cost/return relationships among waste management systems to variations in certain key parameters whose values were specified by assumption.

Selection of dairy waste management systems (and variations of these systems) to include in this study was based upon interviews with East Tennessee dairy farmers and U. S. D. A. Soil Conservation Service (SCS) personnel. Each specific system (determined by herd size, confinement system and waste handling/storage method) was modeled in technical detail with regard to: (1) quantities of waste nutrients preserved through the collection, storage and land application processes; (2) labor and tractor/equipment requirements for the various tasks involved; and (3) mineralization of waste nutrients after land application. The modeling process was accomplished by using budgets for the various technical aspects of dairy waste management.

Based upon technical data synthesized, and primary cost data collected, each specific dairy waste management system was modeled with regard to the economic parameters of initial investment and annual costs/returns. It was assumed that quantifiable economic returns from any system were restricted to the fertilizer value of the waste

nutrients preserved by that waste system. System comparisons were then predicated upon these estimated economic parameters.

The more exotic dairy waste management systems such as methane generation or liquids-solids separation were not included in this analysis. Comprehensive technical and economic data necessary to model these systems is not generally available. In addition, these type manure systems are relatively unimportant on Tennessee dairy farms. Although research involving atypical waste management systems is also desirable and needed, the criteria used to determine the systems compared in this study allowed the inclusion of only those systems most common to Tennessee dairy farms.

This study was not intended to be an engineering design manual for the waste management systems analyzed. Each of the systems described was farm specific, i.e. design, investment outlay, and annual costs vary from farm to farm. Parameters used for each system studied were thought to be "representative," however, further analysis would be required to determine the needs on a specific dairy farm.

An additional point is that the "best" waste management system does not necessarily dictate the best total dairy farm system. The feeding/housing components of the total dairy enterprise must also be considered as well as the effects of the dairy enterprise upon use of total farm resources. Lastly, the study focused only upon the micro effects of dairy waste management. Consideration of macro effects or possible externalities were not included in the analysis. No attempt was made to estimate and compare the relative pollution control effectiveness of the studied waste systems. Rather, the assumption was made

that, through correct design and management of each system, current environmental guidelines would be satisfied.

Review of Literature

Review of literature was restricted to research published since 1969 which dealt with economic comparisons of various dairy waste management systems. Two analytical approaches, least cost system determination and cost/return analysis, have typically been employed in these economic comparisons. Three general techniques of analysis have been used: (1) farm survey and statistical analysis, (2) economic engineering analysis, and (3) computer programming analysis.

In 1970, Kimball et al. (33) used data collected during a 1966 survey to study liquid dairy waste management systems on 43 Wisconsin dairy farms. The liquid systems studied were classified by type of housing and as completely liquid or part-liquid. Four distinct systems resulted from this classification scheme: (1) freestall/all-liquid, (2) freestall/part-conventional, (3) stanchion/all-liquid, and (4) stanchion/part-conventional.

Kimball et al. observed that as herd size increased by a factor of about 4 (from 25 cows to 100 cows), costs per cow were almost halved. They also noted a significant trade-off between labor and equipment costs when moving from a part-conventional to an all-liquid system.

Kimball et al. observed that the rank of the systems (least costly to most costly) depended on the labor cost, labor intensity of the system, length of storage, size of milking herd, and price of

fertilizer nutrients. Although they did not directly adjust the cost of each system for the value of the fertilizer nutrients saved, they did value manure as a substitute for a commercial fertilizer (10-5-10) in determining whether a part-conventional or an all-liquid system was more economical. In addition, they utilized this proxy value of manure nutrients to determine "break-even" herd sizes i.e. "how large a herd is needed to pay for a liquid manure system."

A significant finding was that, given their assumptions, all-liquid systems had practically the same costs as part-conventional systems. When returns were considered however, all-liquid systems were deemed to be "more economical."

In a 1975 study, Bielen and Lessley (3) compiled survey data from 163 dairy herds within the Monacacy River Watershed in Pennslyvania and Maryland. Using both survey information and secondary data sources, the authors (1) developed benchmark planning data for dairy farms; (2) determined the current waste handling practices used on dairy farms in the survey area; and (3) developed labor, initial investment, and annual costs for each dairy waste disposal systems.

Systems were delineated by type of manure handling system, housing system, and herd size. The type of manure handling systems were categorized as: (1) conventional systems (scrape-load-spread, scrape-store-load-spread, scrape-ramp-spread, and scrape-ramp-store-spread); (2) stacker system; and (3) liquid system. The housing systems considered were as follows: (1) stanchion; (2) stanchion-freestall combination; (3) loose; and (4) freestall. The milking herd sizes

included in the study were (1) 0-49, (2) 50-89, (3) 90-129, (4) 130-159, and (5) 160 and over.

Bielen and Lessley found that "economies of scale" (herd size) existed within all systems with regard to initial investment and annual costs per cow. However, this was not necessarily true of the annual labor requirements per cow. It was noted that, once "the initial investment in livestock buildings has become fixed, the type of housing will be a major determinant of the manure handling system." They also observed that systems with low capital requirements typically had high labor requirements and vice versa. The one exception was the stacker system which had relatively high requirements of both inputs.

In the cases that Bielen and Lessley studied, scrape-load-spread (daily haul) systems were found to be the least cost systems in all but one instance. Stacker systems were predominantly the most expensive dairy waste management system, followed by liquid systems with the greatest storage capacity.

Hromadka and Paxton (28) utilized survey data from 70 Louisiana dairy farmers, agricultural engineers, and dairy scientists to examine costs associated with alternative waste handling systems that were technically feasible for Louisiana conditions. The selection of these systems was based on the systems' ability to meet "probable regulations on dairy waste handling techniques and the extent of use within the state and national dairy industry." A modified economic engineering technique was utilized in analyzing the selected waste handling systems on herd sizes of 50, 75, and 150 cows. The analytical approach was to

determine the least cost system. The fertilizer value of the manurial nutrients was ignored.

The economic engineering analysis considered two alternative waste handling methods as "basic systems." One of these systems was defined as the scrape and haul method. The other alternative method was the "basic lagoon system" which consisted of both an anaerobic and aerobic lagoon. Based upon their survey results, the lagoon system was the only waste handling system that was found to increase in preponderance (percent of producers using the system) as herd size increased. The percent of respondents using other types of waste handling systems decreased as herd size increased.

The basic lagoon system was examined using four methods of cleaning the confinement area and two alternative land disposal techniques. The four possible methods of cleaning the confinement area were: (1) scrape and water combination; (2) flush system; (3) high pressure water hose; and (4) cow wash system. The cow wash system was not "generally considered a method of cleaning the confinement area, but sufficient volumes of water are released in the process to do a reasonable job of cleaning the surface" of the holding area. The two alternative land disposal methods considered with each waste handling systems were irrigation and disposal via a tank wagon.

Average per cow investment in "basic" lagoon systems was slightly more than the scrape and haul system for less than 50 cow herds. However, for 50-100 and greater than 100 cow herds, average investment in basic lagoon systems was almost half that for scrape and haul systems. Of the various lagoon systems analyzed, the flush (cleaning)

system was predominantly least cost (annual costs basis) at all herd sizes. It was not, however, the system requiring the lowest initial investment. That distinction belonged to the high pressure water hose (cleaning) system.

In 1973, Henderson and Bauer (22) used the economic engineering technique in describing and analyzing the four most used systems of manure disposal on Tennessee dairy farms. The analytical approach used was least cost system determination. The four systems in the study were: (1) conventional (daily haul); (2) liquid (pit below holding pen); (3) irrigation (liquid with adequate water added); and (4) lagoon (anaerobic). These systems were compared with regard to initial investment, annual operating costs, and labor requirements on a synthesized 100 cow herd. Various holding capacities for the liquid system (15, 30, 45, 60, 75, and 90 days) were included in the analysis.

Conventional systems required by far the lowest initial investment per cow, nearly one-third that of the next lowest system (liquid with 15 days storage). Comparing annual costs, Henderson and Bauer observed the conventional system to be least cost. Total annual costs per cow for conventional systems were only about 67% of the next least cost system (once again liquid with 15 days storage). Total annual cost per cow of a lagoon system was almost 187% of that for a conventional system. However, annual labor requirements for the conventional system were the highest of the compared systems.

Addressing the higher investment and annual costs of liquid and lagoon systems, Henderson and Bauer note that the crucial question is "whether or not these higher costs can be justified on the basis of

more flexible labor requirements." If labor is scarce, the opportunity cost, and hence value, of this resource could possibly cause a change in the conclusions. The authors also note that it is "quite possible" that lagoon and liquid systems could appear "more favorable" at larger herd sizes.

Henderson and Bauer considered the costs of scraping waste into pits or loading over ramps as part of the cleaning operation and did not include them in the disposal costs. They also viewed manure " as strictly a nuisance with no value as fertilizer."

Johnson et al. (31) examined alternative dairy waste management systems adaptable to different agricultural areas of the U.S., various herd sizes, and various housing systems. This study, like most similar research, viewed the installation of waste systems as a response to the implementation of legal environmental controls. Therefore, the systems included in their analysis were "designed for pollution control."

The different geographical areas described by Johnson et. al. were: (1) Lake States; (2) Northeast; (3) Corn Belt; (4) South Atlantic-Gulf Coast; and (5) Southwest. Three general alternative housing systems were listed: (1) stanchion; (2) open-lot freestall housing; and (3) covered freestall housing. Eleven distinct waste handling systems, and variations of some of these, were enumerated. These systems were defined as exclusive to certain types of housing systems and areas of adaptation. The pollution control capabilities of the specific systems were listed, as well as the range in herd sizes with which they were most commonly associated.

The herd sizes synthesized in the economic analysis were 40, 80, and 160 cows. Certain herd sizes were considered exclusive of certain housing systems e.g. the stanchion system (and thus waste handling systems exclusive to it) was not synthesized for the 160 cow herd size. These exclusions, in addition to the consideration of the Lake States, Northeast, and Cornbelt areas as one adaptation region, effectively reduced the number of systems studied.

The various dairy waste management systems, resulting from combinations of waste handling methods, housing systems, and herd sizes, were examined for their region of adaptation on the basis of: (1) labor and tractor requirements; (2) initial investment; and (3) annual costs. Johnson et al. utilized the least cost analytical approach in their analysis. They assumed that "none of these systems will be revenue generating." Some systems could be relatively cost reducing. However, most would be cost increasing and reduce net dairy income for a given herd size.

Generally, Johnson et al. found that daily haul waste systems required less investment and annual costs than alternative systems. An exception was the tractor scraper-two lagoon system for 160 cows in the Southeast-Gulf Coast area; this system had the least annual per cow costs of any system in any adaptation area.

It was noted however, that daily haul systems effected minimal pollution control while most other systems offered improved pollution control capabilities. In addition, daily haul systems required significantly more labor at all herd sizes than alternative waste management systems, most of which utilized storage.

In a 1972 study, Jacobs and Casler (30) described and evaluated the economic, physical, and environmental implications of alternative dairy manure handling systems. The examined systems consisted of stanchion housing with conventional or liquid manure handling systems and freestall housing with conventional, liquid, or lagoon systems.

The waste handling systems were broken into three component parts: (1) collection method; (2) storage method; and (3) disposal method. The storage component varied by length of storage (no storage, 4-months, and 6-months storage) as well as the method involved in storage (stacking or liquid). Certain variations of the storage component were system-specific e.g. conventional systems utilizing daily spreading, by definition, could not be varied by storage capacity. A total of 18 different waste handling systems resulted from the feasible combinations of the system components and housing systems.

Herd sizes of 50 and 100 cows were synthesized for the waste systems specific to stanchion housing; 50, 100, and 200 cow herds were synthesized for the waste systems associated with freestall housing. Using the least cost approach, Jacobs and Casler compared the dairy waste management systems on the basis of investment, labor and power requirements, and annual cost per cow.

Daily haul was observed to typically require the least investment and least annual per cow cost at all analyzed herd sizes. However, it was found that utilizing a "lip" or push-off ramp with daily haul systems lowered investment and annual costs.

Typically, liquid systems with soil injection and lagoon systems with irrigation were most expensive to construct and operate. However, lagoon systems became more competitive as herd size increased.

Traditional inverse relationships were reported between annual per cow labor requirements and capital intensity of the various dairy waste systems. An exception were systems using manure stackers and storage, which required both relatively large annual labor inputs and high initial investment.

In addition to the economic analysis, Jacobs and Casler performed an environmental evaluation, ranking each alternative waste system for each of seven different environmental characteristics. This ranking was based on an opinion survey of 16 individuals "knowledgeable about dairy farm waste handling systems." A weighted value for each characteristic, by system, was developed. These values were summed by system to arrive at a compsite "environmental impact score" for the waste systems studied. It was proposed that these environmental impact numbers could be utilized as coefficients in environmental quality constraints of a linear programming model. The objective would be to determine the least cost waste handling system for a dairy farm subject to these environmental quality constraints.

Jacobs and Casler observed that trade-offs were "made among environmental characteristics between alternative systems." Their results indicate that the environmental differences between the various waste systems were not as great as "that implied by those who have suggested that dairymen should be doing something other than daily spreading."

Waste systems utilizing manure stacking equipment as a component and systems in which stored wastes were irrigated typically received highest (least desired) estimated environmental impact scores. Soil injection lowered scores considerably for liquid systems using this land application technique. In some instances, the score for daily haul systems was significantly less than (better than) for other types of waste systems.

As part of a comprehensive dairy systems analysis, Hoglund (26) developed comparative economic and technical data for alternative waste handling systems common to stall (stanchion) housing and/or freestall housing. The waste systems developed were those typically found on dairy farms in the Lake States and Northern Corn Belt areas.

Two alternative solid systems, daily hauling and 6-months storage, were synthesized for the stanchion housing as well as two liquid systems. The two liquid systems were hydraulic flushing of gutters with outside storage and below-pen (basement) storage. Both liquid systems utilized 6-months storage capacity. The four systems specific to stanchion housing were compared at herd sizes of 40, 75, and 100 cows. Initial investments, labor requirements, and annual costs (total and per cow) were calculated, summarized, and compared to determine the least cost system.

In comparing alternative waste systems specific to stanchion housing, Hoglund observed that the daily haul system (using mechanical gutter cleaners) required the lowest investment per cow, but highest labor per cow. Investment per cow of the most costly waste system (liquid with basement storage) was over five times that for the daily

haul system. Labor savings were only about 21% of the amount for daily haul however.

In the final analysis, the lower capital investment of the daily haul system outweighed the higher labor requirements of this system, resulting in lower annual costs per cow than alternative systems. Annual per cow costs were less than one-half of that for the most costly system (liquid with basement storage). The relationships described were typical for all herd sizes.

Economies of herd size, with regard to investment per cow, labor per cow, and total annual costs per cow, were observed. The most marked improvement in analysis parameters were found as herd size increased from 40 to 75 cows.

Seven alternative manure handling systems, two solid and five liquid, were synthesized for the freestall housing system The two solid systems were daily hauling and 6-months storage. The five liquid systems included: (1) below building storage-tractor scraper; (2) below building storage-mechanical scraper; (3) basement storage-slotted floor; (4) silo storage-liquid spreader; and (5) earthen storage-liquid spreader. All five liquid systems employed 6-months storage. These seven waste handling systems common to freestall housing were compared on varying herd sizes of 100, 150, and 200 cows. Least cost system determination was the analytical approach employed.

Hoglund observed that daily haul was far and away the least cost waste system for all herd sizes. Solid systems, in general, compared very favorably with alternative liquid systems. The most costly systems, liquid with below building strorage-mechanical scraper

collection, required an initial investment over nine times (almost 10 for herd sizes of 150 and 200) that for daily haul systems. However, a labor savings of almost 41% was projected for the most costly system. But the critical analysis regarding total annual costs, showed liquid with below building storage-mechanical scraper having an unfavorable comparison of almost two and one-half times the annual costs for daily haul systems.

Hoglund examined the increased costs incurred if an additional four months storage capacity (for a total capacity of 10-months) was added to the below building storage, above ground silo, and earthen storage systems specific to the 150 cow herd size. Annual costs were estimated to increase by 33%, 18%, and 8.5% for below building storage, above-ground silo, and earthen storage systems respectively.

The possibility of substituting an irrigation system for the liquid spreader as a disposal method was also examined for the 150 cow, freestall housing, earthen storage waste handling system. Irrigation spreading was found to reduce labor requirements significantly (over 26%) while raising initial investment only slightly (1%). A reduction in total annual costs per cow of almost 10% would result. "Break-even" costs were calculated for the two systems (investment cost at which the two systems' costs would be equal). It was estimated that initial investment cost of the irrigation system could increase by over 66% before this break-even point would be reached.

In a 1978 report, White and Forster (73) described and evaluated "alternative systems and/or technologies" employed to manage wastes from facilities used in housing the major productive livestock species

(including dairy) in the U.S. Each species was considered separately. The study was restricted to those concentrated feeding facilities of 1000 animal units or less; an animal unit was defined as one beef animal equivalent. The U.S. was delineated into regions of livestock production. The principal identification factors for these regions were temperature, rainfall, moisture evaporation, livestock production patterns, and topographic features. The primary production regions for each species, including dairy, were located and defined.

An economic (cost/benefit) analysis, as well as an environmental evaluation, was performed for each alternative system. The costs included in the economic analysis were the out-of-pocket expenses of adopting the specific waste system. The calculated benefits, meanwhile, were considered to be the fertilizer nutrient return from the specific system. Two levels of nutrient return were assumed. The first assumed that 100% of the available nutrients (after storing, handling, and spreading losses) were utilized by crops. The second level assumed only 50% utilization. (This assumption was based upon the premise that different crops, e.g. pasture, have different nutrient utilization rates.)

The environmental evaluation included an assessment of each system with regard to controlling water pollution (i.e. quantity and quality of runoff) and odor nuisance. A "pollution scale" of 1 - no pollution to 5 - severe pollution was used to evaluate the systems on each of these three environmental categories. The primary thrust of this report was the determination of economical pollution control technologies for livestock producers of 1000 animal units or less.

White and Forster modeled each of the various dairy waste handling systems according to: (1) feasible herd size (50 to 500 cows); (2) housing system; (3) collection method (including runoff control); (4) storage method; (5) disposal method; and (6) livestock production region(s). Not all potential combinations of these variables were deemed feasible (or typical), and thus some possible combinations were excluded.

The size of storage capacity for those systems utilizing storage structures was restricted to 6-months; no variation in storage capacity was examined. Modeling of the feasible combinations of system components resulted in a total of 59 specific dairy waste management systems enumerated and analyzed.

White and Forster concluded that, although it was not possible to declare any one system as "best" for all circumstances (indeed, some systems were incompatible with certain dairy enterprise variables), storage was generally costly. Trading labor for capital investment was generally found to be cost-increasing. However, if storage was used, plow down or incorporation became "a way of easing the extra cost burden." The authors also note that labor savings due to storage (or other capital investments) will offset a significant amount of the associated increased costs (especially if labor is expensive).

Moore and Wilrich (46) performed a comprehensive economic engineering analysis of six distinct dairy waste management systems common to Oregon. A cost/benefit analysis was employed in comparing each of the alternative waste systems for three sizes of dairy farms. The milking herd sizes were 100, 200, and 300 cows. The assumption was

made that the manure production of all dairy animals located on the farm would be collected into the waste system. Included with every 100 cow herd increment were: (1) 16 dry cows; (2) 37 replacement calves; (3) 37 replacement heifers; and (4) one cleanup bull.

The dairy waste management systems considered by Moore and Wilrich included: (1) dry stack; (2) earthen storage; (3) daily spread; (4) above-ground tank; (5) lagoon flush; and (6) lagoon flush with separator (liquids-solids). Alternative systems were modeled to incorporate 150-days storage capacity. Daily spreading (essentially no storage) and the lagoon systems (12-months capacity) were exceptions.

Moore and Wilrich compared the alternative dairy waste systems at each herd size with regard to initial cost (investment) and net annual cost. The total cost of tractors used for spreading and/or agitation were included in initial costs even though the "% of time devoted to manure handling" was assumed to be only 10% and 20% respectively. Annual system costs included: (1) capital recovery (a substitute for depreciation and interest on capital); (2) repair, taxes, and insurance costs; (3) energy costs (fuel and electricity); (4) labor costs; and (5) bedding costs. The lagoon flush-separator system alone was able to incur negative bedding costs; the solids were assumed to be reused as bedding.

The calculated annual costs for each waste system were offset by the respective value of the manure retained and applied. This "manure value" was calculated as the annual value of nitrogen (N), phosphorus (P), and potassium (K) in the manure after accounting for losses that occur during collection, storage, and after application i.e. before

crop uptake. Assumptions were made in regard to these nutrient loss rates - - during storage and after application - - for each waste management alternative. Net annual system cost was calculated by subtracting the specific manure value from the total annual costs of the particular waste system.

Moore and Wilrich observed that, for all herd sizes, the typical ranking of analyzed systems according to initial costs (lowest to highest) was as follows: (1) earthen storage; (2) lagoon flush; (3) daily spread; (4) lagoon flush-separator; (5) covered dry stack; and (6) aboveground storage tank. Daily spread and lagoon flush systems were not very different with respect to initial costs; in fact, their rankings reversed for the 100 milking cow herd.

Ranking of dairy waste systems according to net annual costs resulted in similar findings. The analyzed systems ranked (lowest to highest) as follows: (1) earthen storage; (2) daily spread; (3) lagoon flush; (4) dry stack; (5) lagoon flush-separator; and (6) aboveground storage tank. The lagoon flush-separator system and aboveground tank system switched rank positions for the 100 milking cow herd. As a general rule, waste systems did not net a negative cost (positive return), rather, dairy waste was a costly by-product for the dairy enterprise. Exceptions were earthen storage systems for 200 and 300 cow milking herds and the daily spread system for the 300 cow herd. Only these systems netted negative annual costs (positive returns).

In a Canadian study, Ogilvie et al. (49) utilized a mathematical programming technique known as Network Analysis in determining the least cost dairy waste management system. A FORTRAN-based computer

algorithm called Shortest Path Network Analysis (SPNA) was employed to reduce the otherwise significant computational cost and time. One of several reasons given for the selection of SPNA over alternative programming techniques was the direct input of nonlinear functions i.e. linear approximation was not necessary. However, it was acknowledged that the algorithm could not cope with the probability distributions often associated with some of the inherent variables.

Ogilvie et al. included in their analysis various housing systems, herd sizes, types and lengths of storage, and sizes of "field spreading unit." Tiestall (stanchion) and freestall arrangements were the housing systems included. Herd sizes examined for the stanchion and freestall housing systems ranged from 40-80 and 60-200 milking cows respectively. No value for the fertilizer value of manure was used.

Four distinct "stages" or phases of the manure management network were enumerated. These stages included: (1) collection; (2) transfer to storage; (3) storage; and (4) transfer to land. Over 100 distinct elements were included in the complete dairy manure handling network for SPNA. The SPNA algorithm listed and calculated the total yearly cost of each feasible pathway (for a given housing system and herd size) through the network. Through examination of the enumerated annual costs for the alternative systems, sensitivity to variations in housing system, herd size, storage capacity, and spreader size were analyzed.

Ogilvie et al. observed that the greatest effect on relative capital cost per head is that of "scale or herd size." Certain waste systems enjoyed greater economies of herd size than others however.

For example, Ogilvie et al. noted that "higher fixed costs for the liquid system . . . make total (annual per head) costs less favorable at larger herd sizes" compared to the status enjoyed at smaller herd sizes.

Differences between the alternative systems (for specific housing arrangements) were also found to be significant. In tie stall housing arrangements, the difference in annual per head total costs between solid and liquid systems were quite large. Liquid systems were 30% more costly than solid systems at a herd size of 40 cows. This difference or gap decreased as herd size increased.

Increase in storage capacity was found to increase annual per head total cost for all systems. However, for an example 60 cow herd, the increase in costs was more marked for selected liquid and semi-solid waste systems than for a solid system.

Olgivie et al. analyzed the effect of increased manure spreader size upon variable and total costs of a semi-solid waste system as herd size increased. Annual per head variable costs of the system decreased for all spreader sizes (130 $ft.^3$, 225 $ft.^3$, and 320 $ft.^3$) as herd size increased to 100 cows. However, as herd size increased further, the smaller spreader sizes effected an increase in annual per head variable costs while a slight decrease was associated with the largest spreader size. Total annual per head costs of the waste system was ever-decreas-ing with all spreader sizes as herd size increased. However, the larger spreader sizes effected a greater decline in annual per head costs. Ogilvie et al. attributed the differences in costs between spreader sizes "to a trade-off of the lower variable cost for

the larger spreader due to reduced traveling time, versus longer average hauling distance for the larger herd sizes." They note that the "overall lower variable cost of the larger spreader may justify its purchase even at smaller herd sizes."

Similar research was reported by Safley et al. (57) in 1976. In their study, "eleven freestall (dairy) waste handling systems were defined and compared on the basis of a given set of input parameters." Network analysis was employed to analyze the eleven systems, on the basis of both initial construction cost and yearly operating cost, for each of two herd sizes and two storage capacities. Milking herd sizes of 50 and 100 cows were included. One-half year and one year storage capacities were also examined for those systems utilizing storage.

A list of almost 350 "manure handling variables" was developed for the definition and analysis of the alternative waste systems. These variables included: (1) costs of machinery; (2) costs of construction; (3) costs of farm labor; (4) depreciation of structures and machinery; (5) time required to perform similar tasks in different systems; (6) quantities of manure produced by different systems; and (7) expected life of machinery and structures.

Each modeled alternative system was described in terms of component stages of manure management. Five possible stages were defined: (1) collection of manure; (2) manure treatment and untreated storage; (3) treated storage; (4) removal from storage; and (5) transporting from storage to land. The possible pathways between the various systems' stages were enumerated and cost estimations assigned. A computer program was written to facilitate the calculation of the

cost of the various waste systems. All possible cost paths through the network were listed to aid in comparison of the alternative systems.

With regard to initial investment, daily hauling was the least cost system for both herd sizes. Daily hauling required approximately 60%, 52%, 61%, and 50% of the investment necessary for next least cost systems for 50 cow-one-half year storage, 50 cow-one year storage, 100 cow-one-half year storage, and 100 cow-one year storage respectively. The figures changed to 15%, 13%, 16%, and 14% respectively when daily haul was compared to the most costly systems.

The daily haul waste system was found to be the least cost system with respect to yearly operation costs in all instances except for 50 cow-one-half year storage, where it ranked second. The ranking of the other alternative waste systems varied somewhat as herd size and storage capacity changed.

Safley et al. stated, "cost alone is insufficient to determine which manure handling system is most suitable" for a particular dairy farm. Other factors proposed as important were aesthetics, odor control, and personal preference. Some of the more costly systems are better able to control odor and "provide a considerable amount of flexibility to the operator." The authors propose that, since each manure handling system has different properties, the enumeration of all system costs is essential to the individual dairy farm manager in his selection process.

CHAPTER II

METHODOLOGY AND PROCEDURES

Typical dairy waste management systems (those utilizing land application) can be delineated into five basic subsystems or processes: (1) collection: (2) transport to storage; (3) storage; (4) transport to land; and (5) soil incorporation. A comprehensive, though not necessarily exhaustive schematic of potential combinations of subsystems is presented in Figure II-1. Possible combinations are restricted to the more common waste systems used in conjunction with freestall housing systems.

This study was primarily concerned with the description and economic analysis of the various combinations of dairy waste handling subsystems most typically observed on Tennessee dairy farms. The analytical approach used was cost/return analysis. Economic engineering was the technique employed in the development of the analysis.

The use of economic engineering in modeling dairy waste management systems necessitated the requirement for technical data as well as economic data. Required technical data included: (1) the amount of manure/waste to be collected, stored, and disposed of; (2) labor and energy coefficients for each task in the subsystem or process; (3) nutrient loss rates during storage and after land application; and (4) mineralization rates for the manurial nutrients after soil incorporation. Reliable estimates for costs (initial, fixed, and variable) and revenues (value of manurial nutrients) were likewise essential.

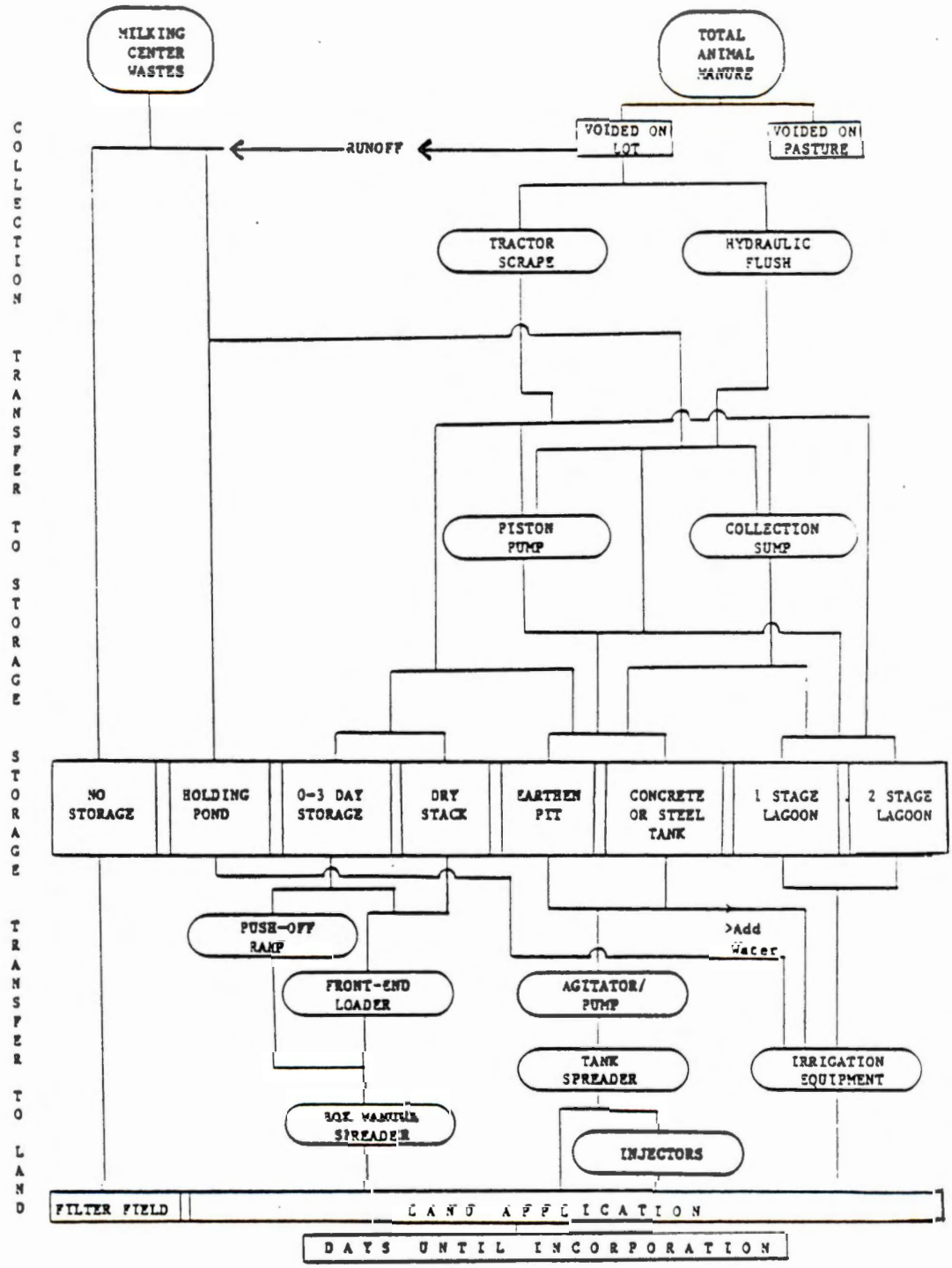


Figure II-1. Network of Potential Combinations of Dairy Waste Management Subsystems. (Each "Path" Through the Network Represents a Specific Waste Management System.)

Satisfaction of these data requirements allowed the use of economic engineering techniques in constructing detailed budgets for the various technical and economic parameters of the selected systems.

Data on the studied dairy waste management systems were available from various sources. The sources utilized in the selection, description, and economic comparison of the waste systems analyzed in this study included: (1) farm surveys and interviews; (2) experimental research results; and (3) professionals knowledgeable in the various aspects of dairy waste management systems.

The first source was useful in the process of selecting the waste systems, herd sizes, and confinement systems to include in this study. The other data sources were vital in obtaining the needed technical and economic information.

Systems Selection Process

There are almost innumerable possible combinations of the subsystems which make up dairy waste management systems (see Figure II-1). Each combination would result in a uniquely-defined waste system.

This study was concerned only with those subsystem combinations (systems) most commonly observed on Tennessee dairy farms. Whipple's (72) comprehensive survey of Tennessee Grade A dairy farms was used as the basis for selecting the "typical" dairy waste systems. The general categories of dairy waste management systems identified to be most common were: (1) daily haul; (2) dry stack[1]; (3) earthen pit; (4) above-ground tank (concrete or steel); and (5) anaerobic lagoon.

[1]The survey did not explicitly allow a respondent to list his dry

On-farm interviews were then conducted in selected Tennessee counties to gain further information such as cost data and management details for the chosen systems. Soil Conservation Service (SCS) personnel in the selected counties were interviewed to determine the most prevalent systems in their respective areas (as a check against the survey results) and to obtain a list of dairy farmers utilizing these systems. Since Tennessee's dairy industry is predominantly concentrated in East Tennessee, the counties selected were East Tennessee counties reporting large numbers of dairy farms (70). Furthermore, Whipple's (72) survey results indicate that the waste systems utilized on East Tennessee dairy farms also predominated throughout the State.

Housing System Selection

Whipple's survey results indicated an overwhelming predominance of freestall housing over other housing systems. Therefore, only the freestall housing system was incorporated into this study.

Waste Systems Selection

Selection of seven distinct dairy waste management systems resulted from the dairy farm survey and the various interviews. The systems selected were as follows: (1) daily haul; (2) dry stack; (3) earthen pit; (4) steel above-ground tank; (5) concrete above-ground tank; (6) single stage lagoon; and (7) two stage lagoon.

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stack facility. After interviews with SCS personnel, it was assumed that a significant proportion of those respondents reporting a front-end loader and manure spreader (assumed to represent a daily haul system) were also utilizing a dry stack storage facility.

To test for possible economies of storage size, the dry stack, earthen pit, and both above-ground tank systems were examined at 3-months and 6-months storage capacity. The 3-months storage size was thought to be a minimum requirement, assuming that winter spreading of dairy waste is undesirable. Six-months storage capacity allows for completion of a cropping season between spreadings (spring and fall). It is generally assumed that enhanced utilization of manurial nutrients results from storage, offsetting part or all of the added costs incurred due to the increased storage size (59). Since, by definition, the daily haul system has insignificant storage capacity, no variation in storage facility size was included for this system.

Additionally, it was assumed that 6-months storage capacity was inherently associated with typical lagoon systems i.e. storage capacity was not varied for these systems. However, two different collection methods were defined and compared for the lagoon systems. The collection methods were defined as standard (tractor and scrape) and flush (hydraulic or water flush) subsystems. This inclusion came about primarily because of the farm survey results (72). Of the 68 respondents reporting anaerobic lagoon waste systems, less than one-fourth of this number reported flush collection subsystems. It was assumed that the standard collection method, using a tractor and scrape, was the primary alternative to flush collection.

Herd Sizes Selected

Each identified waste system was synthesized on milking herd sizes of 80, 160, and 320 cows to test for possible economies accruing to herd size. The survey data indicated that the 80 cow herd was

representative of a majority of Tennessee Grade A dairies (over 50% of the respondents reported dairy herds of 51-120 cows)(72). Likewise, the 160 cow herd size represented a significant number of Tennessee dairy farms (over 11% of the survey respondents reported dairy herds of 121-200 cows)(72). The 320 cow herd size, admittedly atypical of Tennessee dairy farms, was included primarily to determine if the relative ranking of the studied waste systems remained stable at very large herd sizes. National trends toward larger dairy herds and the assumption that smaller dairy farms would find it difficult (financially) to install a waste system other than daily haul led to the exclusion of smaller herd sizes.

Confinement Systems Selected

Since the degree of confinement (time spent on paved lot areas) directly affects the amount of dairy manure collected, variations in confinement methods were incorporated into the analysis. Two alternative confinement methods were defined as (1) partial confinement and (2) total confinement. Essentially, partial confinement consists of housing/feeding the milking herd on paved lots only during inclement weather (e.g.. winter periods) and allowing the herd to roam/graze pasture the remaining time. Conversely, total confinement was defined to consist of housing/feeding the milking herd on paved lots 90% or more of the time year round, with only short periods of access to unpaved exercise or pasture areas. The assumed percent of herd time spent on lots for both partial and confinement systems, as well as variation by 2-month periods, is shown in Appendix A, Table A-2.

Systems Modeling Process

Seventy-eight distinct dairy waste management systems resulted from incorporating three herd sizes, two confinement systems, and seven waste handling systems (with associated variations in storage capacity and collection method) into the analysis. Enumeration and code designation of system variables are found in Table II-1.

Economic engineering of each specific system was accomplished through development of budgets for the various technical and economic aspects of dairy waste management systems. Basically, the purely technical budgets outlined the physical changes that occur as the dairy waste moves through the respective collection, storage, and disposal sub-processes of each waste management system. Technical budgets included: (1) Collection Budgets and (2) Storage and Application Budgets.

Budgets were also developed that included both technical and economic data. Essentially, the economic data involved valuation of the synthesized technical data. These budgets were titled as follows: (1) Annual Labor and Energy Cost Budgets and (2) Nutrient Mineralization and Annual Valuation Budgets.

"Purely economic" budgets were developed as well. Data for these budgets came from the budgets discussed above and other synthesized economic data. Economic budgets included: (1) Initial Investment Budgets; (2) Capital Recovery and Insurance/Repairs/Housing Costs Budgets; and (3) Net Annual Cost Budgets.

Basically, the technical and economic budgets were developed in a "pyramid structure", each budget(s) providing data for the next level of

TABLE II-1. Dairy Herd Sizes, Confinement Systems, Waste Handling Systems and Code Designation for These Variables Used in Synthesizing the Analyzed Dairy Waste Management Systems.

Variable	Code[1]
Dairy Herd Size	
80 Cows	80/
160 Cows	160/
320 Cows	320/
Confinement System	
Partial Confinement	PC/
Total Confinement	TC/
Waste Handling System	
Daily Haul	DH
Dry Stack/3-month Storage	DS/3
Dry Stack/6-month Storage	DS/6
Earthen Pit/3-month Storage	EP/3
Earthen Pit/6-month Storage	EP/6
Steel Above-ground tank/3-month Storage	SAGT/3
Steel Above-ground Tank/6-month Storage	SAGT/6
Concrete Above-ground Tank/3-month Storage	CAGT/3
Concrete Above-ground Tank/6-month Storage	CAGT/6
Single Stage Lagoon/Standard Collection	SSL/SC
Single Stage Lagoon/Flush Collection	SSL/FC
Two Stage Lagoon/Standard Collection	TSL/SC
Two Stage Lagoon/Flush Collection	TSL/FC

[1]Codes are used in combination to identify specific dairy waste management systems. For example, the 320 cow, partial confinement, earthen pit/3-month storage system is identified as 320/PC/EP/3.

budgets, culminating in the Net Annual Cost Budgets. Net annual cost, as well as initial investment, were primary sources of comparison between alternative waste management systems. A more detailed discussion of the various budgets follows.

Collection Budgets

The primary purpose of the collection budgets was to determine the annual quantity and nutrient content of dairy waste (including precipitation) collected with each specific waste system. Annual waste production was modeled in 6, 2-month periods: (1) January-February; (2) March-April; (3) May-June; (4) July-August; (5) September-October; (6) November-December. Seasonal variations in degree of herd confinement (percent of time spent on paved lots) and rainfall/evapotranspiration were primarily responsible for the seasonal differences in quantity of wastes.

Parameters inherent in the development of the collection budgets are discussed below. A complete presentation of example collection budgets is given in Appendix B.

Total manure collectible. This was defined as the total amount of manure produced by the specified herd size over the specified two month (59-61 days) period. Another definition would be the quantity of manure expected to be collected if the milking herd was 100% confined.[2] Appendix A, Table A-1 gives typical daily manure production and composition for various sizes of dairy cows. Since Holsteins are the

[2]Total manure collectible was calculated as follows: daily manure production (Appendix A, Table A-1) x herd size x days in specified two month budget period. Quantities of manurial nutrients collected were likewise computed.

predominant dairy breed in the U.S. (2), dairy cows were assumed to be Holsteins with an average weight of 1400 lbs.

Total manure collected. It was assumed that manure was produced linearly over each day (24-hour period). Therefore, the total manure collected for each budget period was calculated by multiplying the total manure collectible times the respective percent of herd time spent on paved lots (%TOL). The %TOL varied seasonally according to confinement system employed (see Appendix A, Table A-2). Nutrient composition was assumed to be similar to that of "collectible" manure.

Bedding and feed waste. Certain assumptions were made regarding the quantity of bedding and feed waste entering the waste system. These assumptions were based upon data from Bath et. al. (2), Gilbertson et. al. (18), and Moore (46). The quantity of bedding and feed wastes collected was assumed to be a function of the %TOL.[3]

Rainfall collected. Total rainfall (precipitation) in a given budget period was multiplied by lot size[4] to determine the quantity of water potentially collected.[5] Total rainfall for each budget period was calculated as the mean of precipitation totals given by Tennessee

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[3]The assumed relationships between bedding and feed wastes collected and %TOL were as follows: 8, 7, 6, 5, and 2 lbs/cow/day for 95, 90, 80, 65, and 45 %TOL respectively.

[4]Lot sizes for the 80 and 160 cow herds were synthesized at a prescribed 100 $ft.^2$/cow. Since increased density housing is normally implemented at larger herd sizes, 75 $ft.^2$/cow was used for 320 cow herds. Therefore, lot sizes for the 80, 160, and 320 cow herds were 8,000, 16,000, and 24,000 $ft.^2$ respectively (26).

[5]Only rainfall directly reaching the housing lot was included. Freestall barns, dairy parlors, and other buildings connecting the lot were assumed to be guttered and the rainfall diverted away from the housing lot i.e. not collected into the waste system.

stations reporting climatic data (16, 17, 66, 66). Appendix A, Table A-4 gives the mean monthly rainfall (precipitation) measures calculated. The so-called "dry" systems (daily haul and dry stack) attempted to divert as much of this lot rainfall as possible. Liquid (lagoon) and slurry (earthen pit and above-ground tank) systems were designed to collect all of the lot rainfall (runoff).

Parlor wastes. The quantity and constituents of dairy parlor wastes were estimated for each herd size. Estimates were based on data from Bath et. al. (2), Bland et. al. (5), Loehr (39), Matulich et. al. (41), Midwest Plan Service (42), and Zall (75). Appendix A, Table A-3 lists quantities and constituents of parlor wastes for each herd size.

Runoff losses. For daily haul and dry stack systems, rainfall was assumed to leave the housing lot as runoff. (Liquid and slurry systems collected all potential runoff.) The percentage of total rainfall lost as runoff was determined to be inversely proportional to %TOL.[6]

Runoff physically removes a portion of dairy wastes from the lot surface. The literature (12, 18, 42, 44) suggests that runoff may contain up to 3.5% total solids by weight. To better approximate real scenarios, total solids (manure, bedding, and feed wastes) removed by runoff were assumed to be linearly related to %TOL.[7] Resident in the solids removed by runoff are economically valuable nutrients. Due to

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[6]One hundred %TOL was assumed to result in 80% runoff whereas 45 %TOL resulted in 95% runoff. A linear inverse relationship exists between these extremes. (Increases in %TOL results in greater quantities of waste which in turn absorbs larger quantities of rainfall effectively reducing runoff.)

[7]Total solids removed were calculated as total runoff (lbs) x .0035 x %TOL.

different degrees of water solubility, runoff nutrients exist in different concentrations (relative to total solids content) than do manurial nutrients.

Evaporation losses. Moisture content of dairy wastes collected from housing/feeding lots was assumed to be reduced through evaporation. Total moisture lost was a function of the evapotranspiration rate, lot size, and amount of waste on the lot (a function of %TOL).[8] Evapotranspiration rates were calculated for each budget period as the mean of evapotranspiration totals given by Tennessee stations reporting climatic data (16, 17, 62, 66). Appendix A, Table A-4 provides the monthly evapotranspiration rates calculated.

Water added. Since above-ground tank waste systems were assumed to utilize collection sumps in pumping dairy wastes into the storage facility, water had to be added to raise the collected wastes to a pumpable consistency (moisture content). The literature (58, 61) and commercial dealers suggested that dairy wastes be at least 90% moisture before pumping from collection sump to storage facility.

Total wastes collected. Summation of previously discussed waste collection budget parameters resulted in "Total Wastes Collected" for each 2-month period. Moisture content (%) and nutrient content (lbs. of N, P, and K) were calculated in addition to the volume and weight of dairy wasted collected per period with each system. These totals were vital in the preparation of the Storage and Application Budgets.

[8] Interviews with SCS personnel and agricultural engineers resulted in the following approximation of evaporation losses (EL) per budget period (p): EL_p (water) = .7 x evapotranspiration $rate_p$ (due to incomplete covering of the lot) x lot size x %TOL.

Storage and Application Budgets

Budgets were developed to model certain physical changes that occur to dairy wastes after the collection process (i.e. during storage and after land application). Primarily, the physical changes modeled were those specific to each waste management system affecting the volume of dairy wastes handled and the fertilizer nutrient content of these wastes.

Parameters inherent in the development of Storage and Application Budgets are defined and discussed below. Examples of complete Storage and Application Budgets are presented in Appendix C.

Total wastes collected. These values were obtained from the namesake parameters calculated in the previously described Collection Budgets. For systems utilizing storage, values for this parameter were summed over budget periods up to the specified time of land application (i.e. summation totals were given only in budget periods during which land application occurred).[9] Since daily haul systems had little inherent storage capability, land application occurred throughout each budget period. Therefore summation across budget periods was not necessary for this system.

Storage nutrient loss. Ranges in the rates of nutrient (N, P, and K) loss during storage for the various dairy waste systems were obtained from several secondary data sources (4, 25, 35, 45 , 59). Appendix A, Table A-5 provides the ranges in nutrient loss rates for the systems included in this study. Using midpoint values for these loss rate

[9]This summation process was implemented because a significant portion of the physical changes modeled by this specific budget occurred only in the budget periods during which waste was applied to land.

ranges, N, P, and K losses (prior to land application) were calculated for each specific system during each storage period.

Rainfall on storage facility. Rainfall on unroofed waste storage facilities can add significantly to the volume of wastes handled. Costs of waste disposal likewise may rise significantly. For this reason, net rainfall (precipitation)[10] on the storage facility was calculated for each waste management system utilizing unroofed storage. As with previous parameters for the Storage and Application Budgets, net rainfall on storage facilities was summed over budget periods up to the period during which land application occurred.

Water added. This parameter represented the additional water required to facilitate pumping (removal) or treatment of wastes in slurry (earthen pit and above-ground tanks) or liquid (lagoon) systems. For example, it was assumed that dairy wastes in earthen pit storage must be at least 89% moisture to facilitate agitation/pumping (58, 61). Likewise, it was assumed that the various lagoon systems required a minimum dilution volume to operate properly (32, 42).

Total wastes applied. Summation of the four parameters defined above provided total dairy wastes (and associated fertilizer nutrients) applied to cropland.[11]

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[10] Net rainfall was calculated as precipitation minus potential evapotranspiration. The necessary climatic data is presented in Appendix A, Table A-4.

[11] NH_4-N was calculated for each system at this juncture because the quantity of retained NH_4-N was required for developing the Nutrient Mineralization and Valuation Budgets. NH_4-N was calculated as 55.6%, 50%, and 62.5% of total N for solid (daily haul and dry stack), slurry, and liquid systems respectively (67).

Nitrogen loss (irrigation). Ten to 30% of total nitrogen applied via irrigation (lagoon systems) can be lost to the air through ammonia volatilization (as the wastes are sprinkled) (35). A midpoint value of 20% was selected for use in calculating this parameter.

Volatilization loss. The quantity of N volatilized after land application and before soil incorporation of dairy wastes was calculated. Volatilization rates were assumed to be a function of soil temperature/moisture and length of time between application and incorporation (12). Soil incorporation of dairy wastes was assumed to occur no later than four days after land application. Exceptions were systems in which dairy wastes were applied to pasture i.e. no incorporation. Examples are daily haul and summer spread wastes from a system utilizing 3-month storage. Soil temperature/moisture was assumed to be warm/moist in all instances except for wastes applied in the budget period Jan.-Feb., in which case it was assumed to be cool/moist. Appendix A, Table A-6 provides general estimates of volatilization loss rates for various soil temperature/moisture situations.

Runoff losses. Manurial fertilizer nutrients may be lost via field runoff after land application if the applied wastes are not incorporated into the soil. The quantities of manurial nutrients lost by field runoff is a function of numerous variables including total rainfall, rainfall intensity, field topography, and rate of waste application. It was assumed that significant runoff losses of nutrients occurred only in those budget periods during which wastes were applied to pasture or otherwise were not incorporated within four days after land application. Assumed rates of (field) runoff nutrient

losses were based upon data from Hensler (23, 24) and Quisenberry (52).[12]

Total nutrients in-soil. Summation of the Storage and Application Budget parameters created a parameter termed "Total Nutrients In-soil." These values represented the quantities of manurial nutrients, placed in (on) the soil, that are potentially available for growing crops.

Nutrient Mineralization and Valuation Budgets

Dairy waste nutrients incorporated into the soil are not 100% available to crops during the first year after land application. Rather, waste nutrients must be mineralized into inorganic forms which are available for crop uptake. This mineralization occurs over several years (25, 29, 36, 45, 51, 69).

Budgets were developed to model the mineralization process and determine an annual value of the nutrients applied with each waste management system. Only those nutrients that become available during the first four years after land application were modeled. The value of nutrients mineralized after this period were assumed to offset leaching and other losses that may occur after soil incorporation of wastes.

Annual values of each nutrient (N, P, or K) for each waste management system was derived by: (1) determining the annual quantity of nutrient "in-soil" (from the Storage and Application Budgets); (2)

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[12]For simplicity, it was assumed that 10%, 16%, and 30% of applied N, P, and K respectively were lost via field runoff if applied during winter budget periods (Jan.-Feb.). Runoff rates for all other times were 3%, 7.5%, and 15% (dry systems); 4%, 10%, and 20% (slurry and liquid systems) for N, P, and K respectively (23, 24, 52). NH_4-N runoff losses were assumed to be 55% (dry systems) and 45% (slurry and liquid systems) of total N runoff losses (adapted from 40, 52, and 74).

multiplying this sum by the appropriate mineralization rates[13]; (3) applying the specific elemental nutrient prices[14] to these mineralized values; (4) discounting these values to determine the present value of nutrient quantities mineralized each year[15]; and (5) summing these discounted values. Total annual value of dairy waste could then be determined for each waste system by summing the annual values of N, P, and K for the specific system.

A mathematical representation of system-specific annual returns accruing to applied dairy waste is as follows:

$$(NH_4\text{-}N \times .28) + \sum M_i R_y P_i D_y$$

where M_i equals quantities of manurial nutrient in-soil (i= N[16], P, K)

R_y indicates the mineralization rate in year y (y = 1-4)

P_i equals price of nutrient i

D_y indicates the discount factor for year y.

An annual value for sludge removed from TSL systems was calculated. Based on literature data (22, 32, 47, 63), it was assumed that sludge removal occurred at five year intervals over the life of

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[13]For Nitrogen, NH_4-N was assumed to be available for crops the first year after soil incorporation. However, organic N (total N less NH_4-N) for dry and liquid systems was mineralized with 25%, 12.5%, 6.25% and 3.125% of the applied organic N becoming available in years 1, 2, 3, and 4, respectively. The organic N mineralization rate for slurry systems was 30%, 15%, 7.5%, and 3.75% (66). Mineralization rates for P and K (all systems) were 75%, 10%, 5%, 1% and 80%, 8%, 5%, 1% respectively.

[14]Prices for elemental nutrients (N, P, and K) were determined from commercial fertilizer prices obtained through local fertilizer dealers. Prices used for N, P, and K were $.28, $.70, and $.18 respectively.

[15]Since annual valuation of nutrients does not include an inflation factor, an estimated long term real interest rate of 3% was utilized for discounting (6, 8, 53).

[16]N equals total N less NH_4-N (i.e. quantity of organic N applied).

the system (20 years). It was assumed that recoverable nutrients in sludge accumulated at rates of 10%, 40%, and 25% of the annually collected N, P, and K respectively. However, only 75% of these collected nutrients were recovered in the first sludge removal. For all other sludge removals (years 10, 15, and 20) this recovery rate increased to 90%.

Nutrients in sludge were valued similarly to manurial nutrients applied annually. The present value of nutrients in the year of sludge removal was calculated similarly to the annual manurial returns described above.[17] Present values of sludge nutrients calculated for each sludge removal were discounted to year one (using three percent as the discount rate) and summed. These "cumulative" present values were annualized over the life of the system (20 years) using three percent amortization rates to arrive at an "annual" value of sludge nutrients applied. Addition of annual sludge value to the annual value of dairy wastes irrigated each year resulted in total annual returns to the specific TSL system.

A complete presentation of example Nutrient Mineralization and Valuation Budgets can be found in Appendix D.

Annual Labor and Energy Costs Budgets

Labor and energy requirements for each dairy waste management system were synthesized for each budget period. Associated costs were also calculated and summed by budget period. Budget period totals were

[17] Lagoon sludge was assumed to contain 35% of total N as NH_4-N; the mineralization rates were 35%, 10%, 5%, and 1% (29, 36, 54). Mineralization rates for P and K were the same as for annually applied wastes.

summed to determine annual labor and energy costs incurred with each waste management system.

Oftentimes, required data obtained from the literature was not in the exact form necessary. In these instances special equations and other adaptive methods were developed and implemented to better take into account the peculiarities of the studied systems. Annual Labor and Energy Costs Budgets are particularly good examples of this. For the sake of brevity, only the significant adaptations are noted.

Brief descriptions of inherent "task parameters" are presented below. Since not all waste systems required the same set of task parameters (indeed, task parameters similarly titled may vary in technical description by system), delineation is made with regard to association of task parameters to specific waste management systems.

Any individual task parameter may be described by one or more of the following aspects: (1) labor hours and cost; (2) tractor/equipment hours and fuel/lubrication cost; (3) electricity kwh's and cost. Labor was valued at a rate of $5.00 per hour. Fuel and lubrication costs (FLC) were calculated by the following equation (adapted from 6, 46, and 55):

$$FLC = \frac{HP \times LF}{K} \times [\$F \times (1 + LC\%)] \times HU$$

where HP equals the horsepower rating of the tractor used in the task

LF equals the load factor (65%, 70%, or 75% if HP is <80, >=80<100, or >=100 respectively)

K equals a constant for engine type (13.2 for diesel)[18]

[18]All tractors were assumed to have diesel engines.

$F equals fuel price (net of tax rebate)/gallon ($1.00 gallon is assumed)

LC indicates the lubrication cost factor as a percentage (10%, 8%, or 6% if HP is <80, >=80<100, or >=100 respectively)

HU equals the hours of use incurred due to the task performed.

Kilowatt hours used in those tasks requiring electrical energy were estimated based on technical data by Van Arsdall (70) and Frank (15). Electricity was valued at $.05/kwh. A presentation of example Annual Labor and Energy Cost Budgets is given in Appendix E.

Although not universal, it was generally assumed that technical efficiency increased with larger herds due to use of larger tractors and equipment. As a result, many "task coefficients" used to approximate labor and tractor/equipment requirements of the task parameters varied according to herd size.

Daily clean. Labor[19] and tractor/equipment[20] hours necessary to facilitate "daily cleaning" of housing/feeding lots associated with each system were synthesized for each budget period. Associated costs were also tabulated. With the exception of systems utilizing flush collection methods (SSL/FC AND TSL/FC systems), daily cleaning was assumed to be accomplished with a 37 hp tractor and box scrape. Sys-

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[19]Labor hours required (per budget period) were estimated as: (.38 x #days in budget period) + (.0026 x ft.^{3} of lot waste collected) (adapted from 12, 30, 43, and 46).

[20]Twenty-five percent of the fixed daily labor requirement (.38 hr.) was subtracted from the labor equation to arrive at tractor/-equipment hours required.

tems utilizing flush collection methods used a recycle pump and flush tanks instead.[21]

Agitation/transfer. Dairy waste management systems utilizing a SAGT or CAGT storage component were assumed to require a collection sump. Wastes were collected, agitated (after sufficient water was added), and transferred (pumped) to storage. Labor and energy (electricity for agitation/transfer pump) were required for this task.

Estimations were made for agitation time (AT) and transfer time (TT)[22] required each budget period. It was assumed that agitation of the sump would be on-going as the lot was scraped. Therefore, required labor was essentially limited to TT. Tractor/equipment (agitation/-transfer pump) hours were estimated to be: AT + TT.

Loading. Labor and tractor/equipment hours required to load collected dairy waste onto a box manure spreader was synthesized for each DH[23] and DS[24] system. Associated labor and fuel/lubrication

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[21]Labor was calculated as (.0833 hr./2 flush tanks x 2) x #days in budget period. (Lots are flushed 2x/day if %TOL is more than 45, 1x/day otherwise.) A 1/2 hp recycle pump was utilized; it used .7 kwh/hr.

[22]AT was calculated as: (gallons of wastes collected / (gpm rating of pump / 60)) x 8 (a constant). TT was approximated as: (gallons of wastes collected / gpm rating of pump) / 60.

[23]Labor hours for DH systems (all herd sizes) were calculated for each budget period (BP) as: (.25 x 1000 ft.^{3} of wastes collected) + (.1 x %TOL x #days in the BP). Required tractor/equipment hours for each BP were determined by subtracting a "dead time" variable from associated labor hours. This dead time was assumed to vary according to herd size and degree of confinement (adapted from 2, 12, 26, 30, 46, and 73).

[24]Land application of stored wastes only occurred in those BP's indicated by the associated Storage and Application Budget. Labor hours were calculated as: 1.5 + (.25 x 1000 ft.^{3} of wastes stored). Tractor/equipment hours were figured by subtracting a dead time (DT) constant from synthesized labor hours. DT was calculated by the equation : 1.5 x .333 = .5 hours (adapted from 12, 26, 46, and 73).

costs were likewise calculated. It was assumed that the tractor used for daily scraping also possessed a front-end loader.

Agitation/loading. Required labor and tractor/equipment hours for agitation of stored wastes and loading these wastes out of slurry (EP, CAGT, and SAGT) systems were synthesized. Equations based on technical literature (21, 43, 46, 50, 56, 59) were developed to estimate labor[25] and tractor/equipment[26] hours necessary to complete this task. Labor costs and fuel/lubrication costs were calculated in the same manner as described earlier.

It was assumed that constant surveilance (labor) was not required during agitation i.e. agitation could occur unattended for some intermittent periods of time. This "surveilance coefficient" was .75 for EP systems and .5 for CAGT and SAGT systems.

Agitation. Similar to the agitation/loading parameter for slurry systems, labor and tractor/equipment requirements were synthesized for the task of agitating dairy wastes stored in SSL systems. It was assumed that SSL storage facilities were agitated prior to irrigation

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[25]Labor hours for EP systems were approximated by the equation: $1 + [.75(X) \times 1000 \text{ ft.}^3 \text{ of stored wastes}] + .5(AP)$. The agitation coefficient (X) equaled .335, .318, and .302 for 80, 160, and 320 cow herds respectively. The variable (AP) represented the number of additional agitation points required (>1) due to size of facility. Labor hours for CAGT and SAGT systems were calculated similarly: $2 + [(.5)(.8)(X) \times 1000 \text{ ft.}^3 \text{ of stored wastes}]$. Two hours were added for 320 cow herds because two storage structures were involved.

[26]Tractor/equipment hours for EP systems were calculated as: $.5 + [(X) \times 1000 \text{ ft.}^3 \text{ of stored wastes}] + .25(AP)$. For CAGT and SAGT systems the equation used was: $.5 + [.8(X) \times 1000 \text{ ft.}^3 \text{ of stored wastes}]$. One-half hour was also added for herd sizes of 320 cows. The coefficient (X) retained its value used in the labor calculation.

to prevent sludge build-up. Agitation prior to irrigation will also reduce the incidence of irrigation system blockage.

Equations derived to approximate the hours of labor[27] and tractor/equipment requirements[28] were based upon technical literature (21, 43, 50, 59).

Water added. In certain instances, water was added to certain slurry and liquid systems to facilitate agitation/pumping or treatment processes of the stored dairy wastes. Based upon data from Van Arsdall (70) and Frank (15), the energy (and its cost) required to pump necessary volumes of water was calculated.

Hauling. Using Appendix table 9 in Christensen, et. al. (12) as the base source,[29] labor and tractor/equipment hours required in hauling dairy wastes from storage to the point of, and including, land application were synthesized. All of the studied system types except SSL and TSL utilized tractor and spreader (box or tank) as land application method (hauling).

An assumed average field distance of 1000 ft. was used in calculating labor and tractor/equipment hours for systems installed for 80 cow herds. For 160 and 320 cow herds, assumed average field distance was 1500 and 2500 ft. respectively. Using the data from Christensen,

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[27] Labor hours were synthesized according to the derived equation: $2 + [.75(X) \times 1000 \text{ ft.}^3 \text{ of stored wastes}] + .5(AP)$. For SSL systems, (X) equaled .0779, .0623, and .0416 for 80, 160, and 320 cow herds.

[28] Tractor/equipment hours were calculated by the equation: $1 + [(X) \times 1000 \text{ ft.}^3 \text{ of stored wastes}] + .25(AP)$. The agitation coefficient (X) had the same values as in the labor equation.

[29] Interpolation of this data was often necessary to retain consistency with synthesized systems.

et. al. (12), total labor hours for loading/hauling were derived for DH[30] and DS[31] systems. Labor hours for only the hauling task were found by subtracting from this total the respective labor hours used in the loading task (described above).

Required tractor/equipment hours for hauling wastes were calculated for DH systems by subtracting the estimated amount of time that tractors and equipment were idle (dead time or DT) during the hauling task from the associated labor hours required.[32]

Tractor/equipment hours for DS systems were also estimated by subtracting an assumed DT constant from task-specific labor requirements. The constant used in this instance for all herd sizes and confinement systems was one (1) hour.

Christensen et. al. (12) also provided the base source of data in synthesizing the labor and tractor/equipment hours required for hauling (and spreading) of dairy wastes from storage in slurry waste management systems. Since the hauling process did not differ by system, calculation of task labor requirements was similar for all slurry systems (EP, CAGT, and SAGT).[33] Likewise, tractor/equipment hours were approximated

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[30] Labor hours were calculated as: (.31 x %TOL) + [(X) x 1000 ft.^{3} of stored wastes]. In this instance, (X) equaled 2.35, 2.1, and 1.9 for 80, 160, and 320 cow herds.

[31] Labor hours were calculated as: 5 + [(X) x 1000 ft.^{3} of stored wastes]. Here (X) has the same values as defined for DH.

[32] DT was assumed to vary by %TOL and, in some instances, herd size.

[33] Labor hours required during each "hauling period" was estimated as: 2 + [(X) x 1000 ft.^{3} of wastes stored] where (X) equals 1.6, 1.0, and .9 for 80, 160, and 320 cow herds respectively.

using an identical calculation method for all studied slurry waste management systems.[34]

Irrigation. Dairy wastes collected and stored in liquid systems (SSL and TSL) were assumed to be land-applied with irrigation equipment, including a traveling "big gun" sprinkler. Based on data from Midwest Plan Service (42), labor requirements for this task for each liquid system were limited to moving the traveling big gun after each "set".[35]

Since land application of dairy wastes via irrigation is much less labor intensive than alternative methods, tractor/equipment hours required for this task were significantly higher than associated labor requirements. Irrigation pumps used with SSL and TSL systems were assumed to be powered by pto linkage to tractors that varied in hp. rating according to respective herd size.

Assumptions concerning application rates (gpm) for herd size-specific irrigation subsystems, based on data from Midwest Plan Service (42) and Horsefield et. al. (27), resulted in a method of approximating respective tractor/equipment requirements for the irrigation task.[36]

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[34] Tractor/equipment hours required for the hauling process were estimated by the equation: .5 + [(X) x 1000 ft.^{3} of wastes stored] where (X) retained the same values as in the labor calculation.

[35] One "set" was assumed to allow coverage of 10 acres; an average one hour of labor was required per set. Total hours of labor for each irrigation task were calculated as: (total acres covered / 10 x 1.0) + 2. It was assumed that one-half acre inches (13,577 gal.) of liquid wastes were applied per acre.

[36] Tractor/equipment hours were calculated as follows: .5 + [(X) x 1000 ft.^{3} of wastes applied]. (X) equaled .6233, .3562, and .2267 for 80, 160, and 320 cow herds respectively.

Sludge removal. Periodic sludge removal is required for TSL systems (22, 32, 38, 39, 42, 47). For this study, a five year clean-out schedule, as used by Henderson and Bauer (22), was assumed. Since a 20-year life was assumed, sludge removal was required four times during the life of each TSL system (years 5, 10, 15, and 20).

Two primary tasks were associated with sludge removal, agitation and irrigation. Agitation consisted of agitating the first stage lagoon only; sludge build-up in the second stage lagoon was assumed to be minimal. Labor and tractor/equipment hours required for the agitation task, based on data by Smith (63), were synthesized in a similar manner to respective requirements for the agitation tasks associated with SSL systems.[37] Since agitation was an infrequent task (once every five years), tractor-powered agitation units were assumed to be rented. A rental rate of $20 per hour was estimated.[38]

The irrigation task consisted of using waste-type irrigation equipment to apply agitated anaerobic sludge to cropland. Only 75% of the volume of wastes in the first stage lagoon were irrigated to preserve an active anaerobic culture as is recommended (38, 39). Calculation of labor and tractor/equipment requirements were identical to that of the irrigation task parameter for SSL systems.

Costs of completing sludge removal (labor, tractor/equipment, and equipment rental costs) in years 5, 10, 15, 20 of each TSL system's

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[37] Although quite similar, the equations differed in the values used for the (X) coefficient. For sludge removal from TSL waste systems, (X) was valued at .166, .1328, and .0885 for systems associated with 80, 160, and 320 cow herds respectively.

[38] Based on recovery of annual ownership costs over an estimated annual usage rate of 50-60 hours.

operation were discounted to year one using three percent discount factors (long-term real interest rate) (6, 8, 53). Summation of discounted values in each cost category resulted in total present value of sludge removal costs. To obtain an annual evaluation, these cost values were annualized over the life (20 years) of the system using three percent amortization factors. In this way, annualized costs of sludge removal could be added to "real" annual labor and energy costs. Determination of total annual labor and energy costs could then be made.

Initial Investment Budgets

Total initial investment required for installation of modeled dairy waste management systems on various herd sizes utilizing two different types of confinement systems was estimated. Only equipment/-facilities unique to waste handling such as manure spreaders, flush tanks, agitation pumps, and storage structures were included.

Tractors used for agitation, hauling, and irrigation were not included because their proportion of annual use devoted to waste handling is relatively small. However, tractors used for daily scraping and loading tasks were included in initial investment costs because a significant proportion of annual use is devoted to waste handling.

Other items included in calculating initial investment of the various dairy waste management systems were concrete curbing around holding/feeding lots (to prevent runoff onto or off of the lot), additional concrete needed to "link" storage structures to holding/-feeding lots, and fencing around below-grade storage structures (a safety precaution advised by SCS and others) (21, 42, 59, 64, 65).

Costs of the various equipment/facilities were estimated primarily from local and national dealers and manufacturers. Only "new", retail costs were estimated for the purpose of practicality. Certain construction costs, such as excavation of below-grade storage and erection of DS storage facilities, were estimated on a per-unit basis ($ft.^3$ of storage capacity and $ft.^2$ of area covered respectively). Economies of storage size were incorporated into these calculations. Local excavation and construction companies, agricultural engineers (SCS and university), as well as other similar studies (28, 41, 46, 73) provided the basic sources of this data. A complete presentation of Initial Investment Budgets is given in Chapter IV.

Capital Recovery and Insurance/Repairs/Housing Costs Budgets

Capital recovery (a substitute for depreciation and interest on capital) and insurance/repairs/housing costs were estimated for equipment/facilities used with each specific dairy waste management system. Summation of capital recovery for the components of each specific waste system resulted in total capital recovery cost for that system.

Tractors used in agitation, hauling, and irrigation of dairy wastes (items excluded form Initial Investment Budgets) were also included. Based upon a typical annual operating usage of 800 hours (6, 54), a proportionate share of annual capital recovery and insurance/-repairs/housing costs for tractors (used in waste handling tasks) were budgeted to waste handling.[39] All other equipment/facilities

[39]Total annual capital recovery (insurance/repairs/housing) costs calculated times percent of average annual use devoted to waste handling (a system specific variable, derived from labor and energy costs budgets.)

(including irrigation equipment) were assumed to be 100% devoted to waste management.

Annual costs for tractors used in the agitation and irrigation tasks during sludge removal (TSL systems) were derived by first calculating the present value of these cost parameters occurring in sludge removal years. These present values were then annualized over the life of the system. For tractors and pumps used in irrigation tasks, these annualized values were added to "actual" annual capital recovery and insurance/repairs/housing costs for those items of equipment. (Irrigation of second stage lagoon effluent is a bi-annual task.)

Summation of cost parameters for individual, system-specific equipment/facilities resulted in annual capital recovery and insurance/repairs/housing costs for each waste management system. These annual system cost parameters were then utilized in respective Net Annual Cost Budgets.

A brief discussion of the parameters comprising Capital Recovery and Insurance/Repairs/Housing Costs Budgets is given below. A presentation of example budgets is given in Appendix F.

Initial cost. Since this parameter is the basis of calculating necessary cost parameters, initial cost of particular equipment/facilities used with each dairy waste management system were estimated. Most costs were taken directly from associated Initial Investment Budgets. However, since tractors used for agitation, hauling, and irrigation were not included in initial investment analysis, costs of these equipment items were estimated here. A cross-section survey of local dealers provided the necessary retail prices necessary.

Insurance/repairs/housing costs. Annual costs of insurance, repairs or maintenance, and housing or storage were approximated for components of each waste management system. Insurance costs were calculated for equipment only; rates of \$2/\$1000 of initial cost and \$10/\$1000 of initial cost were used for self-propelled and other equipment respectively (54).

Annual repair (maintenance) costs were also calculated as a stated percentage of initial cost. Estimated annual rates were 1.5% for equipment and fencing components; one percent was the rate used for storage facilities and structural components (46, 54).

Housing costs were related to equipment only. Calculation was based upon an estimate of \$.22/ft.^{2} of housing area required for the particular item of equipment (adapted from Tennessee budgets) (54).[40]

Capital recovery. Capital recovery, a substitute for depreciation and interest on capital (6), was calculated for equipment/facilities specific to each dairy waste management system.[41] Since calculation of capital recovery is dependent upon the life of the asset, life expectancies were estimated for all equipment/facilities. Interest rates are also critical in calculating capital recovery. Based upon recent financial data (1), interest rates used were 14% for intermediate

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[40] Housing (storage) facilities were assumed to cost \$4.8/ft.^{2}, have a 30 year life, and \$0 salvage value. Annual repair costs were assumed to be 1.25% of initial cost. As a result, housing costs were calculated as: \$.16/ft.^{2} (depreciation) + \$.06/ft.^{2} (annual repair) = \$.22/ft.^{2}.

[41] Capital recovery was calculated by the equation: [(initial cost - salvage value) x capital recovery factor] + (salvage value x interest rate). Salvage value was assumed to be 10% of initial cost for equipment, 0% for waste facilities. Capital recovery factors were identical to amortization or annuity factors (6, 1).

term assets (equipment) and 12% for longer term assets (storage facilities, etc.) respectively.

As with other cost parameters, determination of annual capital recovery for equipment used for sludge removal (TSL systems) required special calculation methods. Capital recovery cost for these system components included the capitalized present value of capital recovery costs calculated for sludge removal years (5, 10, 15, and 20).[42]

Net Annual Cost Budgets

Net annual cost was estimated for each modeled dairy waste management system. Data necessary for calculation of net annual cost was provided (estimated) by previously described technical and economic budgets. This budget represents the culmination of the systems synthesis procedure. Net annual cost for each system was calculated as follows: capital recovery plus insurance/repairs/housing costs plus equipment rental cost plus energy costs plus labor costs minus annual fertilizer value of dairy waste. A complete presentation of Net Annual Cost Budgets is given in Chapter IV.

Net annual cost was the primary economic parameter used in comparing modeled dairy waste management systems. All the various aspects of waste handling systems are "netted out" in this calculation, providing one number per system which can be used as a comparative tool. It is this figure, more than any other, that determines which waste system (and variation of that system) is the most "economical."

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[42] Discount and amortization rates of three percent (long term real interest rate) were used because inflation is not considered (6, 8, 53).

CHAPTER III

PHYSICAL DESCRIPTION OF MODELED DAIRY WASTE SYSTEMS

In this chapter the modeled waste systems are described in physical detail with regard to such parameters as storage structure size, tractor hp ratings, and additional installation requirements (e.g. concrete). General characteristics of all systems are discussed first. Each basic type of system (e.g. daily haul, dry stack, earthen pit) is then described, general characteristics of all herd sizes/confinement systems first, followed by a more detailed discussion of specific systems.

General Characteristics Of All Systems

General characteristics for all systems (by herd size) include housing/feeding lots, gutters on adjacent buildings, and assumed daily cleaning procedures.

Housing/Feeding Lot Size

Housing/feeding lots for the 80 and 160 cow herds were synthesized at a prescribed rate of 100 $ft.^2$/cow. Since increased housing density is feasible for very large dairy herds, housing/feeding lots were assumed to be 75 $ft.^2$/cow for 320 cow herds (20). Lots sizes specified for 80, 160, and 320 cow herds were 8,000, 16,000, and 24,000 $ft.^2$ respectively.

The housing/feeding lots were assumed to exist in their entirety before the respective dairy waste management system was installed.

Therefore, no cash costs (with regard to waste management) were incurred due to modification of the existing lots.

Curbing Around Holding/feeding Lots

It was assumed that existing housing/feeding lots did not include concrete curbing around their perimeter. Therefore, to prevent runoff from entering onto or leaving from the lot, six inch x eight inch concrete curbing was installed on housing/feeding lots associated with each waste management system.

Housing/feeding lots were assumed to be essentially rectangular in shape. In each instance the length was calculated as one and one-half times the width. As a result of these calculations, concrete curbing required for 80-cow, 160-cow, and 320-cow herds (all confinement systems and waste systems) was 365, 517, and 632 linear ft. respectively.

Guttered Buildings

Freestall barns, dairy parlors, and other buildings connected to housing/feeding lots were assumed to be guttered irrespective of the waste system utilized. Indeed, guttering of buildings was assumed to be independent from dairy waste management systems i.e. the decision to install gutters is not predicated upon the decision to install a particular waste management system. Therefore, even though the building gutters diverted potential rainfall from waste system storage facilities, the cost of these gutters was not incorporated into the analysis.

Average Travel Distance to Fields of Application

For a specific herd size, the average travel distance to fields of application was assumed to be constant across all dairy waste manage-

ment systems requiring hauling and field application of wastes. The average travel distances used in the analysis were 1,000 ft., 1,500 ft., and 2,500 ft. for the 80-cow, 160-cow, and 320-cow herds respectively. Although arguments may be made for and against the assumed travel distances, the comparative analysis of the various waste systems (for a given herd size) would be unaffected by changes in this parameter.

Daily Cleaning

Daily cleaning procedures associated with each system was assumed to be in accordance with proper sanitation. For example, with systems utilizing the tractor and scrape collection method, the lot was scraped no less than once every two days (daily at least 90% of the time). Liquid systems utilizing the flush collection method were assumed to be flushed twice daily. Additionally, collected wastes were moved to a location inaccessible by the dairy herd.

Daily Haul Systems

Physically, daily haul systems were comprised of a scraping/loading tractor, a box scrape, a box-type manure spreader, a tractor for hauling /spreading wastes, and a small concrete pad for temporary (less than four days) storage. The scraping/loading tractor was of a constant size (hp) for all herd sizes and confinement systems. Likewise, the box scrape was assumed to be the same size in all instances.

It was assumed that a 37 hp. diesel tractor (and associated front-end loader) was utilized in all modeled daily haul systems. A box scrape six feet in width was also assumed.

For all herd sizes and confinement schemes, general management of daily haul waste systems were assumed to include daily scraping of the housing/feeding lot. In addition, wastes were loaded and hauled to be field applied on a more or less daily basis. Factors such as inclement weather and labor constraints could interrupt this schedule however.

80-Cow Herds

Equipment and facilities used with daily haul systems for the 80 cow herd size (and other sizes as well) was not varied since storage capability was very limited.

Equipment specific to daily haul waste systems modeled for 80 cow herds are listed below:

one 180 bu. box manure spreader
one 85 hp. diesel tractor (for hauling)

Short-term storage facilities used with 80-cow herds were limited to a 34 ft. x 34 ft. x four inch concrete slab. These equipment/facilities were in addition to equipment common to all daily haul systems.

160-Cow Herds

Equipment specific to daily haul waste systems modeled for the 160-cow herd size are enumerated below:

one 275 bu. box manure spreader
one 105 hp. diesel tractor (for hauling)

Facilities used for temporary storage of wastes included a 48 ft. x 48 ft. x four inch concrete slab.

320-Cow Herds

Equipment associated with daily haul waste systems modeled for the 320-cow herd size are listed below:

one 450 bu. box manure spreader
one 140 hp. diesel tractor (for hauling)

Short-term storage of manure would be available on a concrete slab, 59 ft. x 59 ft. x four inches.

Dry Stack Systems

Modeled dry stack waste management systems consisted of: (1) a scraping/loading tractor; (2) a box scrape; (3) a box manure spreader; (4) a tractor used to haul/spread the collected wastes; (5) a dry stack storage structure; and (6) additional concrete needed to link the housing/feeding lot to the dry stack. Basically, the only variations in dry stack systems installed on different herd sizes and/or confinement systems were variations in size of equipment and/or storage structures.

However, certain parameters were constant over the full range of herd sizes and confinement systems. For each dry stack system modeled, the scraping/loading tractor was assumed to be 37 hp. (diesel) and included a front-end loader. Likewise, the box scrape utilized in each dry stack system was assumed to be six ft. in width.

Considerable variation was found to exist in the construction of dry stack storage structures on dairy farms in East Tennessee. The greatest variation occurred in the materials used to construct the walls of dry stacks. Some variation was also found in the slope of the floor and roof construction.

SCS specifications were utilized for specifying the structures for the analysis (64, 65). Dry stack facilities were assumed to include a floor of reinforced concrete (eight inches thick) sloped at a rate of 12:1, a roof constructed over the facility, and adequate space to allow operation of loading and hauling equipment. The roof would be supported by six inch pressure-treated posts on four ft. centers and set at least four ft. deep.

SCS specifications allowed the use of reinforced concrete, treated tongue-and-groove lumber, or "other approved materials" for the walls of dry stack facilities (65). In some instances, masonry blocks filled with concrete and rebar were approved for use. However, there were indications that this practice was not universally accepted. Due primarily to this and longevity/durability factors, reinforced concrete was assumed to be used for the construction of dry stack walls.

It was assumed that no topographical or physical impediments existed in the location of the dry stack facility. Therefore, the dry stack could be located with a minimum of additional poured concrete (needed to "link" the storage facility with the housing/feeding lot).

Dry stack systems utilizing three month's storage capacity were designed for the most critical storage period, December through February. Total storage volume required was calculated as [(daily per animal waste production x average %TOL) + (.5 x lbs. daily bedding / density of bedding)] x number of animal units x number days of storage.

80-Cow Herds

Certain equipment modeled for 80-cow herds were held constant for all confinement systems and storage capacities. The standard equipment

synthesized for use with dry stack systems on 80-cow herds are as follows:

one 180 bu. box manure spreader
one 85 hp. diesel tractor (for hauling)

The standard scraping/loading tractor and box scrape were also modeled in all dry stack systems associated with 80 cow herds. The primary basis for physical variation was in storage structure size.

80/PC/DS/3. Storage capacity required for the 80/PC/DS/3 system was 13,666 ft.^{3} A dry stack of the following dimensions was modeled to satisfy the capacity requirements:

116.5 ft. in length
25 ft. in width
eight ft. in depth
floor slope of 12:1

Additional concrete of 424 ft.^{2} x four inches was required to "attach" the dry stack facility with the housing/feeding lot. A six inch thick concrete pad extended 15 ft. from the front of the structure to facilitate clean-out. A total of 375 ft.^{2} was covered by the "clean-out" pad.

80/TC/DS/3. Storage capacity for the 80/TC/DS/3 system was modeled to be 16,920 ft.^{3} To satisfy this storage equipment a dry stack was synthesized using the following specifications:

132.5 ft. in length
25 ft. in width
eight in depth
floor slope of 12:1

Additional concrete required to install the dry stack system included a 424 ft.^{2} x four inch concrete slab and a 375 ft.^{2} x six inch clean-out pad.

80/PC/DS/6. Storage capacity modeled for the 80/PC/DS/6 system was 18,720 ft.^{3} Synthesis of a storage facility to meet this requirement resulted in a dry stack of the following specifications:

126 ft. in length
30 ft. in width
eight ft. in depth
floor slope of 12:1

Additional concrete required included a 424 ft.^{2} x four inch slab and a 450 ft.^{2} x six inch clean-out pad extending from the front of the structure.

80/TC/DS/6. Storage capacity for the 80/TC/DS/6 system was modeled to be 30,240 ft.^{3} To satisfy this storage equipment a dry stack was synthesized using the following specifications:

156 ft. in length
35 ft. in width
eight in depth
floor slope of 12:1

Additional concrete required to install the dry stack system included a 424 ft.^{2} x four inch concrete slab and a 525 ft.^{2} x six inch clean-out pad.

160-Cow Herds

Certain equipment utilized for dry stack systems for 160-cow herds remained constant over all confinement schemes and storage capacities. The standard equipment included:

one 275 bu. box spreader
one 105 hp. diesel tractor (for hauling)

In addition, a standard-sized scraping/loading tractor and box scrape were modeled for use in all instances.

160/PC/DS/3. Storage capacity needed for the 160/PC/DS/3 system was calculated to be 27,331 ft.^{3} A dry stack meeting this capacity requirement was modeled according to the following specifications:

146 ft. in length
35 ft. in width
eight ft. in depth
floor slope of 12:1

A concrete slab of 768 ft.^{2} x four inches was synthesized to connect the dry stack facility with the housing/feeding lot. A six inch x 525 ft.^{2} concrete pad extended from the front to the storage structure to facilitate clean-out.

160/TC/DS/3. Calculated storage capacity requirement for 160/TC/-DS /3 systems was 33,840 ft.^{3} A dry stack of appropriate storage capacity was synthesized using the following dimensions:

153 ft. in length
40 ft. in width
eight ft. in depth
floor slope of 12:1

Additional concrete needed was calculated to be 848 ft.^{2} x four inches and 600 ft.^{2} x six inches for a concrete slab and clean-out pad respectively.

160/PC/DS/6. Required storage capacity for the 160/PC/DS/6 system was 37,440 ft.^{3} The dry stack facility incorporated the following specifications:

165 ft. in length
40 ft. in width
eight ft. in depth
floor slope of 12:1

Additional concrete required to link the storage facility to the housing/feeding lot formed a 848 ft.^{2} x four inch slab. Installing a

clean-out pad extending from the front of the facility required concrete of 600 ft.^{2} x six inches.

160/TC/DS/6. Required storage capacity for the 160/TC/DS/6 system was calculated to be 60,480 ft.^{3} A synthesized dry stack facility sized to meet this requirement had the following dimensions:

199 ft. in length
50 ft. in width
eight ft. in depth
floor slope of 12:1

The dimensions may be slightly greater than may be typically found (especially the width). Compensation for these atypical dimensions could result by modification of the other dimensions, such as increasing the maximum depth. Another possibility would be to construct two smaller facilities.

Additional concrete required for the linkage of facility to housing/feeding lot was estimated to be 848 ft.^{2} x four inches. The clean-out pad required a concrete slab dimensioned at 750 ft.^{2} x six inches.

320-Cow Herds

Certain equipment utilized on modeled dry stack systems for 320-cow herds remained constant for all confinement schemes and storage sizes. The standard equipment used were:

one 450 bu. box manure spreader
one 140 hp. diesel tractor (for hauling)

In addition, standard-sized scraping/loading tractors and box scrapes were modeled in all instances.

320/PC/DS/3. Storage capacity required for the 320/PC/DS/3 system was calculated to be 54,662 ft.^{3} A dry stack facility modeled to satisfy storage requirements consisted of the following dimensions:

181.5 ft. in length
45 ft. in width
10 ft. in depth
floor slope of 12:1

A concrete slab measuring 1,696 ft.^{2} x four inches was required to link the storage facility to the housing/feeding lot. A concrete clean-out pad, dimensioned at 675 ft.^{2} x six inches, was specified for the front of the storage structure.

320/TC/DS/3. Storage capacity required for the 320/TC/DS/3 system was calculated to be 67,680 ft.^{3} A dry stack facility, modeled to satisfy this storage requirement, had the following specifications:

207.5 ft. in length
50 ft. in width
10 ft. in depth
floor slope of 12:1

A concrete slab calculated to be 1,696 ft.^{2} x four inches was required to link the storage facility to the housing/feeding lot. The clean-out pad was modeled with dimensions of 750 ft.^{2} x six inches.

320/PC/DS/6. Modeled storage capacity requirements for the 320/-PC/DS/6 system was 74,880 ft.^{3} A dry stack facility satisfying this storage requirement was synthesized using the following specifications:

302 ft. in length
50 ft. in width
10 ft. in depth
floor slope of 12:1

Concrete areas with dimensions of 1,696 ft.^{2} x four inches were necessary to link the housing/feeding lot with the storage facility.

The required concrete clean-out pad was estimated to be 750 ft.^{2} x six inches.

320/TC/DS/6. Storage capacity required for the 320/TC/DS/6 system was calculated to be 120,960 ft.^{3} Two storage facilities were specified for this system, one with a capacity of 64,380 ft.^{3} and the second with a capacity of 39,300 ft.^{3} The dimensions specified for the first storage facility were as follows:

225 ft. in length
50 ft. in width
10 ft. in depth
floor slope of 12:1

The second modeled dry stack storage facility was dimensioned as follows:

170 ft. in length
40 ft. in width
10 ft. in depth
floor slope of 12:1

Concrete areas required to link the storage facility to the housing/feeding lot had dimensions of 1,696 ft.^{2} x four inches. Concrete clean-out pads for the facilities had a total dimension of 1,350 ft.^{2} x six inches.

Earthen Pit Systems

Synthesized earthen pit dairy waste management systems consisted of: (1) a scraping tractor; (2) a box scrape; (3) a tank (liquid) manure spreader; (4) a tractor used to haul/spread collected wastes; (5) a tractor for agitation/loading of stored wastes; (6) an earthen pit storage facility; (7) an agitation/removal pump; and (8) additional concrete necessary to link the housing/feeding lot with the earthen

pit. A 37 hp. tractor (without a front-end loader) and a six ft. box scrape were assumed for all herd sizes, confinement schemes, and storage capacities.

Variations in the other parameters were modeled due to variations in herd sizes, confinement systems, and/or storage capacity. Variations in equipment were due only to variations in herd size while alternative confinement systems and storage capacity requirements also contributed to variations in facility size.

SCS specifications were used in modeling earthen pit storage structures. In addition to handling waste production collected, earthen pit systems were designed to: (1) collect precipitation falling on the facility; (2) collect precipitation falling on the housing/feeding lot; (3) include at least one foot of freeboard; and (4) retain the capacity to absorb a "25 year, 24 hour" storm runoff.

The interior slope of the structural walls were assumed to be 2:1 in all cases. The storage structures were modeled to be square to rectangular in shape with a maximum depth of 12 ft. (21, 42, 60).

One or more push-off ramp/agitation port was specified for each earthen pit storage facility. Multiple agitation ports were required for larger storage structures due to the limited agitation distance of agitation/removal pumps (21, 60). Structural design of these agitation ports was synthesized in accordance with SCS specifications. It was assumed that no topographical or physical impediments existed in the location of the earthen pit. Therefore, the earthen pit could be located with a minimum of additional poured concrete necessary for linkage of the storage facility with the housing/feeding lot. As with

dry stack systems, earthen pit systems utilizing three months storage capacity were designed for the most critical collection period (December though February).

All synthesized earthen pit storage facilities included fencing as suggested by SCS (64, 65). The primary purpose of this fencing was to prevent accidental access (drowning and other hazards) by humans and animals. The size of the storage facility dictated the measurements (and cost) of the fencing utilized with any earthen pit system. Generally, the number of gates associated with the fencing surrounding earthen pit storage structures corresponded to the number of agitation ports. This feature was incorporated for ease of access during agitation/removal processes.

80-Cow Herds

Certain equipment and facility specifications were constant across all earthen pit waste management systems modeled for 80-cow herds. Equipment standardized for all earthen pit systems designed for 80-cow herds were:

one 1,500 gallon tank spreader
one agitation/removal pump
one 65 hp. tractor for agitation/loading
one 85 hp. tractor for hauling/spreading
additional concrete, 530 ft.^{2} x four inches

These equipment were in addition to the standard equipment for all herd sizes.

Primary sources of variation in physical dimensions of earthen pit waste systems modeled for 80-cow herds resulted from variations in storage structure size and associated fencing. These variations are described below.

80/PC/EP/3. Calculated storage capacity necessary for the 80/PC/EP/3 system was 37,750 ft.^{3} An earthen pit and associated fencing of the following specifications were modeled to satisfy the storage requirements and SCS recommendations:

one earthen pit, 95 ft. x 80 ft. x 12 ft.
one concrete agitation port
370 linear ft. of net wire fencing
one 12 ft. aluminum gate

80/TC/EP/3. Storage capacity required for the 80/TC/EP/3 system was calculated to be 43,650 ft.^{3} Following SCS specifications, an earthen pit and associated fencing of the following dimensions were synthesized:

one earthen pit, 105 ft. x 80 ft. x 12 ft.
two concrete agitation ports
390 linear ft. of net wire fencing
two 12 ft. aluminum gates

80/PC/EP/6. It was estimated that 52,500 ft.^{3} of storage capacity was necessary for the 80/PC/EP/6 system. To satisfy storage capacity needs and meet SCS specifications, an earthen pit and associated fencing was synthesized as follows:

one earthen pit, 120 ft. x 80 ft. x 12 ft.
tow concrete agitation ports
420 linear ft. of net wire fencing
two 12 ft. aluminum gates

80/TC/EP/6. Storage capacity required for the 80/TC/EP/6 system system was calculated to be 64,300 ft.^{3} Incorporation of SCS specifications and satisfaction of storage requirements resulted in an earthen pit and associated fencing as follows:

one earthen pit, 140 ft. x 80 ft. x 12 ft.
three concrete agitation ports
460 linear ft. of net wire fencing
three 12 ft. aluminum gates

160-Cow Herds

Certain equipment and facilities modeled on earthen pit systems for 160-cow herds were constant irregardless of confinement scheme or storage capacity. These standardized equipment were as follows:

one 3,000 gallon tank spreader
one agitation/removal pump
one 85 hp. tractor for agitation/loading
one 105 hp. tractor for hauling/spreading
additional concrete, 1,060 ft.^{2} x four inches

These equipment were in addition to equipment standardized for all herd sizes as discussed earlier.

Primary sources of variation in physical dimensions of earthen pit systems for 160-cow herds were a result of alternative storage structure size and associated fencing. These variations are described below.

160/PC/EP/3. Calculated storage capacity necessary for the 160/-PC/EP/3 system was 73,850 ft.^{3} An earthen pit and associated fencing were modeled to satisfy storage requirements and meet SCS specifications. The synthesized storage structure was dimensioned as follows:

one earthen pit, 125 ft. x 100 ft. x 12 ft.
two concrete agitation ports
470 linear ft. of net wire fencing
two 12 ft. aluminum gates

160/TC/EP/3. Storage capacity required for the 160/TC/EP/3 system was calculated to be 81,950 ft.^{3} Following SCS specifications, an earthen pit and associated fencing of the following dimensions were synthesized:

one earthen pit, 135 ft. x 100 ft. x 12 ft.
two concrete agitation ports
490 linear ft. of net wire fencing
two 12 ft. aluminum gates

160/PC/EP/6. It was estimated that 102,200 ft.^{3} of storage capacity was necessary for the 160/PC/EP/6 system. To satisfy storage requirements and meet SCS specifications, and earthen pit and associated fencing was synthesized as follows:

one earthen pit, 160 ft. x 100 ft. x 12 ft.
three concrete agitation ports
540 linear ft. of net wire fencing
three 12 ft. aluminum gates

160/TC/EP/6. Storage capacity required for the 160/TC/EP/6 system was calculated to be 122,450 ft.^{3} Incorporation of SCS specifications and satisfaction of storage requirements resulted in a modeled earthen pit and associated fencing of the following proportions:

one earthen pit, 185 ft. x 100 ft. x 12 ft.
four concrete agitation ports
590 linear ft. of net wire fencing
four 12 ft. aluminum gates

320-Cow Herds

Certain equipment and facility parameters were assumed to be unchanged by variations in confinement system and storage capacity. Equipment held constant for all earthen pit waste systems modeled on 320-cow herds were the following:

one 4,500 gallon tank spreader
one agitation/removal pump
one 125 hp. tractor for agitation/loading
one 140 hp. tractor for hauling/spreading
additional concrete, 2,120 ft.^{2} x four inches

These equipment were in addition to the standard equipment modeled for all herd sizes and systems. Primary sources of variation in earthen pit systems for 320-cow herds resulted form variations in storage structure size and associated fencing. These variations are described below.

320/PC/EP/3. Calculated storage capacity necessary for the 320/PC/EP/3 system was 118,450 ft.^{3} An earthen pit and associated fencing were modeled to satisfy storage requirements and meet SCS specifications. The modeled structure consisted of these dimensions:

one earthen pit, 185 ft. x 100 ft. x 12 ft.
three concrete agitation ports
590 linear ft. of net wire fencing
three 12 ft. aluminum gates

320/TC/EP/3. Storage capacity required for the 320/TC/EP/3 system was calculated to be 140,550 ft.^{3} Following SCS specifications, an earthen pit and associated fencing of the following dimensions were synthesized:

one earthen pit, 200 ft. x 105 ft. x 12 ft.
three concrete agitation ports
630 linear ft. of net wire fencing
three 12 ft. aluminum gates

320/PC/EP/6. It was estimated that 169,200 ft.^{3} of storage capacity was needed with the 320/PC/EP/6 system. To satisfy storage capacity needs and meet SCS specifications, and earthen pit and associated fencing was modeled as follows:

one earthen pit, 200 ft. x 120 ft. x 12 ft.
four concrete agitation ports
660 linear ft. of net wire fencing
four 12 ft. aluminum gates

320/TC/EP/6. Storage capacity required for the 320/TC/EP/6 system was calculated to be 206,000 ft.^{3} Incorporation of SCS specifications and satisfaction of storage requirements resulted in an earthen pit and associated fencing modeled as follows:

one earthen pit, 200 ft. x 150 ft x 12 ft.
four concrete agitation ports
720 linear ft. of net wire fencing
four 12 ft. aluminum gates

Above-ground Tank Systems

Modeled above-ground tank (AGT) waste management systems basically consisted of: (1) a scraping tractor; (2) a box scrape; (3) a tank (liquid) manure spreader; (4) a tractor for hauling/spreading collected wastes; (5) a tractor for agitation/loading of stored wastes; (6) an above-ground tank storage facility; (7) a collection sump (and associated agitation/transfer pump; and (8) additional concrete necessary to link the housing/feeding lot with the above-ground tank. No variation in the modeled scraping tractor or box scrape was incorporated as a result of variations in herd size, confinement system, or storage capacity. In all cases, a 37 hp. tractor (no front-end loader) and six ft. box scrape were assumed.

Variations in other parameters modeled were due to variations in herd sizes, confinement systems, and/or storage capacity. Variations in equipment resulted only from differing herd sizes while alternative confinement systems and storage capacity requirements also contributed to variations in size of collection and storage facilities.

As with earthen pit systems, storage facilities associated with AGT systems were designed to: (1) collect precipitation falling on the storage facility; (2) collect precipitation from the housing/feeding lot; (3) retain the capacity to absorb a 25 year, 24 hour storm runoff; and (4) include at least six inches of freeboard in addition to collection of animal wastes. AGT systems differed from earthen pit systems in that they required a collection sump. The purpose of collection sumps was preliminary waste collection, raising the moisture content to a pumpable consistency, agitation of the wastes, and transfer of the

wastes to the above-ground tank. Collection slumps were connected to AGT by and underground PVC pipe. Addition of wastes from the bottom of the AGT minimized freezing problems and severely reduced surface crust disturbance. Malodor problems and nitrogen loss were curtailed as a result.

Collection sumps were modeled to provide a minimum of three days storage capacity (a precautionary measure to guard against mechanical failures and freezing temperatures). In addition, collection sumps were modeled to utilize a separate agitation/transfer pump driven by an electric motor. Physically, collection sumps were subterranean concrete vats with a concrete supported flat "roof" or top which in turn supported the agitation/transfer pump.

Certain parameters were inextricably linked with the AGT storage structure. As a result, they were included in the physical description and cost of the storage structure itself. These parameter included the concrete foundation or pad supporting the structure, an agitation/removal pump (and accessories) and other accessories attached to the storage structure e.g. ladders and platforms.

Two identifiable types of AGT structures were synthesized in all cases, one with fused glass-to-steel walls and one utilizing concrete walls. Physically, it was assumed that dimensions (and capacity) were unchanged as a result of the different structural components. Only cost was affected.

As an additional note, AGT storage structures, available only in certain discrete sizes, were quite inflexible with regard to meeting capacity requirements. As a result, structures of greater capacity

than needed were sometimes synthesized for a given herd size/confinement system. However, utilizing the next smallest structure would result in undersizing. This sizing difficulty is a problem encountered in real farm situations. Therefore, no assumptions were made to ameliorate the inflexibility of storage structure sizes.

80-Cow Herds

Certain equipment and facility specifications were assumed to be constant across all AGT waste management systems modeled for 80-cow herds. These specifications were the following:

one 1,500 gallon tank spreader
one 65 hp. tractor for agitation/loading
one 85 hp. tractor for hauling/spreading
one 800 gpm agitation/transfer sump pump
additional concrete, 424 $ft.^2$ x four inches

These equipment and facilities were in addition to those assumed to be unchanged over all herd sizes. Those equipment and facility parameters that did vary are described below.

80/PC/AGT/3. To satisfy storage capacity and SCS requirements, an AGT with a rated capacity of 42,270 $ft.^3$ was synthesized for the 80/-PC/AGT/3 system. Physical specifications for the storage facility (given as diameter x height) and associated equipment/facilities are listed below:

one above-ground tank, 62 ft. x 14 ft.
one collection sump with a capacity of 645 $ft.^3$

80/TC/AGT/3. Satisfaction of storage requirements and SCS specifications resulted in the modeling of an above-ground tank with a rated capacity of 42,270 $ft.^3$ for the 80TC/AGT/3 system. Physical

specifications for the storage facility and associated collection sump are given below:

one above-ground tank, 62 ft. x 14 ft.
one collection sump with a capacity of 1,070 ft.^{3}

80/PC/AGT/6. Satisfaction of storage requirements and SCS specifications resulted from synthesizing an above-ground tank with a rated capacity of 55,900 ft.^{3} for the 80/PC/AGT/6 system. Physical specifications for the storage facility and associated collection sump are given below:

one aboveground tank, 62 ft. x 19 ft.
one collection sump with a capacity of 645 ft.^{3}

80/TC/AGT/6. An above-ground tank with a rated capacity of 69,540 ft.^{3} was synthesized for the 80/TC/AGT/6 system to meet storage capacity needs and SCS specifications. Physical dimensions of the facility and associated collection sump are as follows:

one above-ground tank, 62 ft. x 23 ft.
one collection sump with a capacity of 1,070 ft.^{3}

160-Cow Herds

Certain equipment and facility parameters were assumed to remain unchanged across all AGT waste systems modeled on 160-cow herds. The parameters which did not vary as confinement systems and storage capacity varied are as follows:

one 3,000 gallon tank spreader
one 85 hp. tractor for agitation/loading
one 105 hp. tractor for hauling/spreading of wastes
one 1,000 gpm. agitation/transfer pump (sump)
additional concrete, 848 ft.^{2} x four inches

These equipment and facilities were in addition to the scraping tractor and box scrape assumed for all systems. Equipment and facility parameters which did vary are described below.

160/PC/AGT/3. To satisfy storage capacity and SCS requirements, an above-ground tank with a rated capacity of 69,540 ft.^{3} was synthesized for the 160/PC/AGT/3 system. Physical descriptions of the storage facility and associated collection sump are given below:

one above-ground tank, 62 ft. x 23 ft.
one collection sump with a capacity of 1,285 ft.^{3}

160/TC/AGT/3. Satisfaction of storage requirements and SCS specifications resulted in the modeling of an above-ground tank with a rated capacity of 73,450 ft.^{3} for the 160/TC/AGT/3 system. Physical specifications for the storage facility and associated collection sump are given below:

one above-ground tank, 81 ft. x 14 ft.
one collection sump with a capacity of 2,140 ft.^{3}

160/PC/AGT/6. Satisfaction of storage requirements and SCS specifications resulted from synthesizing an above-ground tank with a rated capacity of 97,910 ft.^{3} for the 160/PC/AGT/6 system. Physical descriptions of the storage facility and associated collection sump are given below:

one above-ground tank, 81 ft. x 19 ft.
one collection sump with a capacity of 1,285 ft.^{3}

160/TC/AGT/6. Satisfaction of storage requirements and SCS specifications resulted in the modeling of an above-ground tank with a rated capacity of 120,840 ft.^{3} for the 160/TC/AGT/6 system. Physical specifications for the storage facility and associated collection sump are given below:

one above-ground tank, 81 ft. x 23 ft.
one collection sump with a capacity of 2,140 ft.^{3}

320-Cow Herds

Certain equipment and facility parameters were assumed to remain unchanged across all AGT systems modeled on 320-cow herds. The parameters which did not vary as confinement systems and storage capacity varied were the following:

one 4,500 gallon tank spreader
one 125 hp. tractor for agitation/loading
one 140 hp. tractor for hauling/spreading
one 1,200 gpm agitation/transfer sump pump
additional concrete, 1,696 ft.^{2} x four inches

In addition, the scraping tractor and box scrape modeled for all systems were included on modeled AGT systems for 320-cow herds.

320/PC/AGT/3. In order to satisfy storage capacity needs and SCS specifications, an above-ground tank with a rated capacity of 120,840 ft.^{3} was synthesized for the 320/PC/AGT/3 system. Physical specifications for the storage facility and associated collection sump are listed below:

one above-ground tank, 81 ft. x 23 ft.
one collection sump with a capacity of 2,180 ft.^{3}

320/TC/AGT/3. Satisfaction of storage requirements and SCS specifications resulted in the modeling of two above-ground tanks with a combined rated capacity of 135,940 ft.^{3} Physical descriptions of the storage facilities and associated collection sump are listed below:

one above-ground tank, 81 ft. x 19 ft.
one above-ground tank, 42 ft. x 28 ft.
one collection sump with a capacity of 3,635 ft.^{3}

320/PC/AGT/6. Two above-ground tanks with a combined rated capacity of 163,110 ft.^{3} were synthesized for the 320/PC/AGT/6 system.

It was this capacity which satisfied storage needs and SCS specifications. Physical parameters of the storage facilities and associated collection sump are given below:

one above-ground tank, 81 ft. x 23 ft.
one above-ground tank, 62 ft. x 14 ft.
one collection sump with a capacity of 2,180 $ft.^3$

320/TC/AGT/6. Satisfaction of storage requirements and SCS specifications for the 320/TC/AGT/6 system resulted from modeling two above-ground tanks with a combined rated capacity of 225,000 $ft.^3$ Physical descriptions of the synthesized storage facilities and associated collection sump are given below:

one above-ground tank, 101 ft. x 23 ft.
one above-ground tank, 42 ft. x 28 ft.
one collection sump with a capacity of 3,635 $ft.^3$

Single Stage Lagoon Systems

Basic system components for single stage waste systems (SSL) included: (1) an agitation pump; (2) an irrigation pump; (3) mainline six inch PVC irrigation pipe; (4) a traveling "big gun" irrigation sprinkler; (5) a tractor to run the agitation pump; (6) a tractor used to run the irrigation pump; (7) additional concrete to connect the housing/feeding lot with the SSL; (8) the SSL itself; (9) fencing around the lagoon; and (10) a standard push-off ramp. Two alternative methods of waste collection were analyzed, hydraulic (water flush) and the standard method of tractor and scrape collection.

Those systems utilizing flush collection methods included as physical parameters flush tanks and a recycle pump. Basically, liquid was recycled from the far side of the synthesized lagoon to the flush

tanks and used as the hydraulic medium for waste collection. The flush tanks utilized manual gates and required manual labor to initiate the flushing process.

SCS specifications were used in designing the SSL storage facilities. The storage structures were assumed to be square to rectangular in shape. Interior walls of the structures were modeled with a slope of 2.5:1 (as a precaution against wall failure) (32, 64, 65). Maximum depth was limited to 16 ft.. SSL storage/treatment structures were fenced to prevent accidental access by animals and humans.

SSL systems were designed to be "efficient", i.e. large enough to store diluted wastes for a long enough period so that it can be decomposed (at least partially) by bacteria. Total design volume for an efficient SSL was the sum of its minimum design volume, waste storage volume and dilution volume. However, actual excavated volume included a safety factor commonly called freeboard.

Minimum design volume was the volume needed to insure viable and adequate bacteria populations for waste decomposition. The liquid level of the lagoon was never allowed to drop below this level. Malodor and improper waste treatment would result (32).

Waste storage volume was the space required to store the dairy waste actually produced over a specified time interval (32). Six months storage capacity was modeled in all cases for this analysis i.e. the lagoons were assumed to be "dewatered" twice a year. It was assumed that irrigation of collected wastes in the spring and fall optimizes the value of collected dairy wastes.

Dilution volume was defined as the amount of water that must be added to a lagoon (between each dewatering) to insure proper waste decomposition. Generally, the dilution volume was assumed to equal the waste storage volume (32). If insufficient water from lot runoff, cattle waterers, and milk parlor wash water was added to the lagoon, it was assumed that water was pumped from a stream, well, or pond.

Freeboard volume was simply a safety factor (32). It was included in SSL design to allow for large and sudden amounts of rainfall e.g. 25 year, 24 hour storm. In addition, an emergency spillway was incorporated into the designs of SSL systems to prevent bank failure in the event of an overflow.

Twice a year dewatering (land application of collected wastes) was modeled to include agitation of the SSL facility and irrigation of the agitated wastes on cropland. Agitation was incorporated to minimize sludge buildup. It was assumed that SSL facilities would be dewatered down to the minimum design volume. Adequate bacteria population for waste decomposition could thereby be maintained.

80-Cow Herds

Parameters unchanged with variations in confinement system and collection method for SSL systems on 80-cow herds were as follows:

one agitation pump (3,200 gpm)
one irrigation pump (200 gpm)
one traveling big gun with 850 ft. hose
2,000 ft. of mainline six-inch PVC pipe
one standard push-off ramp
530 ft.^{2} x four inches of additional concrete

80/PC/SSL/SC. To satisfy storage requirements and SCS specifications for the 80/PC/SSL/SC system, a SSL facility with a total capacity

of 213,800 ft.^{3} was modeled. Physical specifications of the storage/-treatment facility and associated parameters are listed below:

one SSL, 200 ft. x 120 ft. x 16 ft.
one 37 hp. scraping tractor
one six ft. box scrape
720 linear ft. of net wire fencing
one 12 ft. aluminum gate

80/PC/SSL/FC. Primarily, the only difference between this system and the 80/PC/SSL/SC system was the method of waste collection. The 80/PC/SSL/FC system used flush tanks and a recycle pump in hydraulic waste collection. There was also $400 of additional lot modifications such as poured concrete required in constructing a foundation for the recycle pump. Physical parameters of this system are given below:

one SSL, 200 ft. x 120 ft. x 16 ft.
two 1,000 gallon flush tanks
one 1/2 hp. recycle pump (20 gpm)
720 linear ft. of net wire fencing
one 12 ft. aluminum gate

80/TC/SSL/SC. In satisfaction of capacity requirements and SCS specifications, a structure with a total capacity of 302,800 ft.^{3} was modeled for the 80/TC/SSL/SC system. Physical specifications of the storage structure and associated parameters are as follows:

one SSL, 200 ft. x 155 ft. x 16 ft.
one 37 hp. tractor for scraping
one six ft. box scrape
790 linear ft. of net wire fencing
one 12 ft. aluminum gate

80/TC/SSL/FC. Basically, this system utilized the same physical parameters as the 80/TC/SSL/SC system. Only the method of collection differed. Physical specifications of this waste system are listed below:

one SSL, 200 ft. x 155 ft. x 16 ft.
two 1,000 gallon flush tanks

one 1/2 hp. recycle pump (20 gpm)
790 linear ft. of net wire fencing
one 12 ft. aluminum gate
other lot modifications totaling $400

160-Cow Herds

Certain physical parameters were assumed constant across all variations in confinement scheme and collection methods for SSL waste systems modeled on 160-cow herds. These constant physical parameters are as follows:

one agitation pump (4,000 gpm)
one irrigation pump (350 gpm)
one traveling big gun with 1,000 ft. hose
3,000 ft. of mainline six-inch PVC pipe
one standard push-off ramp
1,060 ft.^{2} x four inches of additional concrete

160/PC/SSL/SC. To satisfy capacity requirements and SCS specifications for the 160/PC/SSL/SC system, a storage structure with a total capacity of 405,200 ft.^{3} was synthesized. Physical specifications of the storage/treatment facility and associated parameters are given below:

one SSL, 200 ft. x 195 ft. x 16 ft
one 37 hp. scraping tractor
one six ft. box scrape
870 linear ft. of net wire fencing
one 12 ft. aluminum gate

160/PC/SSL/FC. The primary difference between this system and the 160/PC/SSL/SC system was the method of waste collection. This system utilized hydraulic means of waste collection. Certain modifications of the lot were also required for this system. These modifications were mainly to effect proper flush waster diversion. A more complete listing of physical aspects of this waste system follows:

one SSL, 200 ft. x 195 ft. x 16 ft.
one 1/2 hp. recycle pump (20 gpm)
four 1,000 gallon flush tanks
870 linear ft. of net wire fencing
two 12 ft. aluminum gates
other lot modifications totaling $800

160/TC/SSL/SC. Calculated storage structure capacity for the 160/TC/SSL/SC system was 571,600 $ft.^3$ Physical descriptions of the modeled lagoon and associated parameters are given below:

one SSL, 260 ft. x 200 ft. x 16 ft.
one 37 hp. scraping tractor
one six ft. box scrape
1,000 linear ft. of net wire fencing
two 12 ft. aluminum gates

160/TC/SSL/FC. The major variation between this system and the 160/TC/SSL/SC system was in the method of waste collection. This system utilized hydraulic means to collect dairy wastes. Complete physical details for the 160/TC/SSL/FC system are as follows:

one SSL, 260 ft. x 200 ft. x 16 ft.
four 1,000 gallon flush tanks
one 1/2 hp. recycle pump (20 gpm)
1,000 linear ft. of net wire fencing
two 12 ft. aluminum gates
other lot modifications totaling $800

320-Cow Herds

Certain physical parameters were assumed constant across all variations in confinement scheme and collection methods for SSL systems modeled on 320-cow herds. These unvarying parameters are as follows:

one agitation pump (6,000 gpm)
one irrigation pump (550 gpm)
one traveling big gun with 1,300 ft. hose
5,000 ft. of mainline six-inch PVC pipe
one standard push-off ramp
2,120 $ft.^2$ x four inches of additional concrete

320/PC/SSL/SC. Satisfaction of storage requirements and SCS specifications for this system required a SSL with a total capacity of 776,400 ft.^{3} Physical specifications of the storage/treatment facility and associated parameters are given below:

one SSL, 340 ft. x 200 ft. x 16 ft.
one 37 hp. scraping tractor
one six ft. box scrape
1,160 linear ft. of net wire fencing
three 12 ft. aluminum gates

320/PC/SSL/FC. With regard to storage needs, this system was identical to the 320/PC/SSL/SC system. However, collection methods differed for the the two systems. This system utilized hydraulic means to collect dairy waste. Physical parameters for this system are given below:

one SSL, 340 ft. x 200 ft. x 16 ft.
six 1,000 gallon flush tanks
one 1/2 hp. recycle pump (20 gpm)
1,160 linear ft. of net wire fencing
three 12 ft. aluminum gates
other lot modifications totaling $1,200

320/TC/SSL/SC. A SSL with a total physical capacity of 1,090,000 ft.^{3} was synthesized to meet the requirements for the 320TC/SSL/SC system. Complete physical specifications for this system are given below:

one SSL, 300 ft. x 300 ft. x 16 ft.
one 37 hp. scraping tractor
one six ft. box scrape
1,280 linear ft. of net wire fencing
three 12 ft. aluminum gates

320/TC/SSL/FC. AS with the 320/TC/SSL/SC system, 1,090,000 ft.^{3} of total capacity was required for the modeled SSL. Hydraulic means of waste collection were utilized in place of the standard collection

method (i.e. tractor and box scrape). Physical specifications for this system are given below:

one SSL, 300 ft. x 300 ft. x 16 ft.
six 1000 gallon flush tanks
one 1/2 hp. recycle pump (20 gpm)
1,280 linear ft. of net wire fencing
three 12 ft. aluminum gates
other lot modifications totaling $1,200

Two Stage Lagoon Systems

Basic system components of two stage lagoon (TSL) systems included: (1) an irrigation pump; (2) mainline six inch PVC irrigation pipe; (3) a traveling big gun sprinkler; (4) a tractor to run the irrigation pump; (5) additional concrete linking the housing/feeding lot with the TSL facility; (6) a first stage or primary lagoon; (7) a second stage or secondary lagoon; (8) fencing around the lagoons; (9) 10 inch PVC pipe connecting the two lagoons; and (10) a standard push-off ramp. Two alternative methods of waste collection were analyzed, hydraulic flush and standard (tractor and scrape) methods.

Those systems using flush collection included as physical parameters flush tanks and a recycle pump. Generally, liquid was pumped from the second stage lagoon into the flush tanks and used as the hydraulic medium for waste collection. Flush tanks utilized manual gates and required manual labor to initiate the flushing process. SCS specifications were followed in the design and synthesis of TSL facilities. The storage structures were assumed to be square to rectangular in shape. Interior walls were modeled with a slope of 2.5:1 (to prevent wall failure). Maximum depth was limited to 16 ft. for the first stage, eight ft. for the second stage lagoon. In addition, storage/treatment

structures were fenced to prevent accidental access by humans and animals. A push-off ramp similar to that modeled for EP systems was also incorporated on TSL systems.

TSL systems were modeled to be waste treatment structures i.e. large enough to store diluted dairy wastes for a long enough period of time so that decomposition by bacteria could occur. Basically, the first stage lagoon was a deep anaerobic structure that overflowed into a shallower aerobic or facultative second stage lagoon. An effluent with less odor and fewer organic solids than a SSL resulted. This advantage is especially evident where pumping of the effluent can cause plugging (32).

First stage lagoons of TSL systems were designed such that the liquid level remained constant; any fluctuation occurred in the second stage lagoon. In this way a better environment for digesting bacteria could be maintained. Capacity requirements for the first stage lagoons were calculated as minimum design volume plus freeboard.

Total design volume for second stage lagoons of TSL systems was calculated as the sum of minimum design volume, waste storage volume, dilution volume and freeboard. An emergency spillway was included for the second stage lagoon in the event of an overflow. The various design volumes mentioned above retain the definitions given in the description of SSL systems.

With regard to system management, semi-annual irrigation of effluent from the second stage lagoon (down to the minimum design volume) was assumed. Due to the decomposed nature of the effluent, no agitation was necessary.

It is well-documented that sludge buildup occurs in dairy lagoons (32, 38, 39, 42, 47, 68). As a result of this fact, agitation of and sludge removal from the first stage lagoon on a five year rotation was modeled. Sludge removal was accomplished by irrigation using a big gun sprinkler.

Since sludge removal was not an annual task, agitation pumps required in this procedure were assumed to be rented rather than purchased. It was also assumed that tractors of the size necessary to operate rented agitation pumps were already available (owned).

80-Cow Herds

Certain parameters of TSL systems on 80-cow herds were assumed constant over varying confinement schemes and collection methods. These parameters were the following:

one 500 gpm irrigation pump
one traveling big gun with 850 ft. hose
2,000 ft. of mainline six-inch PVC pipe
25 ft. of 10-inch PVC pipe
one 85 hp. tractor for agitation
one 65 hp. tractor for irrigation
one rented agitation pump
one standard push-off ramp
additional concrete, 530 $ft.^2$ x four inches

Parameters which varied by confinement system and/or collection method are discussed below.

80/PC/TSL/SC. Based upon requirements discussed previously, the first stage lagoon was modeled with a total volume of 104,500 $ft.^3$ The second stage lagoon would have a capacity of 169,100 $ft.^3$ A standard tractor and scrape collection method was modeled on this system. Dimensions of the lagoons and parameters specific to this system are as follows:

one first stage lagoon, 140 ft. x 100 ft. x 16 ft.
one second stage lagoon, 200 ft. x 130 ft. x 8 ft.
one 37 hp. tractor for scraping
one six ft. box scrape
1,240 linear ft. of net wire fencing
two 12 ft. aluminum gates

80/PC/TSL/FC. Although first and second stage lagoon volumes were identical to those for the 80/PC/TSL/SC system, collection methods did differ. This system utilized hydraulic flush to collect dairy wastes. Physical parameters unique to this system are listed below:

one first stage lagoon, 140 ft. x 100 ft. x 16 ft.
one second stage lagoon, 200 ft. x 130 ft. x 8 ft.
one 1/2 hp. recycle pump (20 gpm)
two 1,000 gallon flush tanks
lot modifications totaling $400
1,240 linear ft. of net wire fencing
two 12 ft. aluminum gates

80/TC/TSL/SC. Utilizing SCS specifications, a TSL storage/treatment facility was modeled for the 80/TC/TSL/SC system. The first stage lagoon included a total capacity of 174,800 $ft.^3$ The second stage was rated at 216,800 $ft.^3$ A standard collection method using tractor and scrape was also modeled. Specific physical parameters for this system are given below:

one first stage lagoon, 200 ft. x 105 ft. x 16 ft.
one second stage lagoon, 200 ft. x 170 ft. x 8 ft.
one 37 hp. scraping tractor
one six ft. box scrape
1,450 linear ft. of net wire fencing
three 12 ft. aluminum gates

80/TC/TSL/FC. Total capacities of the first and second stage lagoons modeled for this system were identical to those of the 80/TC/-TSL/FC system. However, collection methods differed. Hydraulic flush was utilized to collect dairy waste for this system. Specific physical parameters are given below:

one first stage lagoon, 200 ft. x 105 ft. x 16 ft.
one second stage lagoon, 200 ft. x 170 f.t x 8 ft.
one 1.2 hp. recycle pump (20 gpm)
two 1,000 gallon flush tanks
lot modifications totaling $400
1,450 linear ft. of net wire fencing
three 12 ft. aluminum gates

160-Cow Herds

Certain parameters of TSL systems modeled for 160-cow herds were assumed to be unchanged in response to varying confinement schemes and collection methods. These parameters were the following:

one 700 gpm irrigation pump
one traveling big gun with 1,000 ft. hose
3,000 ft. of mainline six-inch PVC pipe
30 ft. of 10-inch PVC pipe
one 105 hp. tractor for agitation
one 85 hp. tractor for irrigation
one rented agitation pump
one standard push-off ramp
additional concrete 1,060 $ft.^2$ x four inches

Parameters which did vary as confinement system and/or collection method varied are discussed below.

160/PC/TSL/SC. Based upon standard specifications, a TSL system was modeled utilizing first and second stage lagoons with capacities of 200,400 $ft.^3$ and 324,800 $ft.^3$ respectively. A standard tractor and scrape collection method were incorporated in this waste management system. Specific dimensions of the lagoon facilities and other parameters are described below:

one first stage lagoon, 200 ft. x 115 ft. x 16 ft.
one second stage lagoon, 245 ft. x 200 ft. x 8 ft.
one 37 hp. scraping tractor
one six ft. box scrape
1,620 linear ft. of net wire fencing
three 12 ft. aluminum gates

160/PC/TSL/FC. TSL storage facilities identical to those modeled on the 160/PC/TSL/SC system were used with this system. However, due to utilization of hydraulic flush waste collection, parameters associated with waste collection differed between the two systems. Specific physical parameters of this system are as follows:

one first stage lagoon, 200 ft. x 115 ft. x 16 ft.
one second stage lagoon, 245 ft. x 200 ft. x 8 ft.
one 1/2 hp. recycle pump (20 gpm)
four 1,000 gallon flush tanks
lot modifications totaling $800
1,620 linear ft. of net wire fencing
three 12 ft. aluminum gates

160/TC/TSL/SC. First and second stage lagoon structures were modeled for this system according to standard specifications. Total capacities of the modeled first and second stage lagoons were 328,400 $ft.^3$ and 404,000 $ft.^3$ respectively. A standard tractor and scrape waste collection method was utilized. Physical dimensions of the synthesized lagoons as well as other parameters associated with this system are listed below:

one first stage lagoon, 200 ft. x 165 ft. x 16 ft.
one second stage lagoon, 300 ft. x 200 ft. x 8 ft.
one 37 hp. scraping tractor
one six ft. box scrape
1,830 linear ft. of net wire fencing
four 12 ft. aluminum gates

160/TC/TSL/FC. Rated capacities of first and second stage lagoon facilities modeled for this system were identical to those for the 160/TC/TSL/SC system. Because collection methods differed, all physical parameters were not identical however. Specific parameters for this system are as follows:

one first stage lagoon, 200 ft. x 165 ft. x 16 ft.
one second stage lagoon, 300 ft. x 200 ft. x 8 ft.
one 1/2 hp. recycle pump (20 gpm)

four 1,000 gallon flush tanks
lot modifications totaling $800
1,830 linear ft. of net wire fencing
four 12 ft. aluminum gates

320-Cow Herds

Certain parameters of TSL systems modeled for 320-cow herds were assumed constant over varying confinement schemes and collection methods. These constant parameters were the following:

one 1,000 gpm irrigation pump
one traveling big gun with 1,250 ft. hose
5,000 ft. of mainline six-inch PVC pipe
38 ft. of 10-inch PVC pipe
one 165 hp. tractor for agitation
one 125 hp. tractor for irrigation
one rented agitation pump
one standard push-off ramp
additional concrete 2,120 $ft.^2$ x four inches

A discussion of parameters that did vary with variation in confinement system and/or collection method follows.

320/PC/TSL/SC. Lagoon capacities for this system were modeled in accordance with required specifications. The first stage lagoon included a modeled total volume of 401,200 $ft.^3$; the second stage was rated at 605,300 $ft.^3$ A standard tractor and scrape collection method was modeled on this system. Physical parameters are listed below:

one first stage lagoon, 220 ft. 200 ft. x 16 ft.
one second stage lagoon, 300 ft. x 290 ft. x 8 ft.
one 37 hp. scraping tractor
one six ft. box scrape
2,120 linear ft. of net wire fencing
four 12 ft. aluminum gates

320/PC/TSL/FC. Although lagoon capacities modeled for this system were identical to those for the 320/PC/TSL/SC system, collection methods did differ. A hydraulic flush method was utilized on this particular system. Specific physical parameters are enumerated below:

one first stage lagoon, 220 ft.x 200 ft. x 16 ft.
one second stage lagoon, 300 ft. x 290 ft. x 8 ft.
one 1/2 hp. recycle pump (20 gpm)
six 1,000 gallon flush tanks
lot modifications totaling $1,200
2,120 linear ft. of net wire fencing
four 12 ft. aluminum gates

320/TC/TSL/SC. Based upon standard specifications, the first stage lagoon of this TSL system was synthesized at 635,600 $ft.^3$ The second stage lagoon was modeled to be 751,000 $ft.^3$ A standard tractor and scrape collection method was incorporated into the system. Specific parameters are detailed below:

one first stage lagoon, 285 ft. x 200 ft. x 16 ft.
one second stage lagoon, 355 ft. x 300 ft. x 8 ft.
one 37 hp. scraping tractor
one six ft. box scrape
2,380 linear ft. of net wire fencing
five 12 ft. aluminum gates

320/TC/TSL/FC. Total volume capacities of lagoon facilities synthesized for this particular waste management system were identical to those for the 320/TC/TSL/SC system. However, this system differed in that hydraulic flush was utilized as a waste collection method. Specific parameters of this waste system are:

one first stage lagoon, 285 ft. x 200 ft. x 16 ft.
one second stage lagoon, 355 ft. x 300 ft. 8 ft.
one 1/2 hp. recycle pump (20 gpm)
six 1,000 gallon flush tanks
lot modifications totaling $1,200
2,380 linear ft. of net wire fencing
five 12 ft. aluminum gates

CHAPTER IV

ECONOMIC COMPARISONS OF MODELED DAIRY WASTE MANAGEMENT SYSTEMS

Economic comparisons of modeled dairy waste management systems were made based upon initial investment and net annual costs. Initial investment was chosen as a basis of comparison due to the highly leveraged position of many dairy farmers. It is possible that a dairy farm manager may opt for a waste management system that requires the least initial capital outlay even though this system may not be the most economically efficient system in the long run. Net annual cost was also utilized as an analytical method. Net annual cost is the optimal tool for comparison. Annualized costs are charged off against annualized returns (manurial fertilizer value), thus presenting a more complete economic view of the dairy waste management system being analyzed.

Initial Investment

Dairy waste management systems were compared, with initial investment as the criteria, on each herd size and confinement system. Realistically, comparisons of waste systems across confinement systems for a given herd size is not rational (e.g. comparing the 80/PC/EP/3 system with the 80/TC/DS/6 system). It was assumed that the choice of confinement system was not predicated upon the dairy waste system planned for use in the total dairy system or enterprise. Therefore comparisons of this nature were useful only to observe the effect of increased volume of wastes on a particular type of waste system.

Only equipment/facilities predominately utilized for dairy waste management were included in this initial investment analysis. It is these items that would most likely need to be purchased in order to install the particular waste system. Tractors used for hauling/spreading, agitation, and irrigation were assumed to be resident on the dairy farm prior to installation of a particular dairy waste system.

Analysis of Systems on Specific Herd Sizes/Confinement Systems

Initial investment costs were viewed in terms of both total investment and investment per cow.

80/PC. Total initial investment required to install the various dairy waste management systems on 80-cow herds utilizing partial confinement ranged from $22,670 for the DH system to $107,470 for the SAGT/6 system. Tables IV-1 and IV-2 provide a tabular analysis of initial investment costs of the studied systems. A more graphic comparison is given in Figure IV-1.

The SAGT/6 system required over 474% of the investment needed for the DH system. Table IV-3 provides a ranking based on initial investment of the modeled systems and relative investment cost (as compared to the lowest investment cost system).

Storage structure cost was a major determinant in relative initial investment. The relative importance of initial investment in storage structures can be visualized more clearly by expressing storage structure investment as a percent of total system investment. For example, as a class of systems the AGT systems required the greatest investment; on an average, investment in storage structures for AGT systems represented over 66% of the total initial outlay. However, investment in

Table IV-1. Initial Investment Budget for 80/PC/DH,[1] 80/PC/DS/3, 80/PC/EP/3, 80/PC/SAGT/3, 80/PC/CAGT/3, 80/PC/SSL/SC, and 80/PC/TSL/SC Systems.

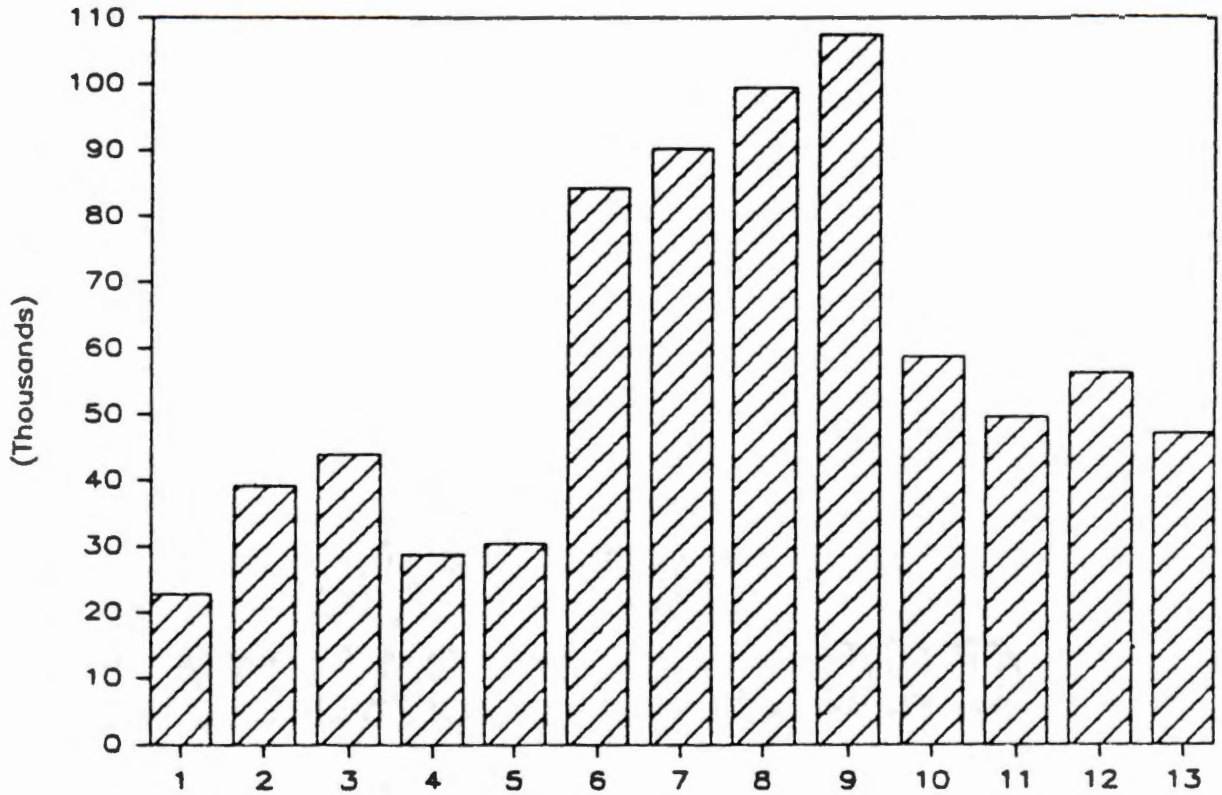
Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	16000	16000	12500	12500	12500	12500	12500
Box scrape (6 ft.)	700	700	700	700	700	700	700
Box spreader (180 bu.)	5000	5000					
Tank spreader (1500 gal.)			6300	6300	6300		
Agitation/removal pump			4300			5600	
Agitation/transfer pump (800 gpm)				6900	6900		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (500 gpm)						7400	7400
Traveling big gun (850 ft. hose)						12900	12900
Mainline PVC (2000 ft.)						7200	7200
Dry stack (13670 ft.^{3})		16020					
Earth. pit (49350 ft.^{3})			3330				
Abvegrnd. tank (42270 ft.^{3})				67400	52300		
Collection sump (645 ft.^{3})				4560	4560		
Single stage lagoon (213800 ft.^{3})						10440	
Two stage lagoon (273600 ft.^{3})							13010
Added concr.and curbing	970	1500	1110	1010	1010	1110	1110
Fencing, gates, etc.			490			830	1460
Total	22670	39220	28730	99370	84270	58680	56280
Per cow	283	490	359	1242	1053	734	704

[1] Equip./structures used primarily for waste handling. Source: Local/national dealers and contractors.

Table IV-2. Initial Investment Budget for 80/PC/DS/6, 80/PC/EP/6, 80/PC/SAGT/6, 80/PC/CAGT/6, 80/PC/SSL/FC, and 80/PC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	16000	12500	12500	12500		
Box scrape (6 ft.)	700	700	700	700		
Box spreader (180 bu.)	5000					
Tank spreader (1500 gal.)		6300	6300	6300		
Agitation/removal pump		4300			5600	
Agitation/transfer pump (800 gpm)			6900	6900		
Recycle pump (1/2 hp)					350	350
Flush tanks (manual)					3600	3600
Irri. pump (500 gpm)					7400	7400
Traveling big gun (850 ft. hose)					12900	12900
Mainline PVC (2000 ft.)					7200	7200
Dry stack (18720 $ft.^3$)	20790					
Eart. pit (66100 $ft.^3$)		5010				
Abvegrnd tank (55900 $ft.^3$)			75500	58300		
Collection sump (645 $ft.^3$)			4560	4560		
Single stage lagoon (213800 $ft.^3$)					10440	
Two stage lagoon (273600 $ft.^3$)						13010
Added concr.and curbing	1590	1110	1010	1010	1410	1410
Fencing, gates, etc.		590			830	1460
Total	44080	30510	107470	90270	49730	47330
Per cow	551	381	1343	1128	622	592

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-1. Initial Investments Required to Install Modeled Dairy Waste Systems on the 80/PC Herd Size/Confinement System.

Table IV-3. Ranking of Dairy Waste Management Systems Modeled for the 80/PC Herd Size/Confinement System.

Rank[1]	System	Investment Cost Index[2]
1	DH[3]	100
2	EP/3	127
3	EP/6	135
4	DS/3	173
5	DS/6	194
6	TSL/FC	209
7	SSL/FC	219
8	TSL/SC	248
9	SSL/SC	259
10	CAGT/3	372
11	CAGT/6	398
12	SAGT/3	438
13	SAGT/6	474

[1]Rank was based upon total investment cost, lowest to highest.

[2]Investment cost index for each system was determined by dividing the total initial investment of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least investment cost system in this instance.

storage structures for all earthen pit systems represented an average of 14% of total system investment.

This relationship between the relatively more expensive storage structures and the more costly system was not consistent however. On the average, initial investment in storage structures on DS systems represented slightly over 44% of total investment costs. However, for SSL systems (which required greater total investment) investment cost was only about 19% of the total cost. Indeed, for TSL systems (which were slightly less costly than corresponding SSL systems) storage structure cost represented over 25% of total system investment on average. The relative cost of components used in each modeled waste system are shown in Tables IV-4 and IV-5.

Lagoon system (both TSL and SSL) utilizing flush collection methods were found to require less initial outlay than similar lagoon systems using standard tractor and scrape methods. Additionally, using methods of this study, TSL systems required less initial investment than their SSL counterparts (based on collection method). This finding was contrary to expectations.

Analysis of the effect of storage size on systems modeled for the 80/PC dairy was also conducted. Doubling storage capacity (from three-months to six-months storage) of DS, EP, CAGT, and SAGT systems increased investment costs by 12%, 6%, 8%, and 7% respectively. Thus, investment economies of system storage capacity are most evident with the EP system. However, in all cases, increasing storage capacity appears to be economically efficient when analyzed from this perspective alone.

Table IV-4. Relative Cost of Waste System Components Modeled on 80/PC/DH, 80/PC/DS/3, 80/PC/EP/3, 80/PC/SAGT/3, 80/PC/CAGT/3, 80/PC/SSL/SC, and 80/PC/TSL/SC Systems.[1]

Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	70.6%	40.8%	43.5%	12.6%	14.8%	21.3%	22.2%
Box scrape (6 ft.)	3.0%	1.8%	2.4%	0.7%	0.8%	1.2%	1.2%
Box spreader (180 bu.)	22.1%	12.7%					
Tank spreader (1500 gal.)			21.9%	6.3%	7.5%		
Agitation/removal pump			15.0%			9.5%	
Agitation/transfer pump (800 gpm)				6.9%	8.2%		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (500 gpm)						12.6%	13.1%
Traveling big gun (850 ft. hose)						22.0%	22.9%
Mainline PVC (2000 ft.)						12.3%	12.8%
Dry stack (13670 ft.^{3})		40.8%					
Earth. pit (49350 ft.^{3})			11.6%				
Abvegrnd. tank (42270 ft.^{3})				67.8%	62.1%		
Collection sump (645 ft.^{3})				4.6%	5.4%		
Single stage lagoon (213800 ft.^{3})						17.8%	
Two stage lagoon (273600 ft.^{3})							23.1%
Added concr.and curbing	4.3%	3.0%	3.9%	1.0%	1.2%	1.9%	2.0%
Fencing, gates, etc.			1.7%			1.4%	2.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-5. Relative Cost of Waste System Components Modeled on 80/PC/DS/6, 80/PC/EP/6, 80/PC/SAGT/6, 80/PC/CAGT/6, 80/PC/SSL/FC, and 80/PC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	36.3%	41.0%	11.6%	13.8%		
Box scrape (6 ft.)	1.6%	2.3%	0.7%	0.8%		
Box spreader (180 bu.)	11.3%					
Tank spreader (1500 gal.)		20.6%	5.9%	7.0%		
Agitation/removal pump		14.1%			11.3%	
Agitation/transfer pump (800 gpm)			6.4%	7.6%		
Recycle pump (1/2 hp)					0.7%	0.7%
Flush tanks (manual)					7.2%	7.6%
Irri. pump (500 gpm)					14.9%	15.6%
Traveling big gun (850 ft. hose)					25.9%	27.3%
Mainline PVC (2000 ft.)					14.5%	15.2%
Dry stack (18720 ft.^{3})	47.2%					
Eart. pit (66100 ft.^{3})		16.4%				
Abvegrnd tank (55900 ft.^{3})			70.3%	64.6%		
Collection sump (645 ft.^{3})			4.2%	5.1%		
Single stage lagoon (213800 ft.^{3})					21.0%	
Two stage lagoon (273600 ft.^{3})						27.5%
Added concr.and curbing	3.6%	3.6%	0.9%	1.1%	2.8%	3.0%
Fencing, gates, etc.		1.9%			1.7%	3.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Investment per cow was also a useful measure to compare investment requirements of various waste systems. Estimated investment for systems modeled on the 80/PC herd ranged from $283 (DH) to $1343 (SAGT/6). Investment per cow for each modeled system is shown in Tables IV-1 and IV-2. At a later point investment per cow will be compared across herd sizes.

As shown in Table IV-3, for the 80-cow herd size utilizing partial confinement, DH was the least costly system class. EP systems were 27-35% higher; DS systems were 73 to 94% higher. Lagoon systems, both standard collection and flush collection methods, would require two to two and one-half times as much investment as DH. The most capital intensive class of systems were the above-ground tank systems, with CAGT systems requiring the lesser investment of the two. Indeed, based upon estimates of this study, a CAGT/6 system could be installed more cheaply than SAGT/3 system. Thus, a dairy farmer could obtain approximately twice the storage capacity for a smaller total capital outlay by choosing a concrete structure over a fused glass-to-steel structure. Among those systems utilizing storage, the most dramatic comparison was found between the EP/6 and the SAGT/6 systems. The SAGT/6 required initial investment over three and one-half times that of the EP/6 system.

80/TC. Total initial investment required to install modeled dairy waste management systems on a 80-cow herd utilizing total confinement ranged from $22,670 for the DH system to $123,580 for the SAGT/6 system. Because the DH system utilized no storage structure, initial investment for the 80/TC herd remained the same as that for the 80/PC

herd. Estimated initial capital investments required for all modeled waste systems associated with the 80/TC herd size/confinement systems are shown in Tables IV-6 and IV-7. A graphic comparison of investment costs of the various systems is shown in Figure IV-2.

The SAGT/6 system would require a capital outlay 542% of the outlay necessary to install the DH system. The relative ranking of the modeled systems (based on the investment parameter) changed in comparison to the 80/PC herd size/confinement system. The rankings of modeled waste systems in terms of relative capital outlay is shown in Table IV-8.

It should be noted that the DS/6 system modeled for this herd size/confinement system required greater capital investment than either of the lagoon systems utilizing flush collection. In addition, in this model, the CAGT/6 system required more investment than the SAGT/3 system. Thus, for this case, it is not possible to obtain six-months storage in an above-ground tank more cheaply than three-months storage merely by substituting concrete walls for steel walls.

Storage structure remained a substantial portion of the investment cost. Storage structure cost represented over 67% of total investment on AGT systems (the most costly class of waste system to install). Conversely, for EP systems (the least cost waste system utilizing storage), storage structure cost represented about 18% of total system investment cost. Storage structure cost for lagoon systems (SSL and TSL) were 18 to 28 percent of total investment compared to 44 to 56 percent for DS systems. Comparisons of the relative cost of system components for the 80/TC systems are shown in Tables IV-9 and IV-10.

Table IV-6. Initial Investment Budget for 80/TC/DH,[1] 80/TC/DS/3, 80/TC/EP/3, 80/TC/SAGT/3, 80/TC/CAGT/3, 80/TC/SSL/SC, and 80/TC/TSL/SC Systems.

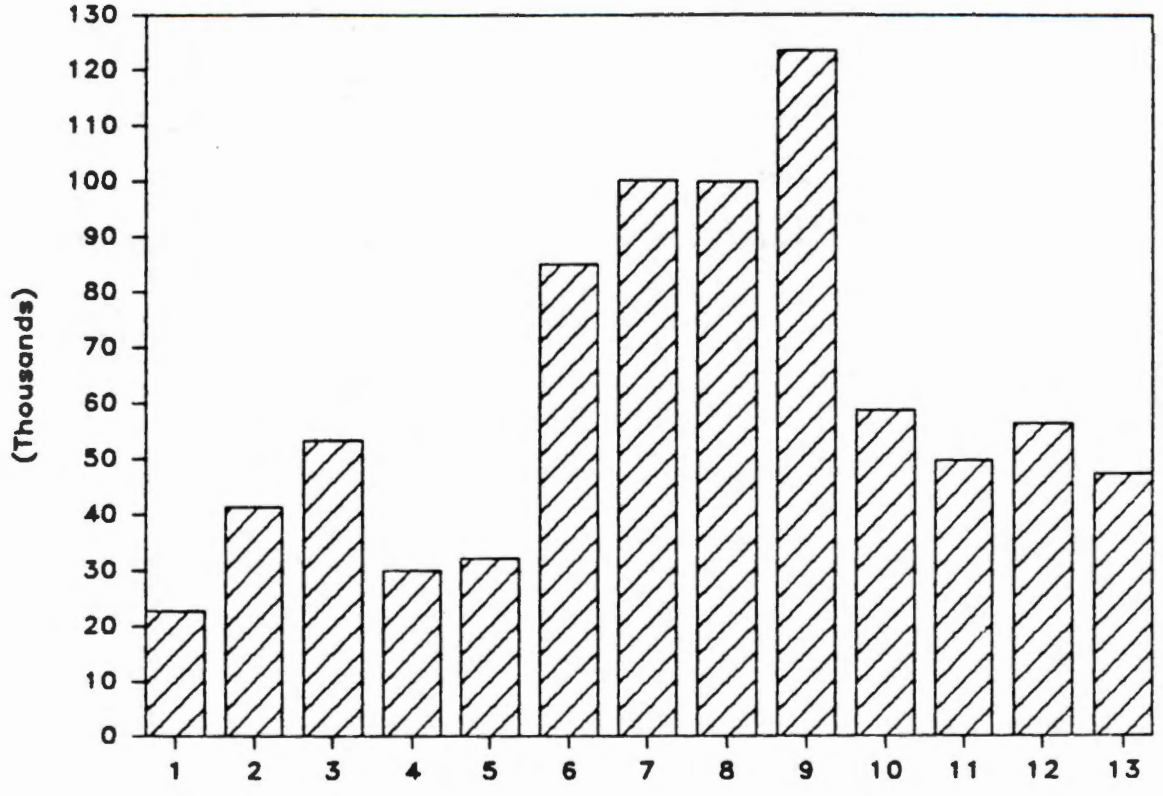
Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	16000	16000	12500	12500	12500	12500	12500
Box scrape (6 ft.)	700	700	700	700	700	700	700
Box spreader (180 bu.)	5000	5000					
Tank spreader (1500 gal.)			6300	6300	6300		
Agitation/removal pump			4300			5600	
Agitation/transfer pump (800 gpm)				6900	6900		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (500 gpm)						7400	7400
Traveling big gun (850 ft. hose)						12900	12900
Mainline PVC (2000 ft.)						7200	7200
Dry stack (16920 ft.^{3})		18230					
Earth. pit (56050 ft.^{3})			4540				
Abvegrnd tank (42270 ft.^{3})				67400	52300		
Collection sump (1070 ft.^{3})				5270	5270		
Single stage lagoon (302800 ft.^{3})						13830	
Two stage lagoon (391600 ft.^{3})							17890
Added concr.and curbing	970	1500	1110	1010	1010	1110	1110
Fencing, gates, etc.			550			890	1720
Total	22670	41430	30000	100080	84980	62130	61420
Per cow	283	518	375	1254	1062	777	768

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-7. Initial Investment Budget for 80/TC/DS/6, 80/TC/EP/6, 80/TC/SAGT/6, 80/TC/CAGT/6, 80/TC/-SSL/FC, and 80/TC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	16000	12500	12500	12500		
Box scrape (6 ft.)	700	700	700	700		
Box spreader (180 bu.)	5000					
Tank spreader (1500 gal.)		6300	6300	6300		
Agitation/removal pump		4300			5600	
Agitation/transfer pump (800 gpm)			6900	6900		
Recycle pump (1/2 hp)					350	350
Flush tanks (manual)					3600	3600
Irri. pump (500 gpm)					7400	7400
Traveling big gun (850 ft. hose)					12900	12900
Mainline PVC (2000 ft.)					7200	7200
Dry stack (30240 ft.^{3})	30030					
Eart. pit (79500 ft.^{3})		6520				
Abvegrnd tank (69540 ft.^{3})			90900	67600		
Collection sump (1070 ft.^{3})			4560	4560		
Single stage lagoon (302800 ft.^{3})					13830	
Two stage lagoon (391600 ft.^{3})						17890
Added concr.and curbing	1690	1110	1010	1010	1410	1410
Fencing, gates, etc.		680			890	1720
Total	53420	32110	123580	100280	53180	52470
Per cow	668	401	1545	1254	665	656

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-2. Initial Investments Required to Install Modeled Dairy Waste Systems on the 80/TC Herd Size/Confinement System.

Table IV-8. Ranking of Dairy Waste Management Systems Modeled for the 80/TC Herd Size/Confinement System.

Rank[1]	System	Investment Cost Index[2]
1	DH[3]	100
2	EP/3	132
3	EP/6	142
4	DS/3	183
5	TSL/FC	231
6	SSL/FC	235
7	DS/6	236
8	TSL/SC	271
9	SSL/SC	274
10	CAGT/3	375
11	SAGT/3	438
12	CAGT/6	442
13	SAGT/6	542

[1]Rank was based upon total investment cost, lowest to highest.

[2]Investment cost index for each system was determined by dividing the total initial investment of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least investment cost system in this instance.

Table IV-9. Relative Cost of Waste System Components Modeled on 80/TC/DH, 80/TC/DS/3, 80/TC/EP/3, 80/TC/SAGT/3, 80/TC/CAGT/3, 80/TC/SSL/SC, and 80/TC/TSL/SC Systems.[1]

Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	70.6%	30.6%	41.7%	12.5%	14.7%	21.3%	22.2%
Box scrape (6 ft.)	3.1%	1.7%	2.3%	0.7%	0.8%	1.2%	1.2%
Box spreader (180 bu.)	22.1%	12.1%					
Tank spreader (1500 gal.)			21.0%	6.3%	7.4%		
Agitation/removal pump			14.3%			9.5%	
Agitation/transfer pump (800 gpm)				6.9%	8.1%		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (500 gpm)						12.6%	13.1%
Traveling big gun (850 ft. hose)						22.0%	22.9%
Mainline PVC (2000 ft.)						12.3%	12.8%
Dry stack (16920 ft.^{3})		44.0%					
Earth. pit (56050 ft.^{3})			15.1%				
Abvegrnd tank (42270 ft.^{3})				67.3%	61.5%		
Collection sump (1070 ft.^{3})				5.3%	6.2%		
Single stage lagoon (302800 ft.^{3})						17.8%	
Two stage lagoon (391600 ft.^{3})							23.1%
Added concr.and curbing	4.3%	3.6%	3.7%	1.0%	1.2%	1.9%	2.0%
Fencing, gates, etc.			1.8%			1.4%	2.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-10. Relative Cost of Waste System Components Modeled on 80/TC/DS/6, 80/TC/EP/6, 80/TC/SAGT/6, 80/TC/CAGT/6, 80/TC/SSL/FC, and 80/TC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	30.0%	38.9%	10.1%	12.5%		
Box scrape (6 ft.)	1.3%	2.2%	0.6%	0.7%		
Box spreader (180 bu.)	9.4%					
Tank spreader (1500 gal.)		19.6%	5.1%	6.3%		
Agitation/removal pump		13.4%			11.3%	
Agitation/transfer pump (800 gpm)			5.6%	6.9%		
Recycle pump (1/2 hp)					0.7%	0.7%
Flush tanks (manual)					7.2%	7.6%
Irri. pump (500 gpm)					14.9%	15.6%
Traveling big gun (850 ft. hose)					25.9%	27.3%
Mainline PVC (2000 ft.)					14.5%	15.2%
Dry stack (30240 ft^3)	56.2%					
Eart. pit (79500 ft^3)		20.3%				
Abvegrnd tank (69540 $ft.^3$)			73.6%	67.4%		
Collection sump (1070 $ft.^3$)			4.3%	5.3%		
Single stage lagoon (302800 $ft.^3$)					21.0%	
Two stage lagoon (391600 $ft.^3$)						27.5%
Added concr.and curbing	3.2%	3.5%	0.8%	1.0%	2.8%	3.0%
Fencing, gates, etc.		2.1%			1.7%	3.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Increasing storage capacity of modeled EP, DS, CAGT and SAGT waste systems from three-months to six-months storage increased investment costs by 7%, 29% 18%, and 24% respectively. Thus, investment economies of storage structure size were found to exist in all systems utilizing storage with the EP system exhibiting the greatest relative economies.

In analyzing initial investment costs on a per cow basis, it was found that costs ranged from $283 per cow for the DH system to $1,536 per cow for the SAGT/6 system. Investment per cow for the various modeled waste systems are shown in Tables IV-6 and IV-7.

Thus, based upon initial investment, DH was the least costly dairy waste system for the 80/TC herd size/confinement system. The EP class of waste systems ranked second. The DS/3 system, and then lagoon systems utilizing flush collection followed. Ranked behind these systems were DS/6 and then lagoon systems using standard collection methods. Generally, AGT systems required the greatest initial investment, with SAGT systems being the more costly of the two types of AGT systems.

160/PC. Estimated total initial investment required to install modeled dairy waste management systems on a 160-cow herd utilizing partial confinement ranged from $25,490 for a DH system to $142,790 for a SAGT/6 system. Complete capital investment data for all dairy waste systems modeled for the 160/PC herd size/confinement system is shown in Tables IV-11 and IV-12. Relative total investment requirements for the various systems are shown graphically in Figure IV-3.

The DH system was easily the least capital intensive system, while the SAGT/6 system was again the most capital intensive. The SAGT/6

Table IV-11. Initial Investment Budget for 160/PC/DH, 160/PC/DS/3, 160/PC/EP/3, 160/PC/SAGT/3, 160/PC/CAGT/3, 160/PC/SSL/SC, and 160/PC/TSL/SC Systems.[1]

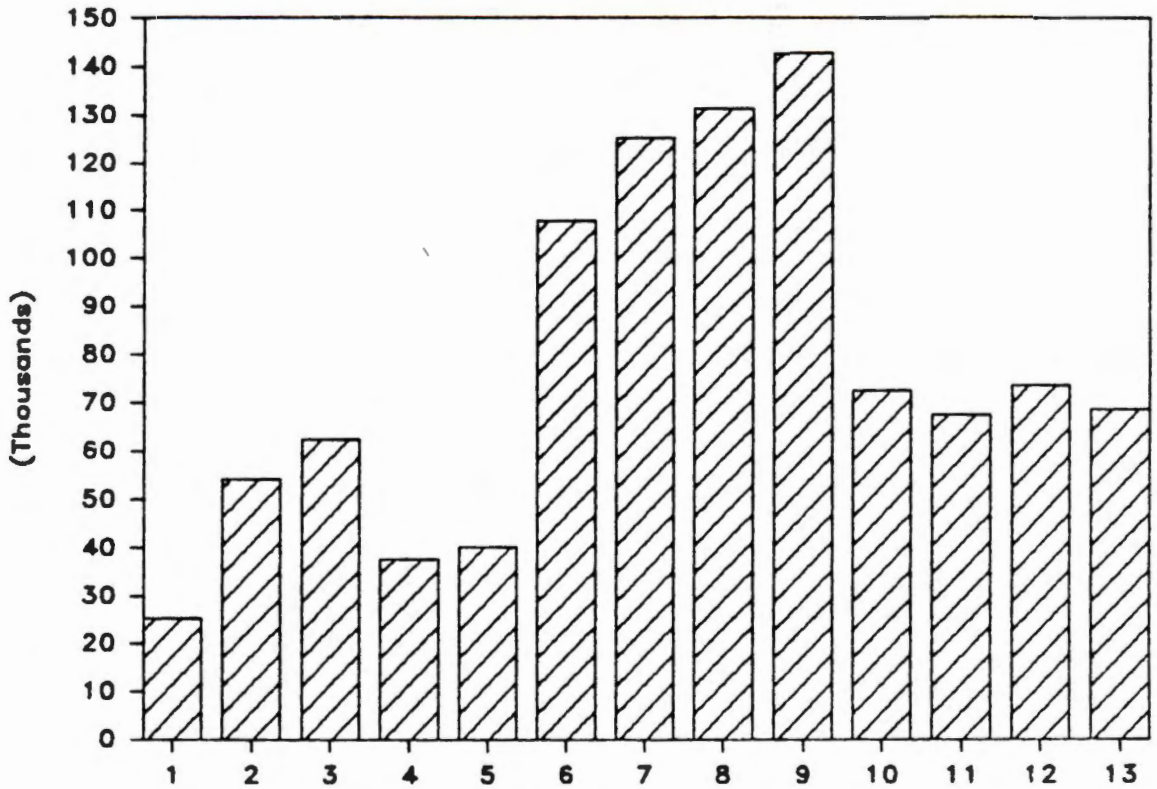
Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	16000	16000	12500	12500	12500	12500	12500
Box scrape (6 ft.)	700	700	700	700	700	700	700
Box spreader (275 bu.)	7200	7200					
Tank spreader (3000 gal.)			11400	11400	11400		
Agitation/removal pump			4300			5600	
Agitation/transfer pump (1000 gpm)				8500	8500		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (700 gpm)						7400	7400
Traveling big gun (850 ft. hose)						15100	15100
Mainline PVC (3000 ft.)						10800	10800
Dry stack (27330 ft.^{3})		28110					
Earth. pit (94350 ft.^{3})			6270				
Abvegrnd tank (69540 ft.^{3})				90900	67600		
Collection sump (1285 ft.^{3})				5620	5620		
Single stage lagoon (405200 ft.^{3})						17410	
Two stage lagoon (525200 ft.^{3})							23010
Added concr.and curbing	1590	2360	1890	1670	1670	1890	1890
Fencing, gates, etc.			640			1040	2220
Total	25490	54370	37700	131290	107990	72440	73620
Per cow	159	340	236	821	675	453	460

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-12. Initial Investment Budget for 160/PC/DS/6, 160/PC/EP/6, 160/PC/SAGT/6, 160/PC/CAGT/6, 160/PC/SSL/FC, and 160/PC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	16000	12500	12500	12500		
Box scrape (6 ft.)	700	700	700	700		
Box spreader (275 bu.)	7200					
Tank spreader (3000 gal.)		11400	11400	11400		
Agitation/removal pump		4300			5600	
Agitation/transfer pump (1000 gpm)			8500	8500		
Recycle pump (1/2 hp)					350	350
Flush tanks (manual)					7200	7200
Irri. pump (700 gpm)					7400	7400
Traveling big gun (850 ft. hose)					15100	15100
Mainline PVC (2000 ft.)					10800	10800
Dry stack (37440 ft.^{3})	36300					
Eart. pit (126200 ft.^{3})		8580				
Abvegrnd tank (97910 ft.^{3})			102400	84800		
Collection sump (1285 ft.^{3})			5620	5620		
Single stage lagoon (405200 ft.^{3})					17410	
Two stage lagoon (525200 ft.^{3})						23010
Added concr.and curbing	2450	1890	1670	1670	2690	2690
Fencing, gates, etc.		760			1040	2220
Total	62650	40130	142790	125190	67590	68770
Per cow	392	251	892	782	422	430

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-3. Initial Investments Required to Install Modeled Dairy Waste Systems on the 160/PC Herd Size/Confinement System.

system required a relative investment cost 560% of that necessary to install the DH system. A complete ranking of the systems by relative investment cost is shown in Table IV-13.

A fairly consistent pattern appeared in systems ranked in Table IV-13. Behind the DH system were EP systems: quite naturally three-months storage required less investment than six months storage. DS systems ranked next, followed by lagoon (SSL and TSL) systems utilizing flush collection and then lagoon systems using standard collection methods. For this herd size, SSL systems required less investment than their TSL counterparts. AGT, as a class, received the highest (least desirable) ranking based upon initial investment. CAGT systems were less expensive than SAGT systems; based upon estimates of this study, a CAGT/6 system could be installed for less capital outlay than a SAGT/3 system. Thus, three additional months storage could be purchased at less cost by altering construction material.

Of those systems incorporating similar storage sizes, the most dramatic comparison was observed between the EP/6 and SAGT/6 systems. The SAGT/6 system required a capital outlay over 355% of that needed to install an EP/6 system.

Storage structure cost was again a major determinant of relative initial investment. As an example, storage structure cost represented an average of almost 68% of total capital outlay for AGT systems. AGT systems were typically the most capital intensive of the systems modeled. Conversely, this same parameter was calculated at 19% for EP systems. EP systems were generally the least capital intensive systems of those incorporating storage. Complete data on relative cost of

Table IV-13. Ranking of Dairy Waste Management Systems Modeled for the 160/PC Herd Size/Confinement System.

Rank[1]	System	Investment Cost Index[2]
1	DH[3]	100
2	EP/3	148
3	EP/6	157
4	DS/3	213
5	DS/6	246
6	SSL/FC	265
7	TSL/FC	270
8	SSL/SC	284
9	TSL/SC	289
10	CAGT/3	424
11	CAGT/6	491
12	SAGT/3	515
13	SAGT/6	560

[1]Rank was based upon total investment cost, lowest to highest.

[2]Investment cost index for each system was determined by dividing the total initial investment of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least investment cost system in this instance.

components incorporated in each modeled system is shown in Tables IV-14 and IV-15.

Doubling storage capacity (from three-months to six-months) on DS, EP, CAGT, and SAGT systems increased investment outlays by 15%, 6%, 16% and 9% respectively. Investment economies of system storage capacity are most evident for the EP system. However, in terms of total investment, increasing storage capacity on all systems would reduce unit cost of storage significantly.

Initial investment costs ranged from $159 per cow for the DH system to $892 per cow for the SAGT/6 system. Investment per cow for each of the modeled waste systems is shown in Tables IV-11 and IV-12.

In summary, based upon the criterion on initial capital outlay, DH was the least cost dairy waste system for the 160/PC herd size/confinement system. EP systems ranked second as a class, followed by DS systems. Lagoon systems ranked next with systems using flush collection generally requiring less initial capital outlay than corresponding systems utilizing standard collection methods. AGT systems ranked last using this criterion. Generally, SAGT systems required an even greater initial investment than similar CAGT systems.

160/TC. Total capital outlays necessary to install modeled dairy waste management systems on a 160-cow herd utilizing total confinement ranged from $25,490 for a DH system to $159,300 for a SAGT/6 system. Complete initial investment data for all dairy waste systems modeled on the 160/TC herd size/confinement system is shown in Tables IV-16 and IV-17. Graphic comparisons of investments required for the various systems are shown in Figure IV-4.

Table IV-14. Relative Cost of Waste System Components Modeled on 160/PC/DH, 160/PC/DS/3, 160/PC/EP/3, 160/PC/SAGT/3, 160/PC/CAGT/3, 160/PC/SSL/SC, and 160/PC/TSL/SC Systems.[1]

Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	62.8%	29.4%	33.2%	9.5%	11.6%	17.3%	17.0%
Box scrape (6 ft.)	2.7%	1.3%	1.9%	0.5%	0.6%	1.0%	1.0%
Box spreader (275 bu.)	28.2%	13.2%					
Tank spreader (3000 gal.)			30.2%	8.7%	10.6%		
Agitation/removal pump			11.4%			7.7%	
Agitation/transfer pump (1000 gpm)				6.5%	7.9%		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (700 gpm)						10.2%	10.1%
Traveling big gun (850 ft. hose)						20.8%	20.5%
Mainline PVC (2000 ft.)						14.9%	14.7%
Dry stack (27330 ft.^{3})		51.7%					
Earth. pit (94350 ft.^{3})			16.6%				
Abvegrnd tank (69540 ft.^{3})				69.2%	62.6%		
Collection sump (1285 ft.^{3})				4.3%	5.2%		
Single stage lagoon (405200 ft.^{3})						24.0%	
Two stage lagoon (525200 ft.^{3})							31.3%
Added concr.and curbing	6.2%	4.3%	5.0%	1.3%	1.5%	2.6%	2.6%
Fencing, gates, etc.			1.7%			1.4%	3.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-15. Relative Cost of Waste System Components Modeled on 160/PC/DS/6,[1] 160/PC/EP/6, 160/PC/-SAGT/6, 160/PC/CAGT/6, 160/PC/SSL/FC, and 160/PC/TSL/FC Systems.

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	25.5%	31.1%	9.5%	10.0%		
Box scrape (6 ft.)	1.1%	1.7%	0.5%	0.6%		
Box spreader (275 bu.)	11.5%					
Tank spreader (3000 gal.)		28.4%	8.7%	9.1%		
Agitation/removal pump		10.7%			8.3%	
Agitation/transfer pump (1000 gpm)			6.5%	6.8%		
Recycle pump (1/2 hp)					0.5%	0.5%
Flush tanks (manual)					10.7%	10.5%
Irri. pump (700 gpm)					10.9%	10.8%
Traveling big gun (850 ft. hose)					22.3%	22.0%
Mainline PVC (3000 ft.)					16.0%	15.7%
Dry stack (37440 ft.^{3})	57.9%					
Eart. pit (126200 ft.^{3})		21.4%				
Abvegrnd tank (97910 ft.^{3})			69.2%	67.7%		
Collection sump (1285 ft.^{3})			4.3%	4.5%		
Single stage lagoon (405200 ft.^{3})					25.8%	
Two stage lagoon (525200 ft.^{3})						33.5%
Added concr.and curbing	3.9%	4.7%	1.3%	1.3%	4.0%	3.9%
Fencing, gates, etc.		1.9%			1.5%	3.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-16. Initial Investment Budget for 160/TC/DH, 160/TC/DS/3, 160/TC/EP/3, 160/TC/SAGT/3, 160/TC/CAGT/3, 160/TC/SSL/SC, and 160/TC/TSL/SC Systems.[1]

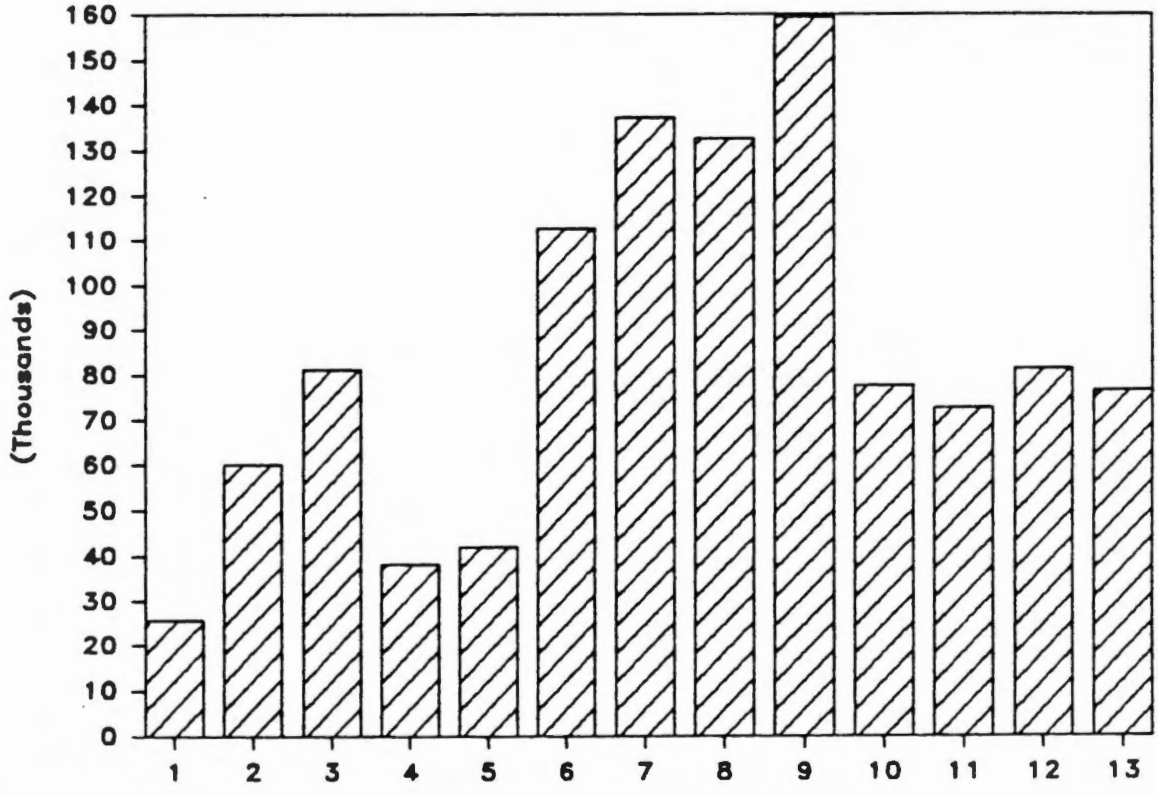
Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	16000	16000	12500	12500	12500	12500	12500
Box scrape (6 ft.)	700	700	700	700	700	700	700
Box spreader (275 bu.)	7200	7200					
Tank spreader (3000 gal.)			11400	11400	11400		
Agitation/removal pump			4300			5600	
Agitation/transfer pump (1000 gpm)				8500	8500		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (700 gpm)						7400	7400
Traveling big gun (850 ft. hose)						15100	15100
Mainline PVC (3000 ft.)						10800	10800
Dry stack (33840 ft.^{3})		33830					
Earth. pit (103450 ft.^{3})			6680				
Abvegrnd tank (73450 ft.^{3})				91000	70900		
Collection sump (2140 ft.^{3})				7030	7030		
Single stage lagoon (571600 ft.^{3})						22450	
Two stage lagoon (732400 ft.^{3})							30560
Added concr.and curbing	1590	2450	1890	1670	1670	1890	1890
Fencing, gates, etc.			660			1170	2520
Total	25490	60180	38130	132800	112700	77610	81470
Per cow	159	376	238	830	704	485	509

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-17. Initial Investment Budget for 160/TC/DS/6, 160/TC/EP/6, 160/TC/SAGT/6, 160/TC/CAGT/6, 160/TC/SSL/FC, and 160/TC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	16000	12500	12500	12500		
Box scrape (6 ft.)	700	700	700	700		
Box spreader (275 bu.)	7200					
Tank spreader (3000 gal.)		11400	11400	11400		
Agitation/removal pump		4300			5600	
Agitation/transfer pump (1000 gpm)			8500	8500		
Recycle pump (1/2 hp)					350	350
Flush tanks (manual)					7200	7200
Irri. pump (700 gpm)					7400	7400
Traveling big gun (850 ft. hose)					15100	15100
Mainline PVC (3000 ft.)					10800	10800
Dry stack (60480 ft.^{3})	54780					
Eart. pit (148950 ft.^{3})		10470				
Abvegrnd tank (120840 ft.^{3})			117500	95400		
Collection sump (2140 ft.^{3})			7030	7030		
Single stage lagoon (571600 ft.^{3})					22450	
Two stage lagoon (732400 ft.^{3})						30650
Added concr.and curbing	2650	1890	1670	1670	2690	2690
Fencing, gates, etc.		810			1170	2520
Total	81330	42070	159300	137200	72760	76620
Per cow	508	263	996	858	455	479

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-4. Initial Investments Required to Install Modeled Dairy Waste Systems on the 160/TC Herd Size/Confinement System.

Initial investment required to install the DH system remained the same as for the 160/PC herd size/confinement system. Obviously then, the DH system was again the least capital intensive of the modeled systems. The most capital intensive waste system (SAGT/6) required an initial capital outlay 625% of that necessary to install the DH system. Rankings of the modeled systems by relative investment cost using DH as the base is shown in Table IV-18.

The relative rankings of the systems changed as compared to herd size/confinement systems discussed previously. EP systems ranked behind DH as the least capital intensive. However, the two DS systems were separated in the ranking. The DS/3 system ranked fourth while the DS/6 system ranked eighth in relative investment cost. This ranking of the DS/6 system represented a drop from previous rank of seventh for a herd size utilizing total confinement (80/TC). The DS/6 system required more capital investment than lagoon systems utilizing standard collection methods, and about the same as the TSL/SC system. AGT systems were again the most capital intensive of these systems modeled, with SAGT systems being more costly than respective CAGT systems.

Comparing initial investment of modeled systems that incorporated similar storage size, it was found that the greatest difference occurred between the SAGT/6 and EP/6 systems. The SAGT/6 system required a capital outlay almost 379% of that required to install the EP/6 system.

Storage structure cost as a proportion of total investment outlay was analyzed for each class of waste system. Generally, types of systems with lower proportionate storage structure costs also required lower total investment requirements. The exception to this was the DS

Table IV-18. Ranking of Dairy Waste Management Systems Modeled for the 160/TC Herd Size/Confinement System.

Rank[1]	System	Investment Cost Index[2]
1	DH[3]	100
2	EP/3	150
3	EP/6	165
4	DS/3	236
5	SSL/FC	285
6	TSL/FC	301
7	SSL/SC	304
8	DS/6	319
9	TSL/SC	320
10	CAGT/3	442
11	SAGT/3	521
12	CAGT/6	538
13	SAGT/6	625

[1]Rank was based upon total investment cost, lowest to highest.

[2]Investment cost index for each system was determined by dividing the total initial investment of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least investment cost system in this instance.

system. It appeared at this point that proportionate storage structure cost becomes increasingly important with increases in herd size and confinement. This observation is quite logical; increases in waste volume requires greater expansions in storage structure size (and cost) than corresponding increases in equipment size (and cost). The net result is that storage structure cost represented an increasingly larger portion of initial investment. Information on proportionate cost of each item necessary to install respective waste systems is shown in Tables IV-19 and IV-20.

Analyzing the effect on capital requirements of increasing storage capacity indicated that doubling storage capacity (from three-months to six-months) on DS, EP, CAGT, and SAGT systems increased investment outlays by 35%, 9%, 22%, and 20% respectively. Substantial economies to size for each type of structure were thus reflected.

Initial investment costs per cow ranged from a low of $159 for DH to $996 for the SAGT/6 system. Investment per cow for the dairy waste management systems modeled for the 160/TC herd size/confinement system are shown in Tables IV-16 and IV-17.

In summary, based upon initial investment the least costly dairy waste system for the 160/TC herd size/confinement system was the DH system. EP systems ranked second as a class, followed by the DS/3 system. Lagoon systems using flush collection ranked next; the DS/6 and lagoon systems using standard collection methods followed. AGT systems, as a class ranked last based upon initial investment. SAGT systems were more costly than corresponding CAGT systems.

Table IV-19. Relative Cost of Waste System Components Modeled on 160/TC/DH, 160/TC/DS/3, 160/TC/EP/3, 160/TC/SAGT/3, 160/TC/CAGT/3, 160/TC/SSL/SC, and 160/TC/TSL/SC Systems.[1]

Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	62.8%	26.6%	32.8%	9.4%	11.1%	16.1%	15.3%
Box scrape (6 ft.)	2.7%	1.2%	1.8%	0.5%	0.6%	0.9%	0.9%
Box spreader (275 bu.)	28.2%	12.0%					
Tank spreader (3000 gal.)			29.9%	8.6%	10.1%		
Agitation/removal pump			11.3%			7.2%	
Agitation/transfer pump (1000 gpm)				6.4%	7.5%		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (700 gpm)						9.5%	9.1%
Traveling big gun (850 ft. hose)						19.5%	18.5%
Mainline PVC (3000 ft.)						13.9%	13.3%
Dry stack (33840 ft.^{3})		56.2%					
Earth. pit (103450 ft.^{3})			17.5%				
Abvegrnd tank (73450 ft.^{3})				68.5%	62.9%		
Collection sump (2140 ft.^{3})				5.3%	6.2%		
Single stage lagoon (571600 ft.^{3})						28.9%	
Two stage lagoon (732400 ft.^{3})							37.5%
Added concr.and curbing	6.2%	4.1%	5.0%	1.3%	1.5%	2.4%	2.3%
Fencing, gates, etc.			1.7%			1.5%	3.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-20. Relative Cost of Waste System Components Modeled on 160/TC/DS/6,[1] 160/TC/EP/6, 160/TC/-SAGT/6, 160/TC/CAGT/6, 160/TC/SSL/FC, and 160/TC/TSL/FC Systems.

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	19.7%	29.7%	9.4%	9.1%		
Box scrape (6 ft.)	0.9%	1.7%	0.4%	0.5%		
Box spreader (275 bu.)	8.9%					
Tank spreader (3000 gal.)		27.1%	7.2%	8.3%		
Agitation/removal pump		10.2%			7.7%	
Agitation/transfer pump (1000 gpm)			5.3%	6.2%		
Recycle pump (1/2 hp)					0.5%	0.5%
Flush tanks (manual)					9.9%	9.4%
Irri. pump (700 gpm)					10.2%	9.7%
Traveling big gun (850 ft. hose)					20.8%	19.7%
Mainline PVC (3000 ft.)					14.8%	14.1%
Dry stack (60480 ft.^{3})	67.4%					
Eart. pit (148950 ft.^{3})		24.9%				
Abvegrnd tank (120840 ft.^{3})			73.8%	69.5%		
Collection sump (2140 ft.^{3})			4.4%	5.1%		
Single stage lagoon (571600 ft.^{3})					30.9%	
Two stage lagoon (732400 ft.^{3})						39.9%
Added concr.and curbing	3.3%	4.5%	1.0%	1.2%	3.7%	3.5%
Fencing, gates, etc.		1.9%			1.6%	3.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

320/PC. Total initial investment required to install modeled dairy waste management systems on a 320-cow herd utilizing partial confinement ranged from $30,060 for a DH system to $229,810 for a SAGT/6 system. Complete capital investment data for all dairy waste systems modeled on the 320/PC herd size/confinement system is shown in Tables IV-21 and IV-22. A graphic comparison of investment cost for the various systems is shown in Figure IV-5. A ranking of the modeled systems by relative investment cost is shown in Table IV-23. The SAGT/6 system required a relative investment cost 765% of that necessary to install the DH system.

Ranked behind the DH system were the EP class of waste systems, followed by the DS class. Obviously, these systems using three-months storage required less investment than those incorporating six months of storage. Ranked next were SSL systems then TSL systems. Lagoon systems utilizing flush collection required less cash outlay than corresponding systems using the standard collection method. As with previous analyses, AGT systems ranked last using initial investment as the criterion.

An interesting comparison can be made between the EP/6 and SAGT/6 systems. Basically, both of these systems are quite similar in nature of operation, i.e. waste is stored and handled as a semi-solid or near-liquid (88% - 90% moisture). However, in terms of cash outlay, the SAGT/6 system required over 433% of the initial investment necessary to install the EP/6 system.

Among the systems, generally the higher the storage structure cost as a proportion of total investment, the higher the total investment

Table IV-21. Initial Investment Budget for 320/PC/DH, 320/PC/DS/3, 320/PC/EP/3, 320/PC/SAGT/3, 320/PC/CAGT/3, 320/PC/SSL/SC, and 320/PC/TSL/SC Systems.[1]

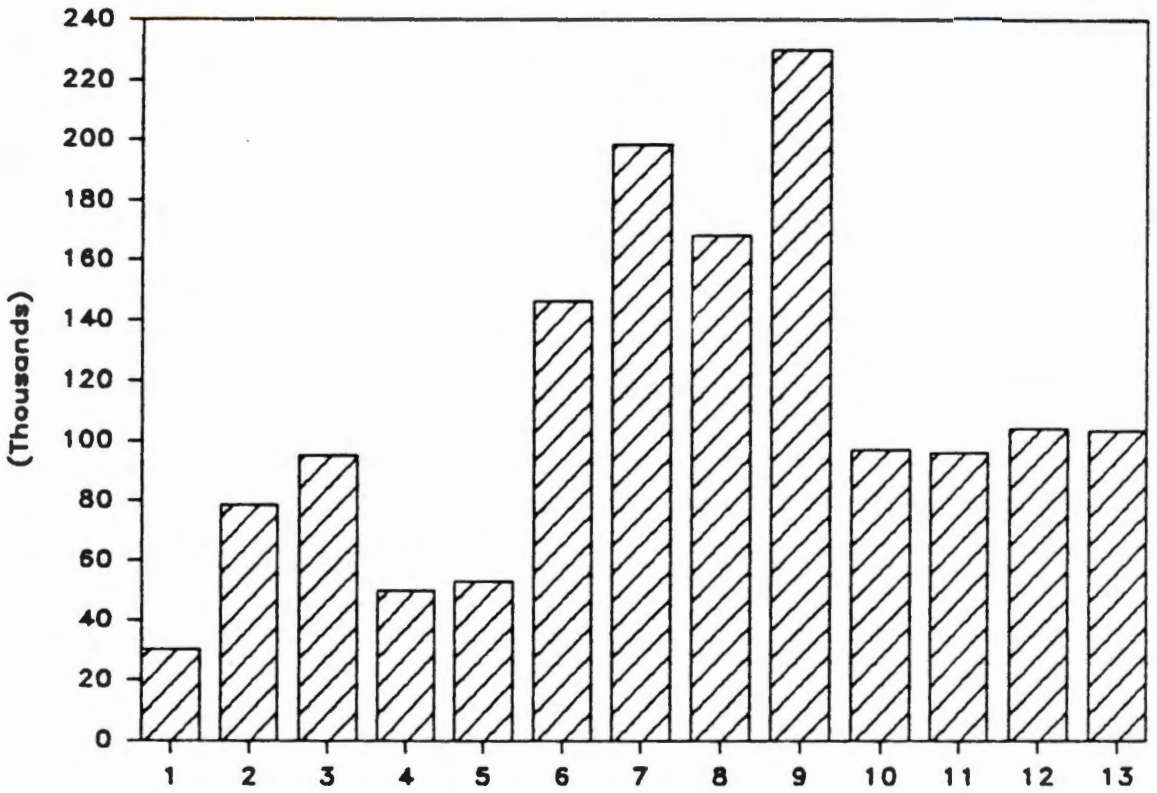
Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	16000	16000	12500	12500	12500	12500	12500
Box scrape (6 ft.)	700	700	700	700	700	700	700
Box spreader (450 bu.)	11200	11200					
Tank spreader (4500 gal.)			18500	18500	18500		
Agitation/removal pump			4500			5900	
Agitation/transfer pump (1200 gpm)				9200	9200		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (1000 gpm)						7400	7400
Traveling big gun (850 ft. hose)						20700	20700
Mainline PVC (5000 ft.)						18000	18000
Dry stack (54660 ft.^{3})		46960					
Earth. pit (148950 ft.^{3})			9560				
Abvegrnd tank (120840 ft.^{3})				117500	95400		
Collection sump (2180 ft.^{3})				7100	7100		
Single stage lagoon (776400 ft.^{3})						27240	
Two stage lagoon (1006500 ft.^{3})							38960
Added concr.and curbing	2160	3590	3130	2710	2710	3130	3130
Fencing, gates, etc.			810			1390	2870
Total	30060	78450	49700	168210	146110	96960	104260
Per cow	94	245	155	526	457	303	326

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-22. Initial Investment Budget for 320/PC/DS/6, 320/PC/EP/6, 320/PC/SAGT/6, 320/PC/CAGT/6, 320/PC/SSL/FC, and 320/PC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	16000	12500	12500	12500		
Box scrape (6 ft.)	700	700	700	700		
Box spreader (450 bu.)	11200					
Tank spreader (4500 gal.)		18500	18500	18500		
Agitation/removal pump		4500			5900	
Agitation/transfer pump (1200 gpm)			9200	9200		
Recycle pump (1/2 hp)					350	350
Flush tanks (manual)					10800	10800
Irri. pump (1000 gpm)					7400	7400
Traveling big gun (850 ft. hose)					20700	20700
Mainline PVC (5000 ft.)					18000	18000
Dry stack (74880 ft.^{3})	63520					
Earth. pit (205200 ft.^{3})		12790				
Abvegrnd tank (163110 ft.^{3})			179100	147700		
Collection sump (2180 ft.^{3})			7100	7100		
Single stage lagoon (776400 ft.^{3})					27240	
Two stage lagoon (1006500 ft.^{3})						38960
Added concr.and curbing	3680	3130	2710	2710	4330	4330
Fencing, gates, etc.		930			1390	2870
Total	95100	53050	229810	198410	96110	103410
Per cow	297	166	718	620	300	323

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-5. Initial Investments Required to Install Modeled Dairy Waste Systems on the 320/PC Herd Size/Confinement System.

Table IV-23. Ranking of Dairy Waste Management Systems Modeled for the 320/PC Herd Size/Confinement System.

Rank[1]	System	Investment Cost Index[2]
1	DH[3]	100
2	EP/3	165
3	EP/6	176
4	DS/3	261
5	DS/6	316
6	SSL/FC	320
7	SSL/SC	323
8	TSL/FC	344
9	TSL/SC	347
10	CAGT/3	486
11	SAGT/3	560
12	CAGT/6	660
13	SAGT/6	765

[1]Rank was based upon total investment cost, lowest to highest.

[2]Investment cost index for each system was determined by dividing the total initial investment of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least investment cost system in this instance.

cost. The major exceptions were the DS systems. Minor exceptions were lagoon systems; flush collection systems required a slightly larger proportion of total investment in storage structure components, even though total investment cost was slightly higher for the standard collection lagoon. Relative investment cost of components for all waste systems modeled on the 320/PC herd size/confinement system are shown in Tables IV-24 and IV-25.

Analysis of the effect of increasing storage size on modeled systems showed that doubling storage capacity (from three-months to six-months) on DS, EP, CAGT, and SAGT systems raised investment outlays by 21%, 6%, 36%, and 37% respectively. Thus, even though economies to size exist for all types of systems, additional capacity could be obtained for the EP systems with much less cost impact than for the other type systems.

Initial investment costs per cow ranged from $94 for the DH system to $718 for the SAGT/6 system. Investment per cow for all waste systems modeled for the 320/PC herd size/confinement system is shown in Tables IV-21 and IV-22.

In summary, based upon the criterion of initial investment, DH was observed to be the least cost dairy waste system. EP systems, as a class, ranked second, followed by the DS class of waste systems. SSL systems ranked third followed by TSL systems (generally, flush collection was associated with the lower cost lagoon system). Ranked last was the AGT class of systems, with CAGT systems generally requiring less investment than similar SAGT systems.

Table IV-24. Relative Cost of Waste System Components Modeled on 320/PC/DH, 320/PC/DS/3, 320/PC/EP/3, 320/PC/SAGT/3, 320/PC/CAGT/3, 320/PC/SSL/SC, and 320/PC/TSL/SC Systems.[1]

Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	53.2%	20.4%	25.2%	7.4%	8.6%	12.9%	12.0%
Box scrape (6 ft.)	2.3%	0.9%	1.4%	0.4%	0.5%	0.7%	0.7%
Box spreader (450 bu.)	37.3%	14.3%					
Tank spreader (4500 gal.)			37.2%	11.0%	12.7%		
Agitation/removal pump			9.1%			6.1%	
Agitation/transfer pump (1200 gpm)				5.5%	6.3%		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (1000 gpm)						7.6%	7.1%
Traveling big gun (850 ft. hose)						21.3%	19.9%
Mainline PVC (5000 ft.)						18.6%	17.3%
Dry stack (54660 ft.^{3})		59.9%					
Earth. pit (148950 ft.^{3})			19.2%				
Abvegrnd tank (120840 ft.^{3})				69.9%	65.3%		
Collection sump (2180 ft.^{3})				4.2%	4.9%		
Single stage lagoon (776400 ft.^{3})						28.1%	
Two stage lagoon (1006500 ft.^{3})							37.4%
Added concr.and curbing	7.2%	4.6%	6.3%	1.6%	1.9%	3.2%	3.0%
Fencing, gates, etc.			1.6%			1.4%	2.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-25. Relative Cost of Waste System Components Modeled on 320/PC/DS/6,[1] 320/PC/EP/6, 320/PC/-SAGT/6, 320/PC/CAGT/6, 320/PC/SSL/FC, and 320/PC/TSL/FC Systems.

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	16.8%	23.6%	5.4%	6.3%		
Box scrape (6 ft.)	0.7%	1.3%	0.3%	0.4%		
Box spreader (450 bu.)	11.8%					
Tank spreader (4500 gal.)		34.9%	8.1%	9.3%		
Agitation/removal pump		8.5%			6.1%	
Agitation/transfer pump (1200 gpm)			4.0%	4.6%		
Recycle pump (1/2 hp)					0.4%	0.3%
Flush tanks (manual)					11.2%	10.4%
Irri. pump (1000 gpm)					7.7%	7.2%
Traveling big gun (850 ft. hose)					21.5%	20.0%
Mainline PVC (5000 ft.)					18.7%	17.4%
Dry stack (74880 ft.^{3})	66.8%					
Earth. pit (205200 ft.^{3})		24.1%				
Abvegrnd tank (163110 ft.^{3})			77.9%	74.4%		
Collection sump (2180 ft.^{3})			3.1%	3.6%		
Single stage lagoon (776400 ft.^{3})					28.3%	
Two stage lagoon (1006500 ft.^{3})						37.7%
Added concr.and curbing	3.9%	5.9%	1.2%	1.4%	4.5%	4.2%
Fencing, gates, etc.		1.8%			1.4%	2.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

320/TC. Total capital investment required to install modeled dairy waste management systems on a 320-cow herd utilizing total confinement ranged from $30,060 (DH system) to $258,910 (SAGT/6 system). Initial investments required for each component for all dairy waste systems modeled on the 320/TC herd size/confinement system are shown in Tables IV-26 and IV-27. Graphic comparisons are shown in Figure IV-6.

Initial investment necessary to install a DH system remained the same as it was for the 320/PC herd size/confinement system. Obviously, the DH system required less initial investment than alternative modeled systems. In comparison, the most capital intensive system (SAGT/6) required an initial cash outlay 861% of that needed to install the DH system. Rankings of the modeled systems in terms of relative investment cost are shown in Table IV-28 .

Overall, a generally consistent pattern exists among the systems in terms of required investment (Table IV-28). Generally, the modeled waste systems arrayed themselves by class in the ranking e.g. EP systems were found grouped together. The lone exception were the DS systems; the DS/3 and DS/6 systems were separated by four places in the ranking.

Comparing initial investment of modeled systems that utilized similar storage capacity, the greatest difference occurred between the SAGT/6 and EP/6 systems. The SAGT/6 system required an initial investment over 472% of that needed to install the EP/6 system.

Storage structure cost as a proportion of total investment outlay was analyzed for each class of waste system. Structure cost was 65% or more of total investment for the DS and AGT systems but only 26% or

Table IV-26. Initial Investment Budget for 320/TC/DH, 320/TC/DS/3, 320/TC/EP/3, 320/TC/SAGT/3, 320/TC/CAGT/3, 320/TC/SSL/SC, and 320/TC/TSL/SC Systems.[1]

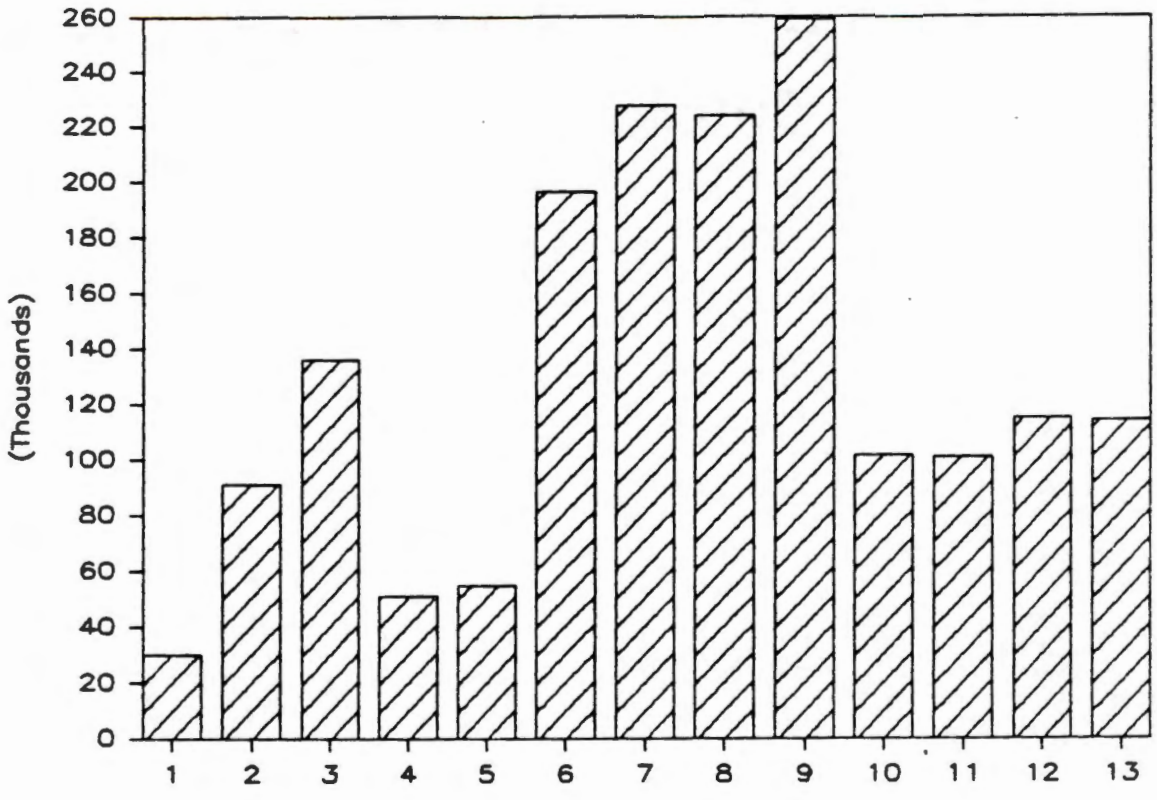
Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	16000	16000	12500	12500	12500	12500	12500
Box scrape (6 ft.)	700	700	700	700	700	700	700
Box spreader (450 bu.)	11200	11200					
Tank spreader (4500 gal.)			18500	18500	18500		
Agitation/removal pump			4500			5900	
Agitation/transfer pump (1200 gpm)				9200	9200		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (1000 gpm)						7400	7400
Traveling big gun (850 ft. hose)						20700	20700
Mainline PVC (5000 ft.)						18000	18000
Dry stack (67680 ft.^{3})		59390					
Earth. pit (173550 ft.^{3})			10600				
Abvegrnd tank (135940 ft.^{3})				170800	143500		
Collection sump (3635 ft.^{3})				9500	9500		
Single stage lagoon (1090000 ft.^{3})						31680	
Two stage lagoon (1386600 ft.^{3})							45050
Added concr.and curbing	2160	3680	3130	2710	2710	3130	3130
Fencing, gates, etc.			850			1510	3230
Total	30060	90970	50780	223910	196610	101520	114710
Per cow	94	284	159	700	614	317	358

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-27. Initial Investment Budget for 320/TC/DS/6, 320/TC/EP/6, 320/TC/SAGT/6, 320/TC/CAGT/6, 320/TC/SSL/FC, and 320/TC/TSL/FC Systems.[1]

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	16000	12500	12500	12500		
Box scrape (6 ft.)	700	700	700	700		
Box spreader (450 bu.)	11200					
Tank spreader (4500 gal.)		18500	18500	18500		
Agitation/removal pump		4500			5900	
Agitation/transfer pump (1200 gpm)			9200	9200		
Recycle pump (1/2 hp)					350	350
Flush tanks (manual)					10800	10800
Irri. pump (1000 gpm)					7400	7400
Traveling big gun (850 ft. hose)					20700	20700
Mainline PVC (5000 ft.)					18000	18000
Dry stack (120960 ft.^{3})	103680					
Earth. pit (248000 ft.^{3})		14490				
Abvegrnd tank (225010 ft.^{3})			205800	174600		
Collection sump (3635 ft.^{3})			9500	9500		
Single stage lagoon (1090000 ft.^{3})					31680	
Two stage lagoon (1386600 ft.^{3})						49050
Added concr.and curbing	4460	3130	2710	2710	4330	4330
Fencing, gates, etc.		990			1510	3230
Total	136040	54810	258910	227710	100670	113860
Per cow	425	171	809	712	315	356

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-6. Initial Investments Required to Install Modeled Dairy Waste Systems on the 320/TC Herd Size/Confinement System.

Table IV-28. Ranking of Dairy Waste Management Systems Modeled for the 320/TC Herd Size/Confinement System.

Rank[1]	System	Investment Cost Index[2]
1	DH[3]	100
2	EP/3	169
3	EP/6	182
4	DS/3	303
5	SSL/FC	335
6	SSL/SC	338
7	TSL/FC	379
8	TSL/SC	382
9	DS/6	453
10	CAGT/3	654
11	SAGT/3	745
12	CAGT/6	758
13	SAGT/6	961

[1]Rank was based upon total investment cost, lowest to highest.

[2]Investment cost index for each system was determined by dividing the total initial investment of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least investment cost system in this instance.

less of total investment for the EP systems. For the lagoon systems, structure cost constituted 31 to 43% of total investment. Proportionate costs of components of modeled dairy waste systems are shown in Tables IV-29 and IV-30.

The effect on capital requirements of increasing storage capacity was also analyzed. Doubling storage capacity (from three months to six months) on DS, EP, CAGT, and SAGT systems resulted in increased investment outlays of 50%, 7%, 16%, and 16% respectively. As for other herd sizes, system expansion of capacity has proportionally less effect on total investment for the EP systems than for other systems.

Investment cost per cow ranged from $94 to $809 for the DH system and SAGT/6 system respectively. Estimated investment per cow for each of the dairy waste systems modeled for the 320/TC herd size/confinement system are shown in Tables IV-26 and IV-27.

Based upon the criterion of initial investment, the least cost dairy waste system for the 320/TC herd size/confinement system was by far the DH system. EP systems ranked second, as a class, followed first by the DS/3 system and then by the SSL class of systems. TSL systems ranked next, followed by the DS/6 system. AGT systems were the most capital intensive waste systems; SAGT systems required greater investment than similar CAGT systems.

Analysis of Systems Across Herd Sizes

Initial investment costs per cow were compared for each specific waste system as herd size was increased from 80 to 160 to 320 cows. Comparisons within a class of confinement system and across herd sizes provide some indication of economies of herd size. In all cases,

Table IV-29. Relative Cost of Waste System Components Modeled on 320/TC/DH, 320/TC/DS/3, 320/TC/EP/3, 320/TC/SAGT/3, 320/TC/CAGT/3, 320/TC/SSL/SC, and 320/TC/TSL/SC Systems.[1]

Equipment/Structures	System/Initial Cost						
	DH	DS/3	EP/3	SAGT/3	CAGT/3	SSL/SC	TSL/SC
Scraper tractor (37hp)	53.2%	17.6%	24.6%	5.6%	6.4%	12.3%	10.9%
Box scrape (6 ft.)	2.3%	0.8%	1.4%	0.3%	0.4%	0.7%	0.6%
Box spreader (450 bu.)	37.3%	12.3%					
Tank spreader (4500 gal.)			36.4%	8.3%	9.4%		
Agitation/removal pump			8.9%			5.8%	
Agitation/transfer pump (1200 gpm)				4.1%	4.7%		
Recycle pump (1/2 hp)							
Flush tanks (manual)							
Irri. pump (1000 gpm)						7.3%	6.5%
Traveling big gun (850 ft. hose)						20.4%	18.0%
Mainline PVC (5000 ft.)						17.7%	15.7%
Dry stack (67680 ft.^{3})		65.3%					
Earth. pit (173550 ft.^{3})			20.9%				
Abvegrnd tank (135940 ft.^{3})				76.3%	73.0%		
Collection sump (3635 ft.^{3})				4.2%	4.8%		
Single stage lagoon (1090000 ft.^{3})						31.2%	
Two stage lagoon (1386600 ft.^{3})							42.8%
Added concr.and curbing	7.2%	4.0%	6.2%	1.2%	1.4%	3.1%	2.7%
Fencing, gates, etc.			1.7%			1.5%	2.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

Table IV-30. Relative Cost of Waste System Components Modeled on 320/TC/DS/6,[1] 320/TC/EP/6, 320/TC/-SAGT/6, 320/TC/CAGT/6, 320/TC/SSL/FC, and 320/TC/TSL/FC Systems.

Equipment/Structures	System/Initial Cost					
	DS/6	EP/6	SAGT/6	CAGT/6	SSL/FC	TSL/FC
Scraper tractor (37hp)	11.8%	22.8%	4.8%	5.5%		
Box scrape (6 ft.)	0.5%	1.3%	0.3%	0.3%		
Box spreader (450 bu.)	8.2%					
Tank spreader (4500 gal.)		33.8%	7.1%	8.1%		
Agitation/removal pump		8.2%			5.9%	
Agitation/transfer pump (1200 gpm)			3.6%	4.0%		
Recycle pump (1/2 hp)					0.3%	0.3%
Flush tanks (manual)					10.7%	9.5%
Irri. pump (1000 gpm)					7.4%	6.5%
Traveling big gun (850 ft. hose)					20.6%	18.2%
Mainline PVC (5000 ft.)					17.9%	15.8%
Dry stack (120960 ft.^{3})	76.2%					
Earth. pit (248000 ft.^{3})		26.4%				
Abvegrnd tank (225010 ft.^{3})			79.5%	76.7%		
Collection sump (3635 ft.^{3})			3.7%	4.2%		
Single stage lagoon (1090000 ft.^{3})					31.5%	
Two stage lagoon (1386600 ft.^{3})						43.1%
Added concr.and curbing	3.3%	5.7%	1.0%	1.2%	4.3%	3.8%
Fencing, gates, etc.		1.8%			1.5%	2.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]Equip./structures used primarily for waste handling. Sources: Local/national dealers and contractors.

rather dramatic initial capital economies accruing to herd size were observed (Table IV-31). For the DH system, investment cost per cow was reduced about 2/3 as herd size was increased from 80 to 320 cows. Increasing herd size from 80 to 320 cows reduced investment cost per cow for the TC/DS/6 system by 36%. For most of the other systems reductions were in the 45 to 55% range.

For systems utilizing storage, TC/SSL/SC systems exhibited the greatest investment economies accruing to herd size. As a class, the EP systems were observed to show the greatest economies of herd size. Conversely, the DS class of waste systems were found to have the least economies of herd size.

Net Annual Costs

Dairy waste management systems were also compared on each modeled herd size/confinement system with net annual cost as the criterion. Unlike the initial investment analysis, all equipment/facilities used on specific dairy waste management systems were included in net annual cost analysis. Included were equipment not predominantly used for dairy waste management e.g. tractors used for hauling wastes. Annualized equipment/facilities costs were prorated based upon estimated proportionate annual use allocated to dairy waste management.

Net annual cost for each system was calculated as follows: capital recovery plus insurance/repairs/housing costs plus annual equipment rental cost plus energy costs plus labor costs minus annual fertilizer value of dairy wastes. Capital recovery, a composite method for determining cost of depreciation and interest on capital, was

Table IV-31. Estimated Initial Investment Cost Per Cow by Herd Size, Type of Waste System, and Degree of Confinement.

Waste System \ Herd Size	80	160	320	% Decrease (80 → 320)
PC/				
DH	283	159	94	66.9
DS/3	490	340	245	50.0
DS/6	551	392	297	46.1
EP/3	359	236	155	56.8
EP/6	381	251	166	56.5
CAGT/3	1,053	675	457	56.7
CAGT/6	1,128	782	620	45.1
SAGT/3	1,242	821	526	57.7
SAGT/6	1,343	892	718	46.5
SSL/SC	734	453	303	58.7
SSL/FC	622	422	300	51.7
TSL/SC	704	460	326	53.7
TSL/FC	592	430	323	45.4
TC/				
DH	283	159	94	66.9
DS/3	518	376	284	45.1
DS/6	668	508	425	36.3
EP/3	375	238	159	57.7
EP/6	401	263	171	57.3
CAGT/3	1,062	704	614	42.2
CAGT/6	1,254	858	712	43.2
SAGT/3	1,251	830	700	44.1
SAGT/6	1,545	996	809	47.6
SSL/SC	777	485	317	59.2
SSL/FC	665	455	315	52.6
TSL/SC	768	509	358	53.4
TSL/FC	656	479	356	45.7

calculated for equipment/facilities specific to each system. Since calculation of capital recovery depended upon the life of the asset, life expectancies were estimated for all equipment/facilities. Interest rates were likewise necessary; current market rates were used.

Annual costs of insurance, repairs or maintenance, and housing were approximated for components of each waste system. Annual equipment rental costs occurred only on TSL systems. These costs were, in fact, incurred at five year intervals (sludge removal). Annual equipment costs incurred during these years were present valued to year one; the sum of these costs were annualized over the life of the system.

Labor and energy requirements for each dairy waste management system were synthesized for each budget (two month) period. Associated costs were also calculated and summed by budget period. Budget period totals were summed to determine annual labor and energy costs incurred with each waste management system. In the case of non-annual tasks, such as sludge removal from TSL systems, costs of completing these tasks in each year of occurrence were first discounted to year one and summed. This total present value of costs was then annualized over the life of the waste system and added to "real" annual labor and energy costs.

Annual fertilizer value of dairy wastes could be made only after accounting for nutrient losses during collection, storage, and application. These nutrient losses were modeled in the Collection Budgets and Storage and Application Budgets. However, nutrients incorporated into the soil are not 100% available to crops during the first year after land application. Rather, waste nutrients are mineralized (over

several years) into inorganic forms which are available for crop uptake. Budgets were developed to model this mineralization process and determine the annual value of nutrients applied through each waste management system.

Annual values of each nutrient (N, P, and K) for each waste system was derived by: (1) determining the annual quantity of nutrients "in-soil"; (2) multiplying this sum by appropriate mineralization rates; (3) applying the specific elemental nutrient prices to the mineralized values; (4) discounting these values to determine the present value of nutrient quantities mineralized each year; and (5) summing these discounted values. Total annual value of dairy waste was determined by summing the annual values of N, P, and K for the specific system. Although it is generally recognized that manure contains inherent value as a soil enhancement (tilth and organic matter), these factors are difficult to quantify and were not included in the analysis.

Net annual cost was the primary economic parameter used in comparing modeled dairy waste management systems. All the various aspects of waste handling systems were netted out in this calculation, providing one number per system which could be used as a comparative tool. It was this figure, more than any other, that determined which waste system (and variation of that system) was most "economical."

Analysis of Systems Modeled on Specific Herd Sizes/Confinement Systems

Net annual costs for the various modeled dairy waste management systems were compared on each specific herd size/confinement system. This comparison was made to determine which system appeared to be most economical for that herd size/confinement system.

80/PC. Net annual costs for the modeled 80/PC herd size/confinement system varied from $4,298 for the DH waste system to $15,555 for the SAGT/6 system. Data used in computation of net annual costs of each manure system modeled for this particular herd size/confinement system is shown in Table IV-32. Net annual cost of each system is shown in graphic form in Figure IV-7.

Of those waste management systems utilizing storage, EP systems required the least net annual costs as a class, with DS systems ranked second. However, when viewed strictly upon a system by system basis, the DS/3 system was observed to be less costly than the EP/6 system. The ranking of the 13 systems modeled in terms of net annual cost is shown in Table IV-33.

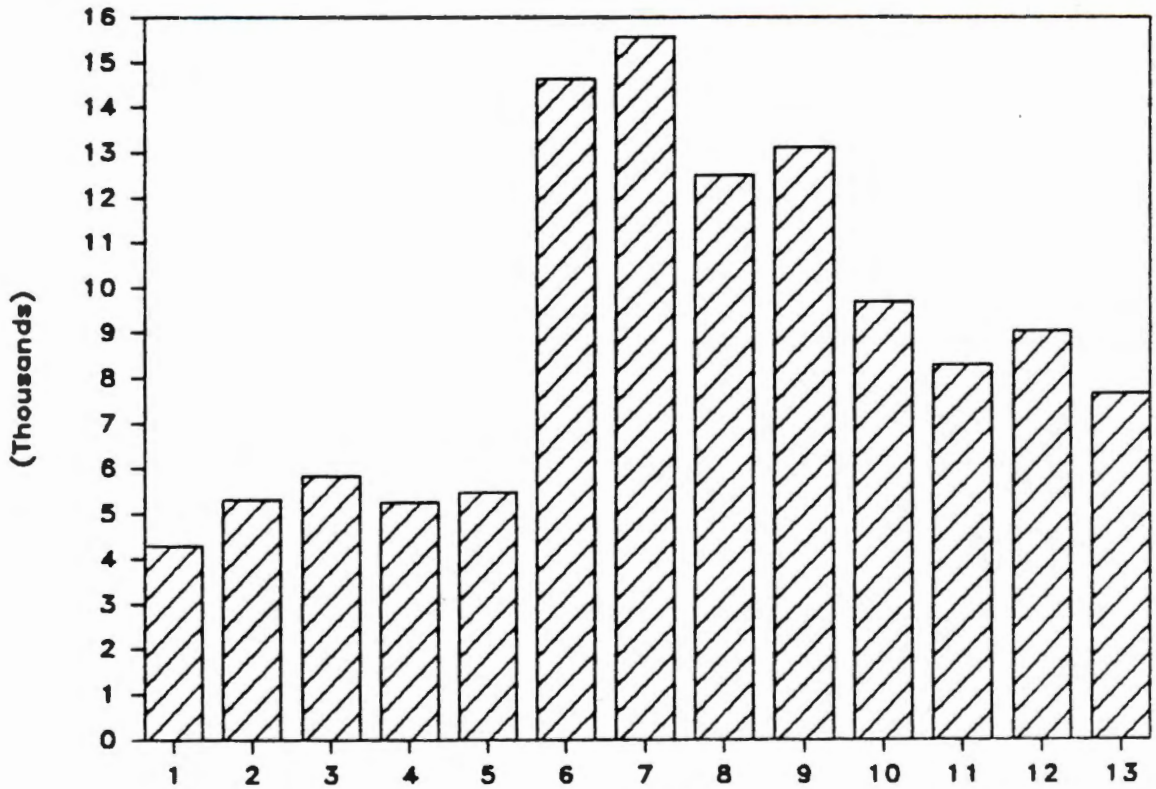
As shown in tables IV-32 and IV-33, installing greater storage capacity on specific classes of systems does not appear to be economical. On all systems for which storage capacity was varied, the systems utilizing larger storage structures incurred greater net annual cost. Apparently, the slight increase in manurial fertilizer value accruing to greater storage capacity was not sufficient to offset the associated greater costs. As a caution, it should be noted that a method of valuing probable enhanced waste removal scheduling and labor management could not adequately be incorporated into the analysis. It is possible that such benefits could outweigh the "negative" net annual cost differential of a system utilizing larger storage capacity.

TSL systems were found to incur less net annual costs than SSL systems. The higher cost for the SSL systems resulted from the requirement of agitation pump. It should be noted that net annual

Table IV-32. Net Annual Cost Budget for 80/PC Systems.[1]

System	Capital Recovery +	Insurance/Repairs/ Housing Costs +	Equipment Rental +	Energy Costs +	Labor Costs -	Manure Value =	Net Annual Cost
80/PC/							
DH	3140	347		912	1823	1924	4298
DS/3	4804	492		767	1575	2323	5315
DS/6	5431	539		754	1550	2424	5850
EP/3	4656	567		1237	2038	3242	5256
EP/6	4981	595		1269	2065	3429	5481
SAGT/3	13776	1171		1178	1968	3466	14627
SAGT/6	14850	1252		1174	1945	3666	15555
CAGT/3	11775	1020		1178	1968	3466	12475
CAGT/6	12570	1080		1174	1945	3666	13103
SSL/SC	9042	1101		864	1303	2639	9671
SSL/FC	8895	1072		552	410	2639	8290
TSL/SC	8322	936	56	829	1205	2317	9031
TSL/FC	8175	907	56	517	312	2317	7650

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.



Legend:

1 - DH	8 - SAGT/3
2 - DS/3	9 - SAGT/6
3 - DS/6	10 - SSL/SC
4 - EP/3	11 - SSL/FC
5 - EP/6	12 - TSL/SC
6 - CAGT/3	13 - TSL/FC
7 - CAGT/6	

Figure IV-7. Net Annual Costs Incurred on Dairy Waste Systems Modeled for the 80/PC Herd Size/Confinement System.

Table IV-33. Ranking (Based on Net Annual Cost) of Dairy Waste Management Systems Modeled for the 80/PC Herd Size/Confinement System.

Rank[1]	System	Net Annual Cost Index[2]
1	DH[3]	100
2	EP/3	122
3	DS/3	124
4	EP/6	128
5	DS/6	136
6	TSL/FC	178
7	SSL/FC	193
8	TSL/SC	210
9	SSL/SC	225
10	CAGT/3	290
11	CAGT/6	305
12	SAGT/3	340
13	SAGT/6	362

[1]Rank was based upon net annual cost, lowest to highest.

[2]Net annual cost index for each system was determined by dividing the net annual cost of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least net annual cost system in this instance.

costs of lagoon systems were significantly reduced when flush collection was substituted for standard collection methods. Reduced labor costs would account for most of this net annual cost differential. Labor costs were reduced by over 68% and 74% on SSL and TSL systems respectively.

The increased retention of manurial fertilizer value by AGT systems was insufficient to recoup the added costs of these systems. Superior retention of fertilizer nutrients is a highly promoted feature of AGT systems. As a comparison, the SAGT/6 system incurred a net annual cost of almost three times that of the EP/6 system. Both systems utilize quite similar technology in terms of waste handling methodology i.e. both are slurry-type waste management systems. Additionally, it was observed that CAGT systems ranked ahead of SAGT system. Indeed, the CAGT/6 system had net annual cost almost $2000 less than the SAGT/3 system. Thus, based on the analysis of this study, it would be less costly to own and operate a concrete waste storage structure with six-months capacity than a steel structure with only three-months capacity.

An effort was made to determine which factor(s) was(were) most influential in the determination of relative net annual costs. Each contributing factor was divided by the total annual cost of the specific waste system, thus indicating the relative importance of capital recovery, insurance/repairs/housing costs, equipment rental, energy costs, labor costs, and manure value in the determination of net annual costs. Basically, each cost parameter was viewed in regard to its proportionate contribution to total annual costs. Conversely, manure

value (or negative cost) was analyzed with respect to the proportion of total annual costs which it offset. The relative importance of each of these factors for each for the 80/PC herd size/confinement system is shown in Table IV-34.

It should be noted that the systems in which manure value offset total annual cost the greatest were not necessarily the least cost systems. Manure value did appear to be a significant factor however. Manure value was 29% to 39% of total annual cost of the DH, DS, and EP systems but less than 22% of annual costs for the various AGT systems.

Labor cost tended to be a lower percent of total annual cost for those systems with the highest net annual cost. Labor cost was 12% or less of total annual cost for the AGT, SSL, and TSL systems but 19% or more of total annual cost for the EP and DS systems.

Capital recovery was the single largest cost parameter for each of the modeled waste systems and accounted for 51% to 82% of total annual cost among the 13 systems modeled. In dollar terms, capital recovery costs were substantially higher for the AGT systems than for any other system considered. Energy costs tended to decline relative to total annual costs as net annual costs increased. Annual energy costs, in absolute terms, was highest for the EP and AGT systems.

80/TC. Net annual costs on the 80/TC herd size/confinement system ranged from $4,768 for the EP/3 waste system to $17,119 for the SAGT/6 system. Net annual costs and component annual cost of various waste management systems modeled for the 80/TC herd size/confinement system are shown in Table IV-35. Net annual costs comparisons are shown graphically in Figure IV-8.

Table IV-34. Proportionate Contribution of Modeled Cost Parameters[1] to Total Annual Costs[2] for 80/PC Systems.

System	Capital Recovery	Insurance/Repairs/ Housing Costs	Equipment Rental	Energy Costs	Labor Costs	Manure Value
80/PC/						
DH	50.5%	5.6%		14.7%	29.3%	30.9%
DS/3	62.9%	6.4%		10.0%	20.6%	30.4%
DS/6	65.6%	6.5%		9.1%	18.7%	29.3%
EP/3	54.3%	6.8%		14.7%	24.3%	38.6%
EP/6	55.9%	6.7%		14.2%	23.2%	38.5%
SAGT/3	76.1%	6.5%		6.5%	10.9%	19.2%
SAGT/6	77.3%	6.5%		6.1%	10.1%	19.1%
CAGT/3	73.9%	6.4%		7.4%	12.3%	21.7%
CAGT/6	75.0%	6.4%		7.0%	11.6%	21.9%
SSL/SC	73.5%	8.9%		7.0%	10.6%	21.4%
SSL/FC	81.4%	9.8%		5.1%	3.8%	24.1%
TSL/SC	73.3%	8.2%	0.5%	7.3%	10.6%	20.4%
TSL/FC	82.0%	9.1%	0.6%	5.2%	3.1%	23.2%

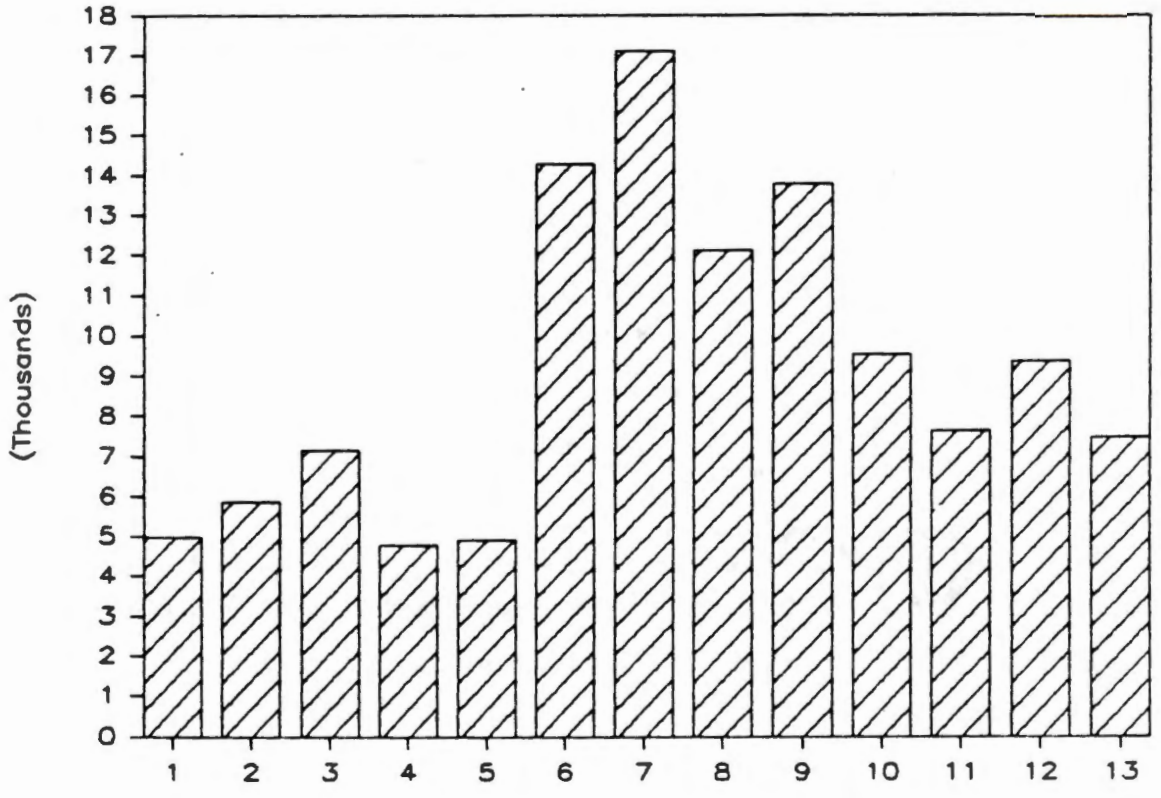
[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.

[2]Manure value was analyzed as a negative cost i.e. the proportion of total annual costs offset.

Table IV-35. Net Annual Cost Budget for 80/TC Systems.[1]

System	Capital + Recovery	Insurance/Repairs/ Housing Costs +	Equipment + Rental	Energy + Costs	Labor - Costs	Manure Value =	Net Annual Cost
80/TC/							
DH	3815	410		1299	2573	3110	4987
DS/3	5654	566		1127	2145	3634	5858
DS/6	7219	681		1105	2098	3934	7169
EP/3	5271	623		1537	2525	5188	4768
EP/6	5643	654		1586	2565	5527	4921
SAGT/3	14369	1225		1568	2540	5421	14281
SAGT/6	17483	1459		1555	2498	5876	17119
CAGT/3	12368	1074		1568	2540	5421	12129
CAGT/6	14396	1226		1555	2498	5876	13799
SSL/SC	9872	1170		1103	1653	4247	9551
SSL/FC	9530	1123		694	548	4247	7648
TSL/SC	9378	1023	92	1074	1519	3714	9372
TSL/FC	9036	976	92	665	414	3714	7469

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-8. Net Annual Costs Incurred on Dairy Waste Systems Modeled for the 80/TC Herd Size/Confinement System.

For waste management systems incorporating storage, EP systems required the least net annual costs as a class, with DS systems ranked second. Indeed, both EP systems ranked slightly ahead of the DH system. The DH system had the lowest total annual cost, but the greater value of manurial fertilizer retained offset the higher capital cost of the EP system. The net annual cost of each system relative to the least cost system (EP/3 in this case) was used to rank the modeled waste systems, from least to greatest net annual cost (Table IV-36).

As for 80/TC systems, for those systems on which storage capacity was varied, installation of greater storage capacity does not seem to be economical. In all cases, three-months storage had lower net annual cost than six-months storage for a given system type. However, as noted before, certain potentially important factors (particularly flexibility in labor use and choice of crop to apply dairy wastes) could not be modeled into the net annual cost analysis. The possibility exists that such factors could partially or wholly offset the greater net annual cost of systems incorporating enhanced storage capacity.

With respect to lagoon systems, utilization of flush collection methods again appeared economically feasible. Savings in energy and labor costs were primarily responsible for this economic advantage. In terms of net annual cost, flush systems were 20% lower than standard collection systems for both the SSL and TSL waste management systems. For the 80/PC models, flush systems had net annual cost 15% lower than standard collection lagoon systems.

Increased preservation of manurial fertilizer nutrients by AGT systems was insufficient to offset the tremendous annual cost disadvan-

Table IV-36. Ranking (Based on Net Annual Cost) of Dairy Waste Management Systems Modeled for the 80/TC Herd Size/Confinement System.

Rank[1]	System	Net Annual Cost Index[2]
1	EP/3[3]	100
2	EP/6	103
3	DH	105
4	DS/3	123
5	DS/6	150
6	TSL/FC	157
7	SSL/FC	160
8	TSL/SC	197
9	SSL/SC	200
10	CAGT/3	254
11	CAGT/6	289
12	SAGT/3	300
13	SAGT/6	359

[1]Rank was based upon net annual cost, lowest to highest.

[2]Net annual cost index for each system was determined by dividing the net annual cost of that system by the investment required for the least cost system and multiplying by 100.

[3]EP/3 was the least net annual cost system in this instance.

tage of these systems. Compared to a dairy waste system incorporating quite similar technology (the EP/6 system) the SAGT/6 system incurred net annual costs almost three and one-half times as great.

Additionally, it was less costly to own and operate a concrete waste storage structure with six-months capacity than it was for a steel structure with three-months capacity. Therefore, given the parameters set forth in this analysis, capturing inherent positive attributes of greater storage capacity, at a reduced cost, is possible by utilizing concrete instead of steel as the structural component.

It should be noted that the relative gap between AGT systems and the least cost system did narrow as compared to the 80/PC analysis. This difference remained quite substantial however - $7,357 or greater. Interestingly, the spread between the least cost and the greatest cost AGT systems widened. Net annual cost differences between CAGT/6 (SAGT/6) and CAGT/3 (SAGT/3) systems was also greater than for the 80/PC systems. The "lumpiness" of AGT storage structure inputs may be the reason.

An analysis was performed to examine if significant relationships existed between specific cost parameters' proportionate contribution to total annual costs and ranking of the modeled systems. Manure value, regarded as a negative cost, was analyzed with respect to the proportion of total annual costs offset. Data for this analysis is shown in Table IV-37.

Those systems for which manure value offset total annual costs by the greatest proportion tended to rank higher. Manurial fertilizer value exceeded 50% of total annual cost of the EP systems, the two

Table IV-37. Proportionate Contribution of Modeled Cost Parameters[1] to Total Annual Costs[2] for 80/TC Systems.

System	Capital Recovery	Insurance/Repairs/ Housing Costs	Equipment Rental	Energy Costs	Labor Costs	Manure Value
80/TC/						
DH	47.1%	5.1%		16.0%	31.8%	38.4%
DS/3	59.6%	6.0%		11.9%	22.6%	38.3%
DS/6	65.0%	6.1%		10.0%	18.9%	35.4%
EP/3	52.9%	6.3%		15.4%	25.4%	52.1%
EP/6	54.0%	6.3%		15.2%	24.6%	52.9%
SAGT/3	72.9%	6.2%		8.0%	12.9%	27.5%
SAGT/6	76.0%	6.3%		6.8%	10.9%	25.6%
CAGT/3	70.5%	6.1%		8.9%	14.5%	30.9%
CAGT/6	73.2%	6.2%		7.9%	12.7%	29.9%
SSL/SC	71.5%	8.5%		8.0%	12.0%	30.8%
SSL/FC	80.1%	9.4%		5.8%	4.6%	35.7%
TSL/SC	71.7%	7.8%	0.7%	8.2%	11.6%	28.4%
TSL/FC	80.8%	8.7%	0.8%	5.9%	3.7%	33.2%

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.

[2]Manure value was analyzed as a negative cost i.e. the proportion of total annual costs offset.

lowest net annual cost systems. Manurial value was 35% to 38% of total annual cost for the DS and DH systems, the third, fourth, and fifth ranking systems in terms of net annual cost. The four highest net annual cost systems (AGT) retained manurial value equal to 26% to 31% of total annual cost. This finding contrasted with observations made for systems modeled on the 80/PC herd size/confinement system.

Capital recovery cost as a percent of total annual cost was 65% or less of total annual cost for DS an 54% or less for the DH and EP systems, the three lowest net annual cost systems. Labor cost as a percent of total annual cost was highest for these three systems. Thus, least net annual cost systems tended to be more labor intensive (less capital intensive) and retain a higher proportion of total annual cost in manurial fertilizer value.

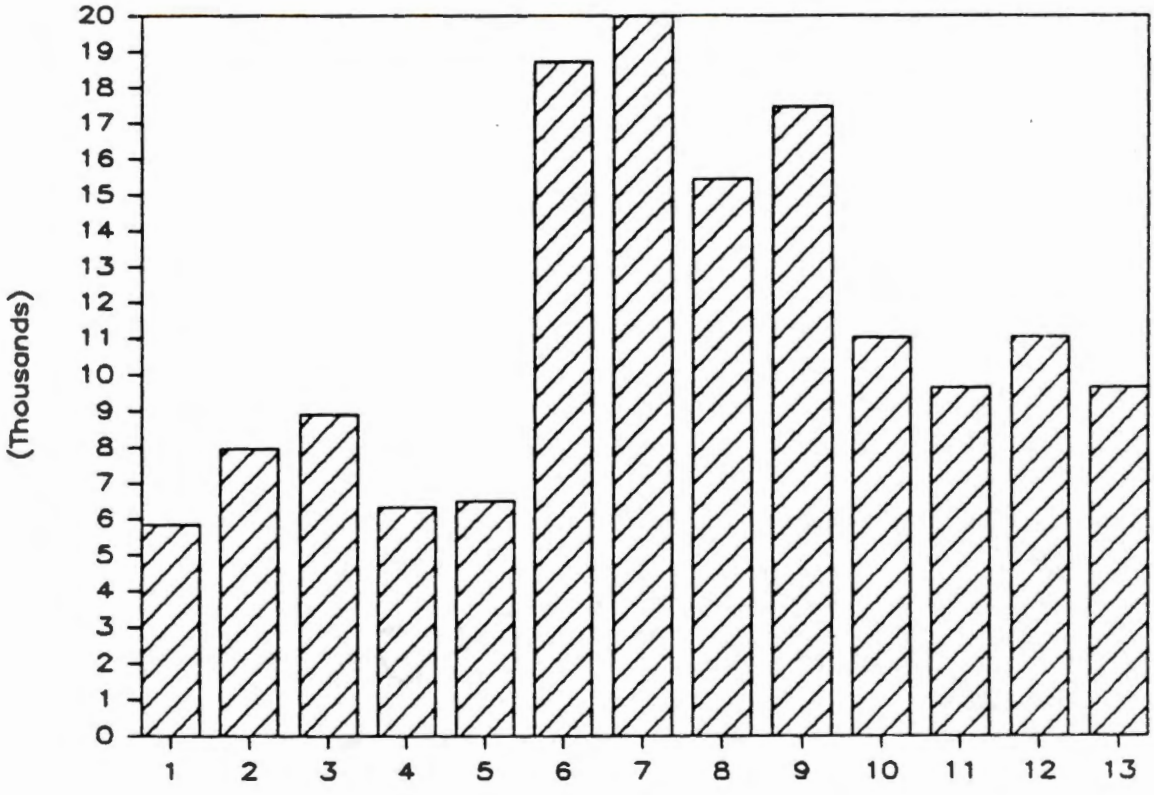
160/PC. Net annual costs for dairy waste systems modeled for the 160/PC herd size/confinement system ranged from $5,852 to $19,969. The DH waste system was found to be least cost, while the greatest cost system was SAGT/6. Itemized cost and estimated net annual costs of waste management systems modeled for the 160/PC herd size/confinement system are shown in Table IV-38. Net annual cost relationships are shown graphically in Figure IV-9.

For those waste systems incorporating storage, estimates indicated that EP systems required the least net annual costs as a class. DS systems ranked second. Rankings of the modeled waste systems and indexes of the net annual cost of each system relative to the least cost system are shown in Table IV-39.

Table IV-38. Net Annual Cost Budget for 160/PC Systems.[1]

System	Capital + Recovery	Insurance/Repairs/ Housing Costs +	Equipment Rental +	Energy Costs +	Labor Costs -	Manure Value =	Net Annual Cost
160/PC/							
DH	4968	521		1577	2555	3769	5852
DS/3	8064	784		1396	2305	4557	7992
DS/6	9137	863		1378	2280	4742	8916
EP/3	7329	848		1914	2658	6415	6334
EP/6	7749	882		1970	2695	6763	6533
SAGT/3	19486	1672		1825	2545	6819	18709
SAGT/6	21045	1791		1852	2500	7219	19969
CAGT/3	16399	1493		1825	2545	6819	15443
CAGT/6	18713	1615		1852	2500	7219	17461
SSL/SC	11700	1334		1361	1835	5195	11035
SSL/FC	11829	1321		941	745	5195	9641
TSL/SC	11333	1194	88	1305	1697	4545	11072
TSL/FC	11462	1181	88	885	607	4545	9678

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-9. Net Annual Costs Incurred on Dairy Waste Systems Modeled for the 160/PC Herd Size/Confinement System.

Table IV-39. Ranking (Based on Net Annual Cost) of Dairy Waste Management Systems Modeled for the 160/PC Herd Size/Confinement System.

Rank[1]	System	Net Annual Cost Index[2]
1	DH[3/]	100
2	EP/3	108
3	EP/6	112
4	DS/3	137
5	DS/6	152
6	SSL/FC	165
7	TSL/FC	165
8	SSL/SC	189
9	TSL/SC	189
10	CAGT/3	264
11	CAGT/6	298
12	SAGT/3	320
13	SAGT/6	341

[1]Rank was based upon net annual cost, lowest to highest.

[2]Net annual cost index for each system was determined by dividing the net annual cost of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least net annual cost system in this instance.

Interestingly, no significant differences were found between SSL and TSL systems utilizing similar collection methods. Indeed, the relative ranking of these systems changed when compared to 80/PC and 80/TC analyses. SSL systems became less costly relative to TSL systems. This switch in ranking likely results from the spreading of the purchase cost and use of agitation pumps over greater and greater quantities of dairy waste, thus resulting in a reduction in unit costs. Inherent economies in SSL systems then allow them to "catch up" with (and eventually surpass) TSL systems.

As shown in Tables IV-38 and IV-39, installing greater storage capacity on particular classes of dairy waste systems cannot be justified on an economic basis. On those waste systems in which storage capacity was varied, in every case the systems utilizing larger storage structures incurred greater net annual costs. However, other factors, not incorporated into this analysis, could possibly offset this cost disadvantage. These "management factors" are farm-specific; thus only an individualized analysis could determine their relative value.

With respect to lagoon systems, flush collection again showed an economic advantage over the standard collection method. Flush systems had net annual cost 65% greater than DH while standard collection systems had cost 89% greater than DH, the least cost system. The cost advantage of flush systems over standard collection systems was relatively less than for the 80/TC herd size/confinement system.

Increased utilization of manurial fertilizer nutrients possible using AGT systems was again insufficient to offset their overwhelming annual cost disadvantage. Comparing waste systems incorporating

similar technology, the SAGT/6 system incurred net annual costs over three times as great as the EP/6 system. Additionally, CAGT systems were again clearly superior to SAGT systems based on net annual costs.

For three-months storage SAGT had net annual cost 21% higher than the CAGT system. For six-months storage, SAGT was 14% higher. For 80/TC systems SAGT was 18% higher for three-months storage and 24% higher for six-months storage.

An analysis was performed to determine if observable relationships existed between specific cost parameters' proportionate contribution to total annual costs and the rank (based on net annual costs) of the modeled systems. Manure value, regarded as a negative cost, was analyzed with regard to the proportion of total annual cost offset. Data for this analysis is shown in Table IV-40.

Generally, as the capital recovery constituted a larger proportion of total annual cost, the particular waste system ranked lower. Capital recovery accounted for 58% or less of total annual cost for the three highest ranking systems (DH, EP/3, EP/6). For the four lowest ranking systems (AGT'S) capital recovery accounted for 74% or more of total annual cost. Additionally, it was observed that as energy costs and labor costs declined relative to total annual costs, dairy waste management systems tended to rank lower. A possible explanation could be that initial investment (reflected to a large degree in the capital recovery parameter) overwhelms any energy and labor savings that may accrue to capital intensive systems. It appears then, that energy and labor efficiency may possibly be over-emphasized as criteria for choosing a dairy waste management system.

Table IV-40. Proportionate Contribution of Modeled Cost Parameters[1] to Total Annual Costs[2] for 160/PC Systems.

System	Capital Recovery	Insurance/Repairs/ Housing Costs	Equipment Rental	Energy Costs	Labor Costs	Manure Value
160/PC/						
DH	51.6%	5.4%		16.4%	26.6%	39.2%
DS/3	64.3%	6.2%		11.1%	18.4%	36.3%
DS/6	66.9%	6.3%		10.1%	16.7%	34.7%
EP/3	57.5%	6.7%		15.0%	20.8%	50.3%
EP/6	58.3%	6.6%		14.8%	20.3%	50.9%
SAGT/3	76.3%	6.5%		7.1%	10.0%	26.7%
SAGT/6	77.4%	6.6%		6.8%	9.2%	26.6%
CAGT/3	73.7%	6.7%		8.2%	11.4%	30.6%
CAGT/6	75.8%	6.5%		7.5%	10.1%	29.3%
SSL/SC	72.1%	8.2%		8.4%	11.3%	32.0%
SSL/FC	79.7%	8.9%		6.3%	5.0%	35.0%
TSL/SC	72.6%	7.6%	0.6%	8.4%	10.9%	29.1%
TSL/FC	80.6%	8.3%	0.6%	6.2%	4.3%	32.0%

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.

[2]Manure value was analyzed as a negative cost i.e. the proportion of total annual costs offset.

160/TC. Net annual costs of dairy waste management systems modeled on the 160/TC herd size/confinement system ranged from $4,844 (EP/3) to $20,784 (SAGT/6) - a difference of $15,940, or over three times the net annual cost of the least cost system. Estimated component and net annual costs of waste management systems modeled on the 160/TC herd size/confinement system are shown in Table IV-41. Graphic comparisons of net annual costs are shown in Figure IV-10.

Among classes of dairy waste management systems utilizing storage, EP systems incurred the least net annual costs. Indeed, EP systems incurred less net annual costs than the DH system (typically expected to be the least cost system). Net annual cost for the DH system was over one and one-half times that incurred with the EP/3 system. Indexes and rankings of net annual costs of each system relative to the least cost system are shown in Table IV-42.

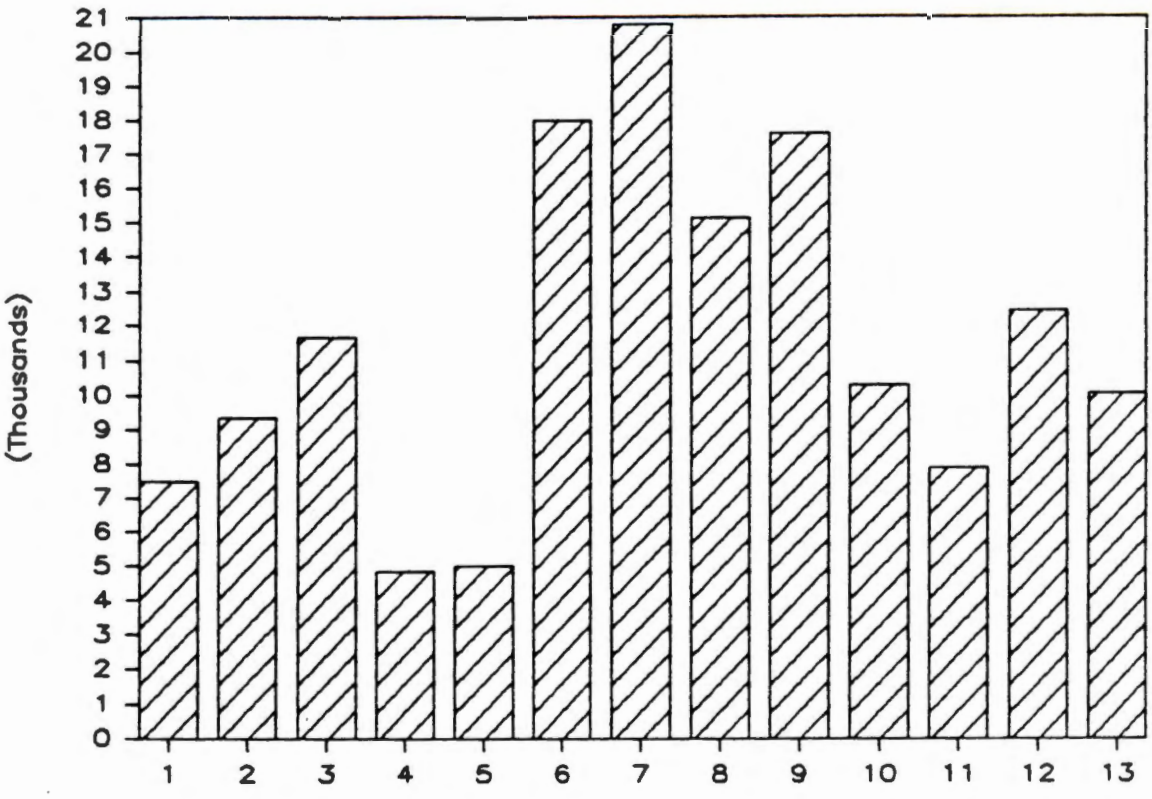
Installing greater storage capacity on those classes of waste systems for which storage capacity was varied does not appear to be economically justified. For each class of system net annual costs were greater for six-months than three-months storage (Tables IV-41 and IV-42). However, as noted earlier, this economic disadvantage could possibly be outweighed by other factors in certain situations.

Of particular note was the fact that the SSL/FC system ranked ahead of both DS systems. Based on estimates, of this study, the SSL/FC system would be over $1,460 less costly per annum than the DS/3 system. This finding was contrary to results of analyses discussed previously. Most lagoon systems were found to advance in the described system rankings (compared to previous rankings). Of the lagoon

Table IV-41. Net Annual Cost Budget for 160/TC Systems.[1]

System	Capital Recovery +	Insurance/Repairs/ Housing Costs +	Equipment Rental +	Energy Costs +	Labor Costs -	Manure Value =	Net Annual Cost
160/TC/							
DH	6388	1106		2460	3785	6248	7491
DS/3	10123	961		2176	3363	7273	9350
DS/6	12903	1169		2143	3313	7873	11655
EP/3	8250	934		2484	3495	10319	4844
EP/6	8872	982		2564	3553	10954	5017
SAGT/3	20765	1788		2639	3560	10743	18009
SAGT/6	24277	2053		2631	3520	11697	20784
CAGT/3	18102	1587		2627	3560	10743	15133
CAGT/6	21348	1832		2619	3520	11697	17622
SSL/SC	13020	1445		1750	2490	8411	10294
SSL/FC	12772	1398		1144	980	8411	7883
TSL/SC	12921	1323	144	1652	2296	5888	12448
TSL/FC	12675	1276	144	1047	786	5888	10040

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-10. Net Annual Costs Incurred on Dairy Waste Systems Modeled for the 160/TC Herd Size/Confinement System.

Table IV-42. Ranking (Based on Net Annual Cost) of Dairy Waste Management Systems Modeled for the 160/TC Herd Size/Confinement System.

Rank[1]	System	Net Annual Cost Index[2]
1	EP/3[3]	100
2	EP/6	104
3	DH	155
4	SSL/FC	163
5	DS/3	193
6	TSL/FC	207
7	SSL/SC	213
8	DS/6	241
9	TSL/SC	257
10	CAGT/3	312
11	CAGT/6	364
12	SAGT/3	372
13	SAGT/6	429

[1]Rank was based upon net annual cost, lowest to highest.

[2]Net annual cost index for each system was determined by dividing the net annual cost of that system by the investment required for the least cost system and multiplying by 100.

[3]EP/3 was the least net annual cost system in this instance.

systems, only the TSL/SC system ranked behind the DS/6 system in this analysis.

As in earlier analyses lagoon systems utilizing flush collection incurred less net annual costs than similar systems incorporating standard collection methods. Labor and energy cost savings appeared to be major factors contributing to the relatively lower cost of flush systems. For SSL systems, those utilizing flush collection had annual cost 23% lower than standard collection systems. For TSL systems, flush collection systems had annual cost about 19% lower.

AGT systems were more effective in preserving manurial fertilizer nutrients but the value of these nutrients was insufficient to offset the considerable annual cost disadvantage of these "tank" systems. Compared to a dairy waste system incorporating quite similar technology and storage capacity (EP/6 system), the SAGT/6 system incurred net annual costs over four times as great (+$15,767). The AGT systems preserved 46% more manurial value than EP systems but annual capital recovery costs of AGT systems were substantially larger.

In addition, it was less costly to own and operate a concrete waste storage structure with six-months capacity than it was for a steel structure with three-months capacity. Therefore, capture of inherent positive attributes of greater storage capacity, at a reduced operating cost, was possible by utilizing concrete rather than steel as the structural component.

An analysis was performed to examine if significant relationships existed between specific cost parameter's proportionate contribution to total annual costs and ranking of the modeled systems. Manure value,

regarded as a negative cost, was analyzed with regard to the proportion of total annual costs offset. Cost data for this analysis is shown in percentage terms in Table IV-43.

Capital recovery cost as a percent of total annual cost was lowest for DH, EP, and DS systems, the highest ranking systems in terms of least net annual cost. These same systems had the highest labor cost as a percent of total annual cost. Value of retained manurial fertilizer nutrients as a percent of total annual cost was lowest for AGT and TSL systems.

320/PC. Net annual costs of dairy waste systems modeled on the 320/PC herd size/confinement system ranged from $5,922 to $31,772. The DH waste system was found to be least cost; the system incurring greatest cost was the SAGT/6 system. Total annual cost of each component and net annual costs of various waste management systems modeled for the 320/PC herd size/confinement system are shown in Table IV-44. A graphical comparison of net annual costs of the various systems is shown in Figure IV-11.

Among waste systems incorporating storage, EP systems required the least net annual costs as a class. As with the 160/TC analysis, the SSL/FC was found to be less costly than the DS/3 system - a difference of $1,295. Indexes of net annual costs relative to the least cost system and ranking of the modeled waste management systems (from least cost to greatest cost) are shown in Table IV-45.

As shown in Tables IV-44 and IV-45, installation of six-months rather than three-months storage capacity (on those systems for which this parameter was varied) resulted in higher net annual cost.

Table IV-43. Proportionate Contribution of Modeled Cost Parameters[1] to Total Annual Costs[2] for 160/TC Systems.

System	Capital Recovery	Insurance/Repairs/ Housing Costs	Equipment Rental	Energy Costs	Labor Costs	Manure Value
160/TC/						
DH	46.5%	8.1%		17.9%	27.5%	45.5%
DS/3	60.9%	5.8%		13.1%	20.2%	43.8%
DS/6	66.1%	6.0%		11.0%	17.0%	40.3%
EP/3	54.4%	6.2%		16.4%	23.0%	68.1%
EP/6	55.6%	6.1%		16.1%	22.2%	68.6%
SAGT/3	72.2%	6.2%		9.2%	12.4%	37.4%
SAGT/6	74.7%	6.3%		8.1%	10.8%	36.0%
CAGT/3	70.0%	6.1%		10.2%	13.8%	41.5%
CAGT/6	72.8%	6.2%		8.9%	12.0%	39.9%
SSL/SC	69.6%	7.7%		9.4%	13.3%	45.0%
SSL/FC	78.4%	8.6%		7.0%	6.0%	51.6%
TSL/SC	70.5%	7.2%	0.8%	9.0%	12.5%	32.1%
TSL/FC	79.6%	8.0%	0.9%	6.6%	4.9%	37.0%

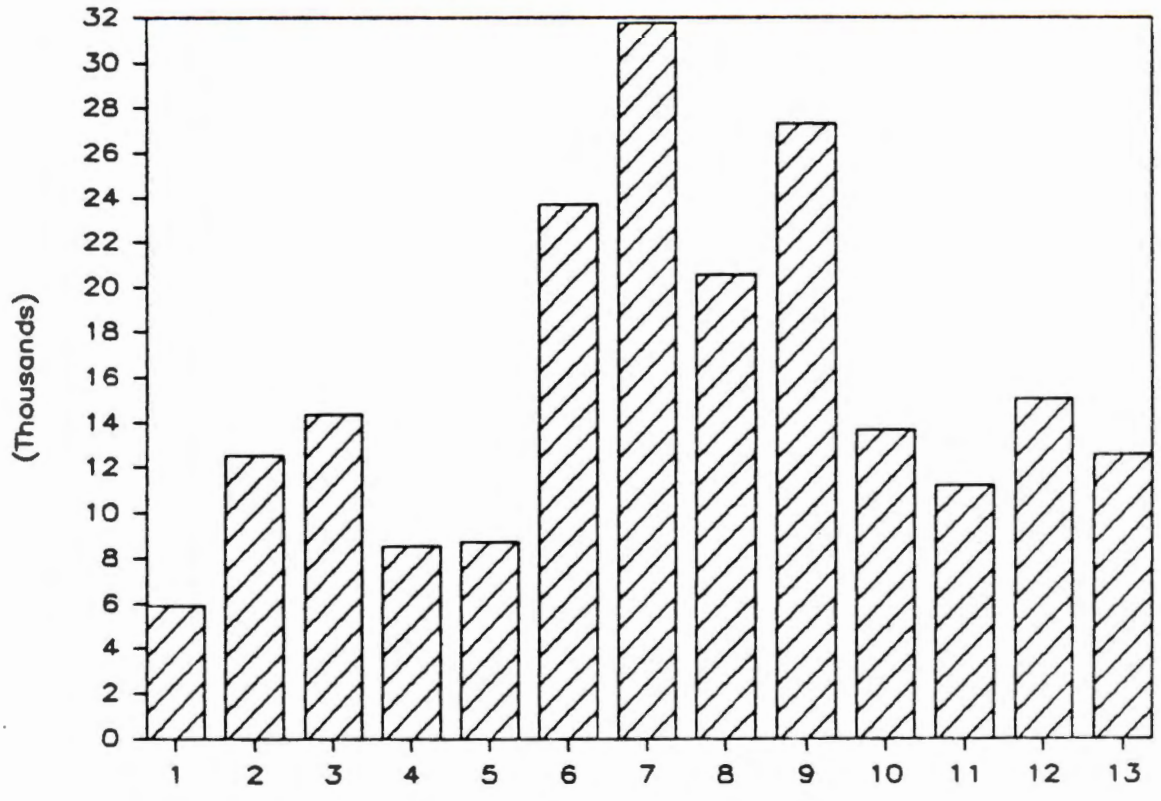
[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.

[2]Manure value was analyzed as a negative cost i.e. the proportion of total annual costs offset.

Table IV-44. Net Annual Cost Budget for 320/PC Systems.[1]

System	Capital Recovery +	Insurance/Repairs/ Housing Costs +	Equipment Rental +	Energy Costs +	Labor Costs -	Manure Value =	Net Annual Cost
320/PC/							
DH	5546	838		3145	4048	7655	5922
DS/3	13744	1293		2913	3795	9225	12520
DS/6	15929	1455		2883	3770	9668	14369
EP/3	12022	1326		3882	4185	12895	8520
EP/6	12642	1376		4002	4243	13505	8758
SAGT/3	27180	2376		3708	4048	13619	23693
SAGT/6	35386	2996		3754	4053	14417	31772
CAGT/3	24251	2155		3708	4048	13619	20543
CAGT/6	31225	2682		3754	4053	14417	27297
SSL/SC	16899	1810		2483	2858	10378	13672
SSL/FC	16966	1783		1764	1090	10378	11225
TSL/SC	17287	1725	116	2329	2702	9156	15003
TSL/FC	17354	1698	116	1610	934	9156	12556

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-11. Net Annual Costs Incurred on Dairy Waste Systems Modeled for the 320/PC Herd Size/Confinement System.

Table IV-45. Ranking (Based on Net Annual Cost) of Dairy Waste Management Systems Modeled for the 320/PC Herd Size/Confinement System.

Rank[1]	System	Net Annual Cost Index[2]
1	DH[3]	100
2	EP/3	144
3	EP/6	148
4	SSL/FC	190
5	DS/3	211
6	TSL/FC	212
7	SSL/SC	231
8	DS/6	243
9	TSL/SC	253
10	CAGT/3	347
11	CAGT/6	400
12	SAGT/3	461
13	SAGT/6	537

[1]Rank was based upon net annual cost, lowest to highest.

[2]Net annual cost index for each system was determined by dividing the net annual cost of that system by the investment required for the least cost system and multiplying by 100.

[3]DH was the least net annual cost system in this instance.

However, for the EP systems, the six-months capacity system had net annual cost only $238 greater than three-months capacity. It is very possible that inherent (and farm-specific) advantages of larger storage capacity not evaluated here could easily offset this cost difference.

It was observed that the utilization of flush collection on lagoon systems again significantly reduced net annual costs. Both SSL and TSL systems incurred net annual cost savings of $2,447 (flush as compared to standard collection). Labor savings of almost one-third accounted for a major proportion of this economic advantage. Energy cost were also significantly lower for the lagoon systems using flush collection methods.

As for systems analyzed earlier, enhanced preservation and/or utilization of manurial fertilizer nutrients accruing to AGT systems were insufficient to offset their considerable annual cost disadvantage. Compared to the EP/6 system, the SAGT/6 system incurred net annual costs over three and one-half times as great (or an annual disadvantage of $23,014). Both systems utilize similar waste handling technology i.e. both are slurry systems.

It should also be noted that, regard to AGT systems, the CAGT/6 system had higher net annual costs than the SAGT/3 system. This was not the case in any previous analyses. This shift in relationships was likely the result of the "lumpiness" factor with respect to acquiring concrete or steel tank structures.

An analysis was performed to examine if significant relationships existed between specific cost parameter's proportionate contribution to total annual costs and ranking of the modeled systems. Manure value, a

negative cost, was analyzed with respect to the percent of total annual costs recovered. Data for this analysis is shown in Table IV-46.

Manurial fertilizer value recovered was the highest percentage of total annual cost for DH and EP systems - the three highest ranked systems (Table IV-45). Manurial value recovered as a percent of total annual cost was lowest for AGT systems - the four lowest ranked systems. Higher ranking systems tended to have a higher proportion of cost in labor and energy and a smaller proportion in capital recovery. Of course, if net annual cost is the sole criterion for choice, the distribution of cost among components is unimportant. Nonetheless, particular systems are often advocated or evaluated on particular characteristics rather than the aggregate cost and benefits.

320/TC. Net annual costs of dairy waste management systems modeled on the 320/TC herd size/confinement system ranged from $6,207 (EP/6) to $34,015 (SAGT/6) - a difference of $27,808. Data on net annual costs of waste management systems modeled for the 320/TC herd size/confinement system are shown in Table IV-47. A graphical comparison is shown in Figure IV-12.

Among dairy waste management systems utilizing storage, EP systems, as a class, incurred the least net annual costs. Indeed, EP systems were found to be lower cost than the DH system (typically expected to be the least cost system available). In this analysis, the SSL/FC and TSL/FC systems incurred less net annual costs than did the DH system - a considerable divergence from the results of previous analyses.

Table IV-46. Proportionate Contribution of Modeled Cost Parameters[1] to Total Annual Costs[2] for 320/PC Systems.

System	Capital Recovery	Insurance/Repairs/ Housing Costs	Equipment Rental	Energy Costs	Labor Costs	Manure Value
320/PC/						
DH	40.8%	6.2%		23.2%	29.8%	56.4%
DS/3	63.2%	5.9%		13.4%	17.5%	42.4%
DS/6	66.3%	6.1%		12.0%	15.7%	40.2%
EP/3	56.1%	6.2%		18.1%	19.5%	60.2%
EP/6	56.8%	6.2%		18.0%	19.1%	60.7%
SAGT/3	72.8%	6.4%		9.9%	10.8%	36.5%
SAGT/6	76.6%	6.5%		8.1%	8.8%	31.2%
CAGT/3	71.0%	6.3%		10.9%	11.8%	39.9%
CAGT/6	74.9%	6.4%		9.0%	9.7%	34.6%
SSL/SC	70.3%	7.5%		10.3%	11.9%	43.2%
SSL/FC	78.5%	8.3%		8.2%	5.0%	48.0%
TSL/SC	71.6%	7.1%	0.5%	9.6%	11.2%	37.9%
TSL/FC	79.9%	7.8%	0.5%	7.4%	4.3%	42.2%

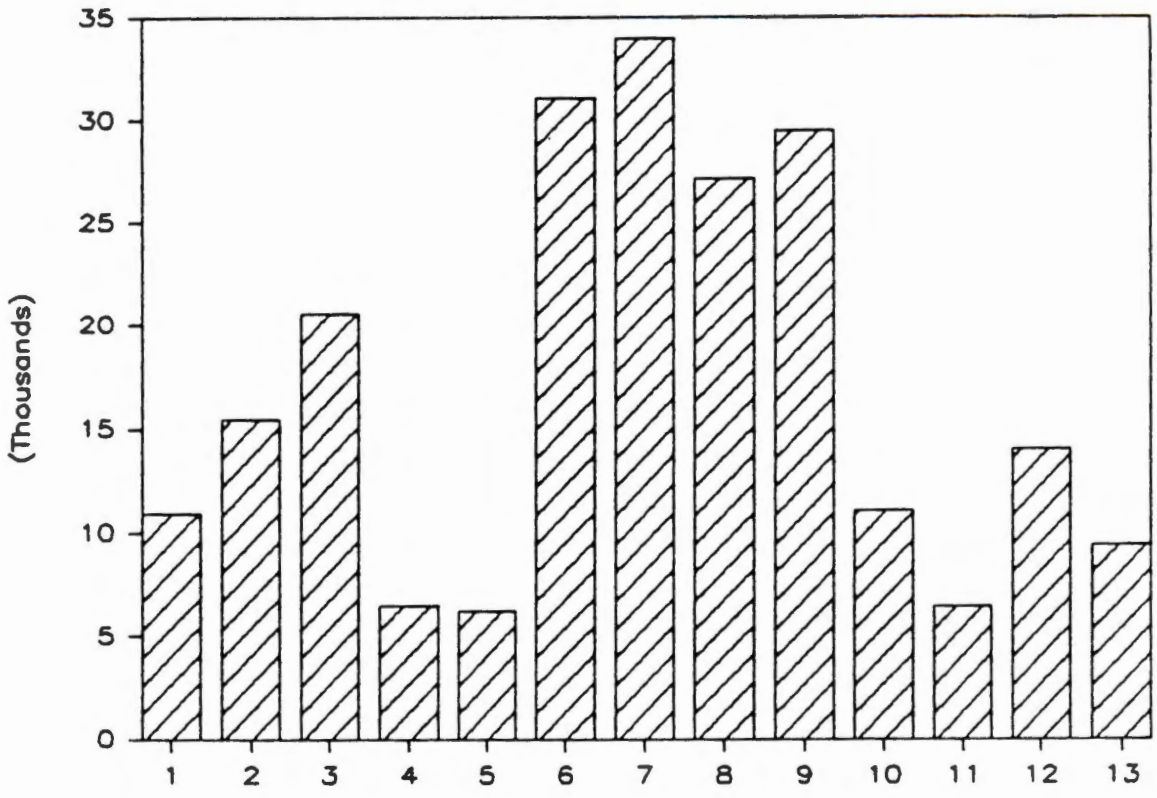
[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.

[2]Manure value was analyzed as a negative cost i.e. the proportion of total annual costs offset.

Table IV-47. Net Annual Cost Budget for 320/TC Systems.[1]

System	Capital Recovery	+ Insurance/Repairs/ Housing Costs	+ Equipment Rental	+ Energy Costs	+ Labor Costs	- Manure Value	= Net Annual Cost
320/TC/							
DH	11226	1106		5057	6270	12699	10960
DS/3	18129	1669		4698	5750	14805	15441
DS/6	24121	2116		4656	5703	16038	20558
EP/3	14236	1530		5353	5828	20432	6515
EP/6	15029	1594		5551	5928	21895	6207
SAGT/3	37275	3187		5842	6043	21242	31105
SAGT/6	41956	3541		5880	6010	23372	34015
CAGT/3	33657	2914		5807	6043	21242	27179
CAGT/6	37821	3229		5845	6010	23372	29533
SSL/SC	18573	1954		3213	4140	16811	11069
SSL/FC	17886	1859		2086	1428	16811	6448
TSL/SC	19759	1929	191	2991	3921	14728	14063
TSL/FC	19072	1834	191	1864	1209	14728	9442

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.



Legend:

1 - DH
2 - DS/3
3 - DS/6
4 - EP/3
5 - EP/6
6 - CAGT/3
7 - CAGT/6
8 - SAGT/3
9 - SAGT/6
10 - SSL/SC
11 - SSL/FC
12 - TSL/SC
13 - TSL/FC

Figure IV-12. Net Annual Costs Incurred on Dairy Waste Systems Modeled for the 320/TC Herd Size/Confinement System.

Of particular note was that the SSL/FC system ranked second in terms of lowest net annual costs. This waste system incurred $67 less in net annual costs than did the EP/3 system and only $241 more than the least cost system (EP/6). Significant savings in labor and energy costs were primarily responsible for this higher ranking. Indexes of net annual costs and rankings of the modeled systems relative to the least cost system are shown in Table IV-48.

As was true for other herd sizes/confinement systems, installing six-months storage capacity rather than three-months does not appear to be economically justified. The only exception was EP systems where EP/6 showed about $300 less net annual cost than EP/3. In all previous analyses, six-months storage had shown a higher net annual cost than three-months capacity. Possible explanations include significant economies of storage size (related to declining per unit excavation costs) and the much larger volume of wastes collected with this herd size/confinement system. As supporting evidence, annual manurial fertilizer value for the EP/6 system was $1,463 greater than that accruing to the DS/3 system. Indeed, manurial fertilizer value for the EP/6 system was $9,196 greater than for the system incurring the least total annual cost (DH system). Obviously, a substantial annual cost disadvantage could be offset by this nutrient value.

In comparison, the highest annual value for nutrient value retained (SAGT/6) was only $1,477 more than for the EP/6 system. However, the much higher capital costs of the SAGT/6 system more than offset its nutrient value advantage. Annual capital recovery for the SAGT/6 system was nearly $27,000 higher than for the EP/6 system.

Table IV-48. Ranking (Based on Net Annual Cost) of Dairy Waste Management Systems Modeled for the 320/TC Herd Size/Confinement System.

Rank[1]	System	Net Annual Cost Index[2]
1	EP/3[3]	100
2	SSL/FC	104
3	EP/3	105
4	TSL/FC	152
5	DH	177
6	SSL/SC	178
7	TSL/SC	227
8	DS/3	249
9	DS/6	331
10	CAGT/3	438
11	CAGT/6	476
12	SAGT/3	501
13	SAGT/6	548

[1]Rank was based upon net annual cost, lowest to highest.

[2]Net annual cost index for each system was determined by dividing the net annual cost of that system by the investment required for the least cost system and multiplying by 100.

[3]EP/3 was the least net annual cost system in this instance.

As herd size has been increased, lagoon systems became less costly relative to the least cost system. All lagoon systems ranked higher than either of the DS systems. Change in relative ranking probably reflect the fact that (1) per unit construction costs for dry stack facilities do not decline as precipitously as per unit excavation costs for lagoon systems; and (2) labor and energy cost savings for lagoon systems become more evident for larger herd sizes. Labor and energy savings are especially evident for lagoon systems utilizing flush collection. As a result, SSL/FC and TSL/FC systems were $4,621 less costly than SSL/SC and TSL/SC systems. TSL systems incurred net annual cost about $3,000 higher than SSL comparable SSL systems.

AGT systems were again the highest cost systems analyzed. AGT systems were 4.4 to 5.5 times as expensive in terms of net annual cost as the EP/3 system, the least cost system for the 320/PC analysis. Expressed on a unit basis, the net annual cost for the AGT systems ranged from $85 to $106 per milk cow.

An analysis was performed to determine if the relationships between specific cost parameter's proportionate contributions to total annual costs and ranking of the modeled systems. Manure value, a negative cost, was analyzed in regard to the percentage of total annual costs offset. Data for this analysis is shown in Table IV-49.

Manurial fertilizer value, as a percentage of total annual costs, was highest for the highest ranked systems (Table IV-48). For the three highest ranked systems, manurial fertilizer value was 72% or more of total annual cost. For the four lowest ranked systems (AGT's), manurial value was 44% or less of total annual cost. As for systems

Table IV-49. Proportionate Contribution of Modeled Cost Parameters[1] to Total Annual Costs[2] for 320/TC Systems.

System	Capital Recovery	Insurance/Repairs/ Housing Costs	Equipment Rental	Energy Costs	Labor Costs	Manure Value
320/TC/						
DH	47.4%	4.7%		21.4%	26.5%	53.7%
DS/3	59.9%	5.5%		15.5%	19.0%	48.9%
DS/6	65.9%	5.8%		12.7%	15.6%	43.8%
EP/3	52.8%	5.7%		19.9%	21.6%	75.8%
EP/6	53.5%	5.7%		19.8%	21.1%	77.9%
SAGT/3	71.2%	6.1%		11.2%	11.5%	40.6%
SAGT/6	73.1%	6.2%		10.2%	10.5%	40.7%
CAGT/3	69.5%	6.0%		12.0%	12.5%	43.9%
CAGT/6	71.5%	6.1%		11.0%	11.4%	44.2%
SSL/SC	66.6%	7.0%		11.5%	14.8%	60.3%
SSL/FC	76.9%	8.0%		9.0%	6.1%	72.3%
TSL/SC	68.6%	6.7%	0.7%	10.4%	13.6%	51.2%
TSL/FC	78.9%	7.6%	0.8%	7.7%	5.0%	60.9%

[1]Data obtained from Capital Recovery/Insurance/Repairs/Housing Costs Budgets, Annual Labor and Energy Budgets, and Nutrient Mineralization and Valuation Budgets.

[2]Manure value was analyzed as a negative cost i.e. the proportion of total annual costs offset.

analyzed earlier, capital recovery was by far the largest component of total annual cost. This parameter ranged from 79% of total annual cost for the TSL/FC system to 47% for the DH system.

Analysis of Systems Across Herd Sizes

Net annual costs per cow were compared for each specific waste system as herd size was increased from 80 to 320 cows. This analysis was an effort to observe potential economies of herd size. These comparisons were restricted within similar types of confinement systems. Since waste removal and land application is a costly process, costs per cow on a given herd size would be expected to increase if the volume of wastes collected (a function of confinement) increased. This held true in this analysis with one exception.

In all instances, rather dramatic net annual cost economies accruing to herd size were observed (Table IV-50).

PC Systems. For waste systems modeled for herds utilizing partial confinement, cost economies were most apparent on SSL/FC systems. Net annual costs per cow declined from $104 to $35 (about 66%) as herd size was increased from 80 to 320 cows. Over the same range, net annual cost for the DH systems declined from $54 to $19 (about 65%). DH systems were also the least cost system for all herd sizes using partial confinement. In terms of dollars, expanding from 80 to 320 cows was estimated to reduce net annual cost of dairy waste management by $69 and $35 annual savings per cow for SSL/FC and DH systems respectively.

Generally, if a specific waste system was less costly than a compared system at the 80-cow herd size, it would retain a relative cost advantage at the 320-cow herd size. However, this was not always true.

Table IV-50. Comparisons of Net Annual Cost Per Cow of Waste Management Systems by Herd Size, Type of Waste System, and Level of Confinement.

Waste System \ Herd Size	80	160	320	% Decrease (80 -> 320)
PC/				
DH	54	37	19	65.6
DS/3	66	50	39	41.1
DS/6	73	56	45	38.6
EP/3	66	40	27	59.5
EP/6	69	41	27	60.1
CAGT/3	156	97	64	58.8
CAGT/6	164	109	85	47.9
SAGT/3	183	117	74	59.5
SAGT/6	194	125	99	48.9
SSL/SC	121	69	43	64.7
SSL/FC	104	60	35	66.1
TSL/SC	113	69	47	58.5
TSL/FC	96	60	39	59.0
TC/				
DH	62	47	34	45.1
DS/3	73	58	48	34.1
DS/6	90	73	64	28.3
EP/3	60	30	20	65.8
EP/6	62	31	19	68.5
CAGT/3	152	95	85	44.0
CAGT/6	172	110	92	46.5
SAGT/3	179	113	97	45.5
SAGT/6	214	130	106	50.3
SSL/SC	119	64	35	71.0
SSL/FC	96	49	20	78.9
TSL/SC	117	78	44	62.5
TSL/FC	93	63	30	68.4

In comparing the EP/3 and EP/6 systems, the EP/3 system incurred a cost advantage of $3 per cow at the 80-cow herd size. However, these systems were roughly equivalent when compared on 320-cow herds.

Similarly, the TSL/FC system was found to be $8 per cow less costly than the SSL/FC system on modeled 80-cow herds. On the 320-cow herd however, the SSL/FC system had a $4 per cow cost advantage. A similar relationships existed when comparing the SSL/SC and TSL/SC systems. A plausible reason for this relationship relates to spreading of the cost of an agitation pump, and its associated costs, over larger volumes of wastes. At some point, it became more economical to agitate wastes every year (using an owned pump) rather than agitate once every five years (using a rental pump). Inherent efficiencies and greater retention of manurial nutrients by SSL systems also contributed to this relationship.

TC Systems. For waste systems modeled for herds utilizing total confinement, the most dramatic economies due to herd size were observed for SSL/FC systems. Per cow net annual costs fell from $96 to $20, a decline of almost 79%. Over the same herd size range, net annual cost per cow for the SSL/SC system declined from $119 to $35, a drop of 71%.

No one type of dairy waste management system exhibited a clear cost advantage over all herd sizes i.e. the same type of system was not least cost on all herd sizes. For 80 and 160-cow herds utilizing total confinement, EP/3 systems were least cost. However, for the 320/TC herd size/confinement system, the EP/6 system was as the least cost system.

Among the total confinement systems, several instances of changes in relative cost advantage appeared as herd size was increased from 80 to 320 cows. For example, all lagoon systems incurred greater cost (often substantially more) than either DS system at the 80-cow herd size. However, when modeled for the 320/TC herd size/confinement system, all lagoon systems had lower costs than DS systems. The shift in cost relationship was particularly evident between the SSL/SC and DS/3 systems. At 80 cows, the SSL/SC system had a net annual cost disadvantage of $46. But, when compared at 320 cows, the SSL/SC was $13 per cow less costly.

A myriad of interrelated factors are important in determining the least cost waste system on a given herd size/confinement system. Furthermore, the relationships among these factors change, both in absolute and relative terms, as the herd size and confinement system are varied. It is obvious then, that generalities as to which system is "best" cannot be made without strict qualifications.

CHAPTER V

SENSITIVITY ANALYSIS

Certain critical parameters were varied to test the stability of the performed net annual cost analysis. Parameters deemed to be critical included manurial nutrient loss rates (during storage), value of manurial fertilizer nutrients (per unit), and labor cost (per hour). The relative effects of these variations were measured by ranking the systems according to net annual costs (from lowest to highest). A change in system ranking then indicated a sensitivity to variations of the parameters in question i.e. a "significant" impact occurred.

Varying Nutrient Loss Rates (During Storage)

Nutrient losses during storage are highly variable parameters (35, 44, 45, 42, 59). A sensitivity analysis was performed to examine the effect (if any) on relative net annual costs from alteration of these parameters. Nutrient loss rates (during storage only) were varied from the lower to upper extremes of those presented in Appendix A, Table A-5. Nutrient loss rates for N, P, and K differed for the various types of dairy waste management systems.

Each dairy waste management system modeled on specific herd sizes/confinement systems were compared at extreme points of storage loss rates. It was assumed that environmental conditions affected all systems similarly i.e. if conditions existed that promoted increased nutrient loss in one system, all systems would experience increased

nutrient losses. However, this may not be universally true. The possibility exists that nutrient losses may occur at the mid-point value for one system while another may experience relatively higher nutrient losses. The analysis here is to demonstrate the effect of variation in nutrient loss rates rather than to model a representative type of system. An analytical sketch of the effect of nutrient loss variation on each herd size/confinement system combination follows.

80/PC Systems

Relative net annual costs of dairy waste management systems modeled for the 80/PC herd size/confinement system were not significantly affected by varying nutrient loss rates in storage. This is evidenced by information provided in Table V-1. The ranking order of the modeled waste systems remained constant at all calculated loss rates.

Obvious (and anticipated) absolute effects on net annual costs did occur. Net annual costs for each modeled system were reduced (increased) when the respective nutrient loss rate was calculated at its lower (upper) extreme. Net annual costs were one to four percent higher at high nutrient loss levels as compared to low nutrient loss levels.

80/TC Systems

No major changes in relative net annual costs resulted from varying nutrient loss rates in storage. The EP/6 system and the TSL/FC system became less costly compared to the EP/3 system and the DS/6 system respectively when storage losses were calculated at the lower extreme.

Table V-1. Effect on Net Annual Costs of 80/PC Systems When Manurial Nutrient Storage Loss Rates Were Varied.[1]

System	Total Annual Costs	Low		High		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Mid.	Low	High
80/PC/								
DH	6222	2043	4179	1800	4422	1	1	1
DS/3	7638	2518	5120	2130	5508	3	3	3
DS/6	8274	2627	5647	2222	6052	5	5	5
EP/3	8398	3463	4935	3020	5378	2	2	2
EP/6	8910	3666	5244	3199	5711	4	4	4
SAGT/3	18093	3744	14349	3288	14805	12	12	12
SAGT/6	19221	3926	15295	3461	15670	13	13	13
CAGT/3	15941	3744	12197	3288	12653	10	10	10
CAGT/6	16769	3926	12843	3461	13308	11	11	11
SSL/SC	12310	3013	9297	2268	10042	9	9	9
SSL/FC	10929	3013	7916	2268	8661	7	7	7
TSL/SC	11348	2511	8837	2005	9343	8	8	8
TSL/FC	9967	2511	7456	2005	7962	6	6	6

[1]Nutrient storage loss rates were varied from the lower extreme to the upper extreme of ranges reported in Appendix A, Table A-5.

[2]Rank when loss rates were calculated at the mid-point value (used in the base analysis), lower extreme, and upper extreme. Net annual cost for mid-point value nutrient loss rates are shown in Table IV-20.

However, in absolute terms, net annual costs for a specific system varied by as much as $1,200 (SSL systems) from one extreme to another. In relative terms, the net annual cost for the SSL/FC system was about 17% higher at high as compared to low nutrient loss level assumption. Net annual cost of the EP/6 system was 21% higher at high as compared to low nutrient loss levels (Table V-2).

160/PC Systems

Variation of nutrient loss rates impacted very little upon relative net annual costs of wasted systems modeled on the 160/PC herd size/confinement system. Indeed, system rankings were unchanged when nutrient loss rates were calculated at the lower extreme (Table V-3).

When nutrient loss rates were calculated at the upper extreme, SSL systems became more costly relative to comparable TSL systems. No other significant changes in relative net annual costs occurred.

In absolute terms, net annual costs varied by as much as $1496 (SSL systems) in response to varying nutrient loss rates. This amount represented over 15% of net annual cost calculated for the SSL/FC system in the base analysis. Overall however, nutrient loss rates did not appear to impact significantly on the cost rankings of the various systems.

160/TC Systems

Slightly more significant effects resulted from the sensitivity analysis on 160/TC systems. However, no system improved or regressed relative to other modeled systems by more than one position in the ranking.

Table V-2. Effect on Net Annual Costs of 80/TC Systems When Manurial Nutrient Storage Loss Rates Were Varied.[1]

System	Total Annual Costs	Low		High		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Mid.	Low	High
80/TC/								
DH	8097	3318	4779	2776	5321	3	3	3
DS/3	9492	3937	5555	3330	6162	4	4	4
DS/6	11103	4261	6842	3605	7498	5	6	5
EP/3	9956	5541	4415	4839	5117	1	2	1
EP/6	10448	6078	4370	5155	5291	2	1	2
SAGT/3	19702	5829	13873	5119	14583	12	12	12
SAGT/6	22995	6331	16664	5553	17442	13	13	13
CAGT/3	17546	5829	11717	5119	12427	10	10	10
CAGT/6	19675	6331	13344	5553	14122	11	11	11
SSL/SC	13798	4847	8951	3647	10151	9	9	9
SSL/FC	11895	4847	7048	3647	8248	7	7	7
TSL/SC	13086	4366	8720	3213	9873	8	8	8
TSL/FC	11183	4366	6817	3213	7970	6	5	6

[1]Nutrient storage loss rates were varied from the lower extreme to the upper extreme of ranges reported in Appendix A, Table A-5.

[2]Rank when loss rates were calculated at the mid-point value (used in the base analysis), lower extreme, and upper extreme. Net annual cost for mid-point value nutrient loss rates are shown in Table IV-23.

Table V-3. Effect on Net Annual Costs of 160/PC Systems When Manurial Nutrient Storage Loss Rates Were Varied.[1]

System	Total Annual Costs	Low		High		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Mid.	Low	High
160/PC/								
DH	9621	4007	5614	3538	6083	1	1	1
DS/3	12549	4940	7609	4177	8372	4	4	4
DS/6	13658	5140	8518	4346	9312	5	5	5
EP/3	12749	6854	5895	5985	6764	2	2	2
EP/6	13296	7224	6072	6309	6981	3	3	3
SAGT/3	25528	7347	18181	6444	19084	12	12	12
SAGT/6	27188	7784	19404	6827	20361	13	13	13
CAGT/3	22262	7347	14915	6444	15818	10	10	10
CAGT/6	24680	7784	16896	6827	17853	11	11	11
SSL/SC	16230	5934	10296	4438	11792	8	8	9
SSL/FC	14836	5934	8902	4438	10398	6	6	7
TSL/SC	15617	5167	10450	3931	11686	9	9	8
TSL/FC	14223	5167	9058	3931	10292	7	7	6

[1] Nutrient storage loss rates were varied from the lower extreme to the upper extreme of ranges reported in Appendix A, Table A-5.

[2] Rank when loss rates were calculated at the mid-point value (used in the base analysis), lower extreme, and upper extreme. Net annual cost for mid-point value nutrient loss rates are shown in Table IV-26.

Lagoon systems (SSL and TSL) improved relatively when loss rates were calculated at the lower extreme. However, the TSL/FC system also improved (relative to the base analysis) when loss rates were calculated at the upper extreme.

In absolute terms, net annual costs varied by as great as $2385 for a given waste management system as nutrient loss rates were varied from low to high. Once again, the greatest spread occurred with the SSL systems. Net annual cost for the SSL/FC system was about three percent higher at high loss rates as compared to low loss rates. The rate of nutrient loss during storage impacted significantly upon net annual costs for several of the systems (Table V-4).

320/PC Systems

Relative net annual costs of dairy waste management systems modeled for the 320/PC herd size/confinement system were not significantly affected by varying nutrient loss rates. No system improved or regressed by more than one relative position in the system ranking.

Lagoon systems, especially those utilizing flush collection, appeared to become relatively less costly when nutrient loss rates were calculated at the low extreme. This advantage was lost at the upper extreme of nutrient loss rates. Indeed, at the upper extreme, the DS/6 system improved as compared to a lagoon system (SSL/SC).

With regard to absolute variation, a maximum spread of $3,070 (SSL/SC and SSL/FC systems) existed between net annual costs calculated at the lower and upper extremes. For the SSL/FC system, net annual cost was estimated to increase about 31% as nutrient loss rates were varied from the low to the high rate.

Table V-4. Effect on Net Annual Costs of 160/TC Systems When Manurial Nutrient Storage Loss Rates Were Varied.[1]

System	Total Annual Costs	Low		High		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Mid.	Low	High
160/TC/								
DH	13739	6644	7095	5827	7912	3	4	3
DS/3	16623	7880	8743	6661	9962	5	6	6
DS/6	19528	8537	10991	7215	12313	8	9	9
EP/3	15163	11023	4140	9622	5541	1	1	1
EP/6	15971	11699	4272	10220	5751	2	2	2
SAGT/3	28752	11576	17176	10154	18598	12	12	12
SAGT/6	32481	12619	19862	11056	21425	13	13	13
CAGT/3	25876	11576	14300	10154	15722	10	10	10
CAGT/6	29319	12619	16700	11056	18263	11	11	11
SSL/SC	18705	9607	9098	7222	11483	7	7	7
SSL/FC	16295	9607	6688	7222	9073	4	3	4
TSL/SC	18336	8395	9941	6392	11944	9	8	8
TSL/FC	15928	8395	7533	6392	9536	6	5	5

[1]Nutrient storage loss rates were varied from the lower extreme to the upper extreme of ranges reported in Appendix A, Table A-5.

[2]Rank when loss rates were calculated at the mid-point value (used in the base analysis), lower extreme, and upper extreme. Net annual cost for mid-point value nutrient loss rates are shown in Table IV-29.

Nutrient loss rates appeared to significantly influence (in absolute terms) net annual costs. Relative rankings were not significantly changed by varying loss rates (Table V-5).

320/TC Systems

Greater impacts from varying nutrient loss rates occurred with the 320/TC systems than for other systems analyzed. Most notable was the fact that the EP/3 system improved its relative position when nutrient loss rates were calculated at the upper extreme. At the upper loss rate, the EP/3 system actually became the second least cost system, displacing the SSL/FC system. Conversely, while the EP/6 system was least cost in the base analysis, it fell to second at the lower extreme of nutrient loss rates (Table V-6).

In absolute terms, a maximum difference between net annual costs calculated at lower and upper nutrient loss rates was $4763 and occurred for SSL systems. For the SSL/FC system, estimated net annual cost was 117% greater at high nutrient loss rates as compared to low rates.

For all systems considered, variations in nutrient loss rates had rather limited effect on the relative ranking of the systems in terms of net annual cost. However net annual costs (in absolute terms) for a specific dairy waste system may be significantly affected. Differences in dollar terms were greatest on those systems designed to retain smaller proportions of manurial nutrients - AGT and EP systems. Indeed, this result is consistent with that of the analyses on all herd sizes/-confinement systems. The wider range in nutrient loss rates was the probable cause.

Table V-5. Effect on Net Annual Costs of 320/PC Systems When Manurial Nutrient Storage Loss Rates Were Varied.[1]

System	Total Annual Costs	Low		High		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Mid.	Low	High
320/PC/								
DH	13577	8154	5423	7177	6400	1	1	1
DS/3	21745	10003	11742	8452	13293	5	6	5
DS/6	24037	10481	13556	8855	15182	8	8	7
EP/3	21415	13693	7722	11956	9459	2	2	2
EP/6	22263	14424	7839	12597	9666	3	3	3
SAGT/3	37312	14682	22630	12834	24478	12	12	12
SAGT/6	46189	15543	30646	13630	32559	13	13	13
CAGT/3	34162	14682	19480	12834	21328	10	10	10
CAGT/6	41714	15543	26171	13630	28084	11	11	11
SSL/SC	24050	11852	12198	8782	15268	7	7	8
SSL/FC	21603	11852	9751	8782	12821	4	3	4
TSL/SC	24159	10401	13758	7929	16230	9	9	9
TSL/FC	21712	10401	11311	7929	13783	6	5	6

[1]Nutrient storage loss rates were varied from the lower extreme to the upper extreme of ranges reported in Appendix A, Table A-5.

[2]Rank when loss rates were calculated at the mid-point value (used in the base analysis), lower extreme, and upper extreme. Net annual cost for mid-point value nutrient loss rates are shown in Table IV-32.

Table V-6. Effect on Net Annual Costs of 320/TC Systems When Manurial Nutrient Storage Loss Rates Were Varied.[1]

System	Total Annual Costs	Low		High		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Mid.	Low	High
320/TC/								
DH	23659	13513	10146	11890	11769	5	6	5
DS/3	30246	16055	14191	13568	16678	8	8	8
DS/6	36596	17391	19205	14692	21904	9	9	9
EP/3	26947	21826	5121	19055	7892	1	3	2
EP/6	28102	23381	4721	20422	7680	3	2	1
SAGT/3	52347	22892	29455	20082	32265	12	12	12
SAGT/6	57387	25198	32189	22095	35292	13	13	13
CAGT/3	48421	22892	25529	20082	28339	10	10	10
CAGT/6	52905	25198	27707	22095	30810	11	11	11
SSL/SC	27880	19198	8682	14435	13445	6	5	6
SSL/FC	23259	19198	4061	14435	8824	2	1	3
TSL/SC	28791	16719	12072	12671	16120	7	7	7
TSL/FC	24170	16719	7451	12671	11499	4	4	4

[1]Nutrient storage loss rates were varied from the lower extreme to the upper extreme of ranges reported in Appendix A, Table A-5.

[2]Rank when loss rates were calculated at the mid-point value (used in the base analysis), lower extreme, and upper extreme. Net annual cost for mid-point value nutrient loss rates are shown in Table IV-35.

Varying Nutrient Values (Prices)

As a test for sensitivity to valuation of manurial nutrients, an increase in values of 25% and 50% were incorporated into the analysis. Since cost of commercial sources of N, P, and K have fluctuated in recent years, changes in values of manurial sources of these nutrients could have significant impact on the comparison of various systems. Rises in value of nutrients would tend to favor waste management systems that retain larger proportions of the nutrients while in storage.

80/PC Systems

Relative net annual costs of dairy waste management systems modeled on the 80/PC herd size/confinement system were not significantly affected by increasing manurial values (Table V-7). The ranking of the modeled waste systems remained relatively constant as valuation rates were increased.

Anticipated (and obvious) effects on absolute net annual costs did no occur. The greatest reduction in net annual costs occurred on the SAGT/6 and CAGT/6 systems, a reduction of $1,828 or almost 14% of net annual cost calculated in the base analysis for the CAGT/6 system. The effect on net cost for the various systems is shown in Table V-7.

80/TC Systems

Relative net annual costs of modeled dairy waste management systems were not radically affected by increases in manurial nutrient values. The major change was the EP/6 system becoming the least cost system at both the 25% and 50% valuation adjustment levels (instead of EP/3). For the base analysis, the EP/6 system had ranked second. Even

Table V-7. Effect on Net Annual Costs of 80/PC Systems When Manurial Nutrient Values Were Increased Twenty-five and Fifty Percent.[1]

System	Total Annual Costs	25% Increase		50% Increase		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Cur.	25%	50%
80/PC/								
DH	6222	2401	3821	2881	3341	1	1	1
DS/3	7638	2905	4733	3485	4153	3	4	4
DS/6	8274	3032	5242	3638	4636	5	5	5
EP/3	8398	4054	4344	4866	3532	2	2	2
EP/6	8910	4290	4620	5148	3762	4	3	3
SAGT/3	18093	4332	13761	5197	12896	12	12	12
SAGT/6	19221	4580	14641	5494	13727	13	13	13
CAGT/3	15941	4332	11609	5197	10744	10	10	10
CAGT/6	16769	4580	12189	5494	11275	11	11	11
SSL/SC	12310	3298	9012	3958	8352	9	9	9
SSL/FC	10929	3298	7631	3958	6971	7	7	7
TSL/SC	11348	2897	8451	3476	7872	8	8	8
TSL/FC	9967	2897	7070	3476	6491	6	6	6

[1]Nutrients were valued after storage losses, field application losses, and mineralization rates were considered.

[2]Rank when nutrient values were calculated at the current market prices (used for the basic analysis), increased by 25%, and increased by 50%. Net annual costs for waste systems when nutrients were valued at current market prices are shown in Table IV-20.

at the 50% level, its hold on the least cost ranking was tenuous. Only $19 separated the EP/6 system from the next least cost system (EP/3). The only other change in system rankings occurred at the 50% adjustment level. The SSL/SC system displaced the TSL/SC system as the eighth least cost dairy waste management system (Table V-8).

With regard to absolute costs, the most significant reduction in net annual costs was $2,939 on SAGT/6 and CAGT/6 systems. This amount represented a reduction of over 24% of the net annual cost as compared to the base analysis for the CAGT/6 system. Impact of changes in manurial nutrient value on net annual cost of each system is shown in Table V-8.

160/PC Systems

Increases in manurial nutrient values affected relative rankings for the 160/PC herd size/confinement system only slightly. The DH system fell from first (least cost) to third as manurial fertilizer value was increased by 25% and 50%. The EP/3 system was the least cost system when nutrient values were increased by 25% and 50% above the base levels (Table V-9).

Net annual costs declined, in absolute terms, when nutrient values were increased for each waste system. When nutrient values were increased by 50%, the greatest decline ($3,612) was for the SAGT/6 and CAGT/6 systems. Net annual cost for the CAGT/6 system was reduced 26% as result of the 50% increase in manure nutrient value.

Table V-8. Effect on Net Annual Costs of 80/TC Systems When Manurial Nutrient Values Were Increased Twenty-five and Fifty Percent.[1]

System	Total Annual Costs	25% Increase		50% Increase		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Cur.	25%	50%
80/TC/								
DH	8097	3891	4206	4668	3429	3	3	3
DS/3	9492	4541	4951	5449	4043	4	4	4
DS/6	11103	4917	6186	5900	5203	5	5	5
EP/3	9956	6485	3471	7782	2174	1	2	2
EP/6	10448	6910	3538	8292	2155	2	1	1
SAGT/3	19702	6777	12925	8131	11571	12	12	12
SAGT/6	22995	7346	15649	8815	14180	13	13	13
CAGT/3	17546	6777	10769	8131	9415	10	10	10
CAGT/6	19675	7346	12329	8815	10860	11	11	11
SSL/SC	13798	5309	8489	6371	7427	9	9	8
SSL/FC	11895	5309	6586	6371	5524	7	7	7
TSL/SC	13086	4644	8442	5571	7515	8	8	9
TSL/FC	11183	4644	6539	5571	5612	6	6	6

[1]Nutrients were valued after storage losses, field application losses, and mineralization rates were considered.

[2]Rank when nutrient values were calculated at the current market prices (used for the basic analysis), increased by 25%, and increased by 50%. Net annual costs for waste systems when nutrients were valued at current market prices are shown in Table IV-23.

Table V-9. Effect on Net Annual Costs of 160/PC Systems When Manurial Nutrient Values Were Increased Twenty-five and Fifty Percent.[1]

System	Total Annual Costs	25% Increase		50% Increase		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Cur.	25%	50%
160/PC/								
DH	9621	4709	4912	5651	3970	1	3	3
DS/3	12549	5698	6851	6837	5712	4	4	4
DS/6	13658	5927	7731	7113	6545	5	5	5
EP/3	12749	8021	4728	9625	3124	2	1	1
EP/6	13296	8455	4841	10147	3149	3	2	2
SAGT/3	25528	8520	17008	10225	15303	12	12	12
SAGT/6	27188	9026	18162	10831	16357	13	13	13
CAGT/3	22262	8520	13742	10225	12037	10	10	10
CAGT/6	24680	9026	15654	10831	13849	11	11	11
SSL/SC	16230	6495	9735	7795	8435	8	8	8
SSL/FC	14836	6495	8341	7795	7041	6	6	6
TSL/SC	15617	5681	9936	6818	8799	9	9	9
TSL/FC	14223	5681	8542	6818	7405	7	7	7

[1]Nutrients were valued after storage losses, field application losses, and mineralization rates were considered.

[2]Rank when nutrient values were calculated at the current market prices (used for the basic analysis), increased by 25%, and increased by 50%. Net annual costs for waste systems when nutrients were valued at current market prices are shown in Table IV-26.

160/TC Systems

Relative net annual costs of dairy waste management systems modeled on the 160/TC herd size/confinement system were somewhat sensitive to increases in manurial nutrient values (Table V-10).

DH fell in rank from third to fourth and the EP/3 system fell from first to second as nutrient values increased by 50%. However, both SSL systems and the EP/6 system became less costly, in relative terms, over the same value variation. Indeed, the EP/6 system was ranked as least cost when nutrient values improved by 50%

Positive annual returns to waste management systems were calculated for the first time in this study when nutrient values increased by 50%. These positive returns (negative net annual costs) accrued to both the EP/3 and EP/6 systems. However, the returns appeared quite modest.

In absolute terms, net annual costs fell as much as $5,847 when manurial nutrients rose in value. The greatest decline occurred on the SAGT/6 and CAGT/6 systems; a reduction of over 33% of the "base" net annual cost was indicated (CAGT/6 system).

320/PC Systems

Relative net annual costs of dairy waste management systems modeled on the 320/PC herd management system were affected slightly by increasing manurial nutrient values. The DH became relatively more costly as nutrient values increased by 50%. Indeed, the DH system fell from first to third (Table V-11). Conversely, the EP/6 became relatively less costly over the same range. The EP/6 system became least cost at the upper level of nutrient valuation.

Table V-10. Effect on Net Annual Costs of 160/TC Systems When Manurial Nutrient Values Were Increased Twenty-five and Fifty Percent.[1]

System	Total Annual Costs	25% Increase		50% Increase		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Cur.	25%	50%
160/TC/								
DH	13739	7808	5931	9369	4370	3	4	4
DS/3	16623	9088	7535	10906	5717	5	5	5
DS/6	19528	9840	9688	11810	7718	8	8	8
EP/3	15163	12900	2263	15479	(316)	1	1	2
EP/6	15971	13694	2277	16433	(462)	2	2	1
SAGT/3	28752	13428	15324	16113	12639	12	12	12
SAGT/6	32481	14621	17860	17544	14937	13	13	13
CAGT/3	25876	13428	12448	16113	9763	10	10	10
CAGT/6	29319	14621	14698	17544	11775	11	11	11
SSL/SC	18705	10515	8190	12617	6088	7	6	6
SSL/FC	16295	10515	5780	12617	3678	4	3	3
TSL/SC	18336	7360	10976	8832	9505	9	9	9
TSL/FC	15928	7360	8568	8832	7096	6	7	7

[1] Nutrients were valued after storage losses, field application losses, and mineralization rates were considered.

[2] Rank when nutrient values were calculated at the current market prices (used for the basic analysis), increased by 25%, and increased by 50%. Net annual costs for waste systems when nutrients were valued at current market prices are shown in Table IV-29.

Table V-11. Effect on Net Annual Costs of 320/PC Systems When Manurial Nutrient Values Were Increased Twenty-five and Fifty Percent.[1]

System	Total Annual Costs	25% Increase		50% Increase		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Cur.	25%	50%
320/PC/								
DH	13577	9567	4010	11480	2097	1	1	3
DS/3	21745	11532	10213	13839	7906	5	5	5
DS/6	24037	12083	11954	14499	9538	8	8	8
EP/3	21415	16118	5297	19342	2073	2	2	2
EP/6	22263	16883	5380	20258	2005	3	3	1
SAGT/3	37312	17024	20288	20429	16883	12	11	11
SAGT/6	46189	18024	28165	21628	24561	13	13	13
CAGT/3	34162	17024	17038	20429	13733	10	10	10
CAGT/6	41714	18024	23690	21628	20086	11	12	12
SSL/SC	24050	12970	11080	15564	8486	7	7	7
SSL/FC	21603	12970	8633	15564	6039	4	4	4
TSL/SC	24159	11446	12713	13734	10425	9	9	9
TSL/FC	21712	11446	10266	13734	7978	6	6	6

[1] Nutrients were valued after storage losses, field application losses, and mineralization rates were considered.

[2] Rank when nutrient values were calculated at the current market prices (used for the basic analysis), increased by 25%, and increased by 50%. Net annual costs for waste systems when nutrients were valued at current market prices are shown in Table IV-32.

Contrary to other situations analyzed, the SAGT/3 system became less costly than the CAGT/6. This reversal occurred at both the 25% and 50% increase in nutrient valuation.

Increasing manurial nutrient values by 50% resulted in a decline of net annual costs of up to $7,211 (the SAGT/6 and CAGT/6 systems). For the CAGT/6 system, this represented a reduction of over 26% of net annual cost compared to the base analysis.

320/TC Systems

Relative net annual costs (and therefore rankings) of dairy waste management systems modeled on the 320/TC herd size/confinement system were not affected significantly by increases in manurial fertilizer nutrient values (Table V-12). The DH, SSL/FC and EP/3 systems became more costly relative to other systems as nutrient values increased by 25% and 50%.

Conversely, the EP/6 system and both SSL/SC systems improved their rankings over the same range. The EP/6 system rose from third to first in terms of being the least cost system. The SSL/SC system rose from sixth to fifth.

Three waste systems, EP/3, EP/6, and SSL/FC, incurred negative net annual costs (positive returns) when manurial nutrients were valued 50% above current market prices. Of these systems, the EP/6 system earned the highest rate of return on investment, 8.65%. Obviously, manurial nutrient values would need to rise considerably before waste management systems would appear lucrative as investments purely from an investment analysis.

Table V-12. Effect on Net Annual Costs of 320/TC Systems When Manurial Nutrient Values Were Increased Twenty-five and Fifty Percent.[1]

System	Total Annual Costs	25% Increase		50% Increase		Rank[2]		
		Manure Value	Net Annual Costs	Manure Value	Net Annual Costs	Cur.	25%	50%
320/TC/								
DH	23659	15875	7784	19049	4610	5	6	6
DS/3	30246	18509	11737	22210	8036	8	8	8
DS/6	36596	20047	16549	24057	12539	9	9	9
EP/3	26947	25541	1406	30650	(3703)	1	2	2
EP/6	28102	27368	734	32842	(4740)	3	1	1
SAGT/3	52347	26553	25794	31864	20483	12	12	12
SAGT/6	57387	29217	28170	35060	22327	13	13	13
CAGT/3	48421	26553	21868	31864	16557	10	10	10
CAGT/6	52905	29217	23688	35060	17845	11	11	11
SSL/SC	27880	21012	6868	25215	2665	6	5	5
SSL/FC	23259	21012	2247	25215	(1956)	2	3	3
TSL/SC	28791	18407	10384	22092	6699	7	7	7
TSL/FC	24170	18407	5763	22092	2078	4	4	4

[1]Nutrients were valued after storage losses, field application losses, and mineralization rates were considered.

[2]Rank when nutrient values were calculated at the current market prices (used for the basic analysis), increased by 25%, and increased by 50%. Net annual costs for waste systems when nutrients were valued at current market prices are shown in Table IV-35.

An increase in manurial fertilizer value by 50% resulted in a reduction in net annual costs of up to $11,688 (SAGT/6 and CAGT/6 systems). For the CAGT/6 system, this translated to a reduction of almost 40% of net annual cost calculated for the base analysis.

Varying Labor Costs (Hourly)

Dairy waste management systems are typically considered to be labor intensive. Variations in opportunity costs of labor could therefore impact upon the choice of system installed. To test for possible sensitivity to this parameter, labor costs were increased and decreased by 40% on each modeled dairy waste management system. This method was adopted as a proxy for a more complete and detailed analysis. Opportunity costs of labor vary according to season, labor restrictions, environmental conditions, as well as quality. However, these factors are predominantly farm-specific and thus could not be adequately incorporated into a general analysis.

80/PC Systems

Dairy waste systems modeled on the 80/PC herd size/confinement system were not extremely sensitive to changes in labor cost. As labor costs increased, the more labor intensive systems did not become significantly more costly. The DS/3 system replaced the EP/3 system as the second least cost system as labor costs increased by 40%. The EP/3 system, as modeled, was more labor intensive than the DS/3 system (Table V-13).

When labor costs were calculated at $3.00 per hour, the annual cost for the DS/3 system was lower than for the EP/6 system. The EP/6

Table V-13. Effect on Net Annual Costs of 80/PC Systems When Labor Costs Were Varied by Forty Percent.[1]

System	Labor Cost Level						Ranking[2]		
	Low		Base		High				
	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Low	Base	High
80/PC/									
DH	1094	3569	1823	4298	2552	5027	1	1	1
DS/3	945	4685	1575	5315	2205	5945	4	3	2
DS/6	930	5230	1550	5850	2170	6470	5	5	5
EP/3	1223	4441	2038	5256	2853	6071	2	2	3
EP/6	1239	4655	2065	5481	2891	6307	3	4	4
SAGT/3	1181	13840	1968	14627	2755	15414	12	12	12
SAGT/6	1167	14777	1945	15555	2723	16333	13	13	13
CAGT/3	1181	11688	1968	12745	2755	13262	10	10	10
CAGT/6	1167	12325	1945	13103	2723	13881	11	11	11
SSL/SC	782	9150	1303	9672	1824	10192	9	9	9
SSL/FC	246	8126	410	8290	574	8454	7	7	7
TSL/SC	723	8549	1205	9031	1687	9513	8	8	8
TSL/FC	187	7525	312	7650	437	7775	6	6	6

[1]Labor charges (per hour) were increased by 40% and reduced by 40% i.e. labor was charged in at $3.00 and $7.00 per hour.

[2]Rank when labor was calculated at the base level (used for the base analysis), decreased by 40%, and increased by 40%.

system required an annual labor input 98 hours greater than that of the DS/3 system.

In absolute values, varying labor wages resulted in a maximum net annual cost difference of $826 (EP/6 system). This value represented a 15% change compared to base net annual cost.

80/TC Systems

Variation of labor charges on dairy waste systems modeled on the 80/TC herd size/confinement system impacted relative net annual costs only slightly (Table V-14). When labor costs were valued 40% higher, the DS/6 system was displaced by two lagoon systems (SSL/FC and TSL/FC) in the net annual cost ranking. Lagoon systems are typically not labor intensive; incorporation of flush collection methods results in additional labor savings.

Varying labor costs resulted in a maximum difference from "base" net annual costs for a specific waste system of $1,029. This absolute difference, occurring on the DH system, represented over 20% of the net annual cost calculated in the base analysis. An increase in labor costs of 40% resulted in a rise in net annual cost of only 20% for the DH system.

160/PC Systems

Dairy waste systems modeled on the 160/PC herd size/confinement system were also quite insensitive to variations in labor costs. No significant changes in relative net annual costs occurred when per hour labor charges were reduced by 40% (Table V-15).

Table V-14. Effect on Net Annual Costs of 80/TC Systems When Labor Costs Were Varied by Forty Percent.[1]

System	Labor Cost Level						Ranking[2]		
	Low		Base		High				
	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Low	Base	High
80/TC/									
DH	1544	3958	2573	4987	3602	6016	3	3	3
DS/3	1287	5000	2145	5858	3003	6716	4	4	4
DS/6	1259	6330	2098	7169	2937	8008	5	5	7
EP/3	1515	3758	2525	4768	3535	5778	1	1	1
EP/6	1539	3895	2565	4921	3591	5947	2	2	2
SAGT/3	1524	13625	2540	14281	3556	15297	12	12	12
SAGT/6	1499	16120	2498	17119	3497	18118	13	13	13
CAGT/3	1524	11113	2540	12129	3556	13145	10	10	10
CAGT/6	1499	12800	2498	13799	3497	14798	11	11	11
SSL/SC	992	8890	1653	9551	2314	10212	9	9	9
SSL/FC	329	7429	548	7648	767	7867	7	7	6
TSL/SC	911	8764	1519	9372	2127	9980	8	8	8
TSL/FC	248	7303	414	7469	580	7635	6	6	5

[1]Labor charges (per hour) were increased by 40% and reduced by 40% i.e. labor was charged in at $3.00 and $7.00 per hour.

[2]Rank when labor was calculated at the base level (used for the base analysis), decreased by 40%, and increased by 40%.

Table V-15. Effect on Net Annual Costs of 160/PC Systems When Labor Costs Were Varied by Forty Percent.[1]

System	Labor Cost Level						Ranking[2]		
	Low		Base		High				
	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Low	Base	High
160/PC/									
DH	1533	4830	2555	5852	3577	6874	1	1	1
DS/3	1383	7070	2305	7992	3227	8914	4	4	4
DS/6	1386	8004	2280	8916	3192	9828	5	5	5
EP/3	1595	5271	2658	6334	3721	7397	2	2	2
EP/6	1617	5455	2695	6533	3773	7611	3	3	3
SAGT/3	1527	17691	2545	18709	3563	19727	12	12	12
SAGT/6	1500	18969	2500	19969	3500	20969	13	13	13
CAGT/3	1527	14425	2545	15443	3563	16461	10	10	10
CAGT/6	1500	16461	2500	17461	3500	18461	11	11	11
SSL/SC	1101	10301	1835	11035	2569	11769	8	8	9
SSL/FC	447	9343	745	9641	1043	9939	6	6	7
TSL/SC	1018	10393	1697	11072	2376	11751	9	9	8
TSL/FC	364	9435	607	9678	850	9921	7	7	6

[1]Labor charges (per hour) were increased by 40% and reduced by 40% i.e. labor was charged in at $3.00 and $7.00 per hour.

[2]Rank when labor was calculated at the base level (used for the base analysis), decreased by 40%, and increased by 40%.

When labor costs were increased to $7.00 per hour, the only significant changes in relative net annual costs occurred on labor saving lagoon systems. Basically, TSL systems, which are only slightly more labor efficient, displaced SSL systems in the net annual cost ranking. That is, the TSL/SC and TSL/FC systems traded rank positions with the SSL/SC and SSL/FC systems, respectively.

The greatest absolute effect on net annual costs of any specific waste system occurred on the EP/6 system. A 40% change in labor cost from the base rate of $5.00 per hour resulted in a difference of $1,078 in net annual cost, or approximately 16% of net annual cost at the base level.

160/TC Systems

Dairy waste systems modeled for the 160/TC herd size/confinement system were somewhat sensitive to variations in per unit labor costs, particularly as labor costs were increased. When labor costs were reduced by 40%, the SSL/SC system became relatively less costly than the TSL/FC system, a somewhat less labor intensive waste management system. This change in system rank was the only significant change in net annual costs as labor costs were reduced (Table V-16).

When labor costs were increased by 40%, two labor intensive waste systems (DH and DS/3) fell one position in the net annual cost ranking. Two labor efficient waste systems (SSL/FC and TSL/FC respectively) improved in ranking. Thus, the opportunity cost of labor could possibly impact upon the choice of dairy waste management system at this particular herd size/confinement system.

Table V-16. Effect on Net Annual Costs of 160/TC Systems When Labor Costs Were Varied by Forty Percent.[1]

System	Labor Cost Level						Ranking[2]		
	Low		Base		High				
	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Low	Base	High
160/TC/									
DH	2271	5977	3785	7491	5299	9005	3	3	4
DS/3	2018	8005	3363	9350	4708	10695	5	5	6
DS/6	1988	10330	3313	11655	4638	12980	8	8	8
EP/3	2097	3446	3495	4844	4893	6242	1	1	1
EP/6	2132	3596	3553	5017	4974	6438	2	2	2
SAGT/3	2136	16585	3560	18009	4984	19433	12	12	12
SAGT/6	2112	19376	3520	20784	4928	22192	13	13	13
CAGT/3	2136	13709	3560	15133	4984	16557	10	10	10
CAGT/6	2112	16214	3520	17622	4928	19030	11	11	11
SSL/SC	1494	9298	2490	10294	3486	11290	6	7	7
SSL/FC	588	7491	980	7883	1372	8275	4	4	3
TSL/SC	1378	11530	2296	12448	3214	13366	9	9	9
TSL/FC	472	9726	786	10040	1100	10354	7	6	5

[1]Labor charges (per hour) were increased by 40% and reduced by 40% i.e. labor was charged in at $3.00 and $7.00 per hour.

[2]Rank when labor was calculated at the base level (used for the base analysis), decreased by 40%, and increased by 40%.

In absolute terms, the maximum impact of labor cost variation occurred on the DH system. A 40% change in labor cost would change net annual cost of this system by $1,514 - over 20% of the net annual cost calculated for the base analysis.

320/PC Systems

Relative rankings (in terms of net annual costs) of dairy waste management systems modeled on the 320/PC herd size/confinement system changed little due to changes in labor charges. When per hour labor costs were reduced by 40% (to $3.00), no significant change in relative net annual costs occurred (Table V-17).

When labor costs increased by 40%, only one significant change resulted. The TSL/FC system replaced the DS/3 system as the fifth least cost dairy waste system. As before, lagoon systems, especially those utilizing flush collection, were much less labor intensive than other waste systems. In fact, the TSL/FC system required only 21% as many annual labor hours as did the DS/3 system.

The maximum effect that the labor cost variation had on net annual cost of any specific modeled waste system was $1697 (EP/6 system). A 40% change (+ or -) in labor cost would increase (decrease) the net annual cost about 19% as compared to the base level cost.

320/TC Systems

Dairy waste management systems modeled on the 320/TC herd size/-confinement system were more sensitive to variations in labor costs than other systems modeled (Table V-18).

Table V-17. Effect on Net Annual Costs of 320/PC Systems When Labor Costs Were Varied by Forty Percent.[1]

System	Labor Cost Level						Ranking[2]		
	Low		Base		High				
	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Low	Base	High
320/PC/									
DH	2429	4303	4048	5922	5667	7541	1	1	1
DS/3	2277	11002	3795	9225	5313	14038	5	5	6
DS/6	2262	12861	3770	14369	5278	15877	8	8	8
EP/3	2511	6846	4185	12895	5859	10194	2	2	2
EP/6	2546	7061	4243	8758	5940	10455	3	3	3
SAGT/3	2429	22074	4048	23693	5667	25312	12	11	11
SAGT/6	2432	30151	4053	31772	5674	33393	13	13	13
CAGT/3	2429	18924	4048	20543	5667	22162	10	10	10
CAGT/6	2432	25676	4053	27297	5674	28918	11	12	12
SSL/SC	1715	12529	2858	13672	4001	14815	7	7	7
SSL/FC	654	10789	1090	11225	1526	11661	4	4	4
TSL/SC	1621	13922	2702	15003	3783	16084	9	9	9
TSL/FC	560	12182	934	12556	1308	12930	6	6	5

[1]Labor charges (per hour) were increased by 40% and reduced by 40% i.e. labor was charged in at $3.00 and $7.00 per hour.

[2]Rank when labor was calculated at the base level (used for the base analysis), decreased by 40%, and increased by 40%.

Table V-18. Effect on Net Annual Costs of 320/TC Systems When Labor Costs Were Varied by Forty Percent.[1]

System	Labor Cost Level						Ranking[2]		
	Low		Base		High				
	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Labor Costs	Net Annual Costs	Low	Base	High
320/TC/									
DH	3762	8452	6270	10960	8778	13468	4	5	6
DS/3	3450	13141	5750	15441	8050	17741	8	8	8
DS/6	3422	18277	5703	20558	7984	22839	9	9	9
EP/3	3497	4184	5828	6515	8159	8846	2	1	3
EP/6	3557	3836	5928	6207	8299	8578	1	3	2
SAGT/3	3626	28688	6043	31105	8460	33522	12	12	12
SAGT/6	3606	31611	6010	34015	8414	36419	13	13	13
CAGT/3	3626	24762	6043	27179	8460	29596	10	10	10
CAGT/6	3606	27129	6010	29533	8414	31937	11	11	11
SSL/SC	2484	9413	4140	11069	5796	12725	6	6	5
SSL/FC	857	5877	1428	6448	1999	7019	3	2	1
TSL/SC	2353	12495	3921	14063	5489	15631	7	7	7
TSL/FC	725	8958	1209	9442	1693	9926	5	4	4

[1]Labor charges (per hour) were increased by 40% and reduced by 40% i.e. labor was charged in at $3.00 and $7.00 per hour.

[2]Rank when labor was calculated at the base level (used for the base analysis), decreased by 40%, and increased by 40%.

When per hour labor charges were reduced by 40%, two significant changes in relative net annual costs occurred. First, the EP/3 system improved to become the second least cost system (behind the EP/6 system), displacing the SSL/FC system (which fell to third). Second, the DH system replaced the TSL/FC system (which required considerably less labor) as the fourth least cost system.

Conversely, when labor charges rose by 40%, the SSL/FC system displaced the EP/6 system as the least cost dairy waste system. Another labor intensive system, DH, also incurred a significant increase in relative net annual cost. The SSL/SC system replaced the DH as the fifth least cost dairy waste system.

Overall, the DH and SSL/FC systems appeared most sensitive to fluctuations in per hour labor cost. Both systems incurred significant changes in net annual costs at either extreme of the labor cost variation. The other modeled systems changed relative position in the net annual cost ranking no more than once in this analysis.

The largest absolute change in net annual cost for any specific dairy waste system was $2,508. For the DH system, increasing (decreasing) the labor cost by 40% would increase (decrease) the net annual cost about 23%.

In summary, for all herd sizes/confinement systems, the results of the analysis indicate little significant shifting in ranking of the various systems due to changes in actual or opportunity cost of labor. However, although the variations in labor costs were considered major (+ and - 40%), opportunity costs of labor are likely to vary over a wider range during the course of a year. Opportunity costs of labor on

a given farm depend on absolute restrictions on labor available, degree of competition for labor particularly during planting and harvesting seasons, climatic conditions, and quality of labor assigned to waste management. A more accurate determination of appropriate cost of labor would necessarily include data that is farm-specific e.g. seasonal demands of labor for various farm uses.

CHAPTER VI

SUMMARY AND CONCLUSION

The purpose of this research was to make a comparative evaluation of the various waste management systems most commonly found on Tennessee dairy farms. Systems deemed to be most typical were classified as: (1) daily haul (DH); (2) dry stack (DS); (3) earthen pit (EP); (4) above-ground tank (AGT) (steel or concrete); (5) single stage lagoon (SSL); and (6) two stage lagoon (TSL). Variation in storage capacity of 3-months and 6-months was assumed for DS, EP, and AGT systems.

The dairy waste management systems were compared for various sizes of milking herds and alternative confinement systems. The sizes of milking herds modeled were 80, 160, and 320 cows. Alternative confinement systems were defined as partial and total confinement. Seventy-eight distinct dairy waste systems resulted from incorporating the three herd sizes, two confinement systems, and seven waste systems (with associated variation in storage capacity and collection methods) into the analysis.

Selection of dairy waste management systems (and variations of these systems) to include in this study was based primarily upon interviews with East Tennessee dairy farmers and U. S. D. A. Soil Conservation Service personnel. Each specific system (determined by herd size, confinement system and waste handling/storage method) was modeled in technical detail with regard to: (1) quantities of waste nutrients preserved through the collection, storage and land application proces-

ses; (2) labor and tractor/equipment requirements for the various tasks involved; (3) mineralization of waste nutrients after land application.

The modeling process was effected through the development of budgets for the various technical and economic aspects of dairy waste management. The purely technical budgets outlined physical changes that occur as dairy waste moves through the respective collection, storage, and disposal subprocesses of each waste management system. Purely technical budgets included: (1) Collection Budgets and (2) Storage and Application Budgets.

Budgets were also developed that included both technical and economic data. Essentially, the economic data was a valuation of synthesized technical data. These budgets were the following: (1) Annual Labor and Energy Cost Budgets and (2) Nutrient Mineralization and Annual Valuation Budgets.

Purely economic budgets were likewise constructed. Data for these budgets came from the hybrid budgets and other synthesized economic data. Economic budgets included: (1) Initial Investment Budgets; (2) Capital Recovery and Insurance/Repairs/Housing Costs Budgets; and (3) Net Annual Cost Budgets.

Based upon this synthesized technical data and primary cost date collected, initial investment and annual costs/returns estimates were made for each specific dairy waste management system. It was assumed that quantifiable economic returns from any system were restricted to the fertilizer value of the waste nutrients preserved by that waste system.

Analysis of Modeled Systems

Economic comparisons of modeled dairy waste management systems were based upon both initial investment and net annual costs. Initial investment was included as a basis of comparison due to the highly leveraged position of many dairy farmers. It is possible that a dairy farm manager would opt for a waste management that requires the least initial capital outlay even though this system may not be the most economically efficient system in the long run. Net annual cost was also utilized as an analytical method. This method of economic analysis is the optimal tool for comparison. Total annualized costs are charged off against annualized returns (manurial fertilizer value), thus presenting a more complete economic portrayal of the dairy waste management system analyzed.

Initial Investment

Dairy waste management systems were compared, with initial investment as the criteria, on each herd size and confinement system. Only equipment/facilities predominantly used for waste management were included. These items would most likely need to be purchased in order to install the particular waste system. Items, such as tractors used for hauling/spreading, agitation, and irrigation were assumed to be on the dairy farm prior to installation of a particular dairy waste system.

Initial investment was viewed in terms of both total investment and per cow investment costs. Analyzing per cow investment costs allowed for determination of possible economies attributed to herd size.

In each case (specific herd size/confinement system) analyzed, the DH system required the lowest initial investment. Generally EP (particularly EP/3) systems were the next least cost systems. However, the difference between the least cost and next least cost systems was often substantial. The greatest difference (320/TC analysis) was 69%; the narrowest margin was 27% (80/PC analysis).

AGT systems were consistently the greatest investment cost systems. Generally, SAGT systems required even larger capital outlays than similar CAGT systems.

DS systems typically ranked below EP systems and above lagoon systems (TSL and SSL) with regard to initial investment costs. However, TSL and SSL systems were quite competitive on 320 cow herds. Indeed, these systems required significantly less capital outlay than the DS/6 system on the 320/TC herd size/confinement system.

In addition, lagoon systems incorporating flush collection generally were cheaper to install than similar systems using standard collection methods. Inclusion of a scraper tractor into investment costs for SSL/SC and TSL/SC systems was the probable reason for this divergence from expected results.

Definite economies of herd size occurred. Per cow investment costs of DH systems fell by almost 70% as herd size was increased from 80 to 320 cows. Similar economies, albeit of smaller magnitude, occurred on all waste management system types. The smallest decline in initial investment costs as herd size was increased from 80 to 320 cows occurred on TC/DS/6 systems (36.3%).

For those systems on which storage capacity was varied, doubling storage capacity resulted in considerably less than double initial investment cost. Therefore, strictly from an analysis of initial capital outlay, purchasing additional capacity appeared to be a "bargain." However, when analyzed with regard to net annual costs this observation was not necessarily true.

Net Annual Costs

Dairy waste management systems were also compared on each modeled herd size/confinement system with net annual cost as the criterion. Unlike the initial investment analysis, all equipment/facilities used on specific dairy waste management systems were included in net annual cost analysis. Equipment not predominantly used in dairy waste management (e.g. tractors used for hauling wastes) were included also. Annualized equipment/facilities costs were prorated based upon estimates of proportionate annual use allocated to dairy waste management.

Net annual cost for each system was calculated as follows: capital recovery plus insurance/repairs/housing costs plus annual equipment rental cost plus energy costs plus labor costs minus annual fertilizer value of dairy wastes. Capital recovery, a substitute for depreciation and interest on capital, was calculated for equipment/-facilities specific to each system. Since calculation of capital recovery depended upon the life of the asset, life expectancies were estimated for all equipment/facilities. Current market rates were used.

Annual costs of insurance, repairs or maintenance, and housing were approximated for components of each waste system. Annual

equipment rental costs occurred only on TSL systems. These costs were, in fact, incurred at five year intervals (sludge removal). Annual equipment costs incurred during these years were present valued to year one; the sum of these costs were then annualized over the life of the system.

Labor and energy requirements for each dairy waste management system were synthesized for each budget (two month) period. Associated costs were also calculated and summed by budget period. Budget period totals were summed to determine annual labor and energy costs incurred with each waste management system. In the case of non-annual tasks, such as sludge removal from TSL systems, costs of completing these tasks in each year of occurrence were first discounted to year one and summed. This total present value of costs was then annualized over the life of the waste system and added to reflect "real" annual labor and energy costs.

Annual fertilizer value of dairy wastes could be made only after accounting for nutrient losses during collection, storage, and application. These nutrient losses were modeled in the Collection Budgets and Storage and Application Budgets. However, nutrients incorporated into the soil are not 100% available to crops during the first year after land application. Rather, waste nutrients are mineralized (over several years) into inorganic forms which are available for crop uptake. Budgets were developed to model this mineralization process and determine the annual value of nutrients applied with each waste management system.

Annual values of each nutrient (N, P, and K) for each waste system was derived by: (1) determining the annual quantity of nutrients "in-soil"; (2) multiplying this sum by appropriate mineralization rates; (3) applying the specific elemental nutrient prices to these mineralized values; (4) discounting these values to determine the present value of nutrient quantities mineralized each year; and (5) summing these discounted values. Total annual value of dairy waste was then determined by summing the annual values of N, P, and K for the specific system. Although it is generally recognized that animal manure contains inherent value as a soil enhancement (tilth and organic matter), these factors can not be easily quantified and were not included in the analysis.

Net annual cost was the primary economic parameter used in comparing modeled dairy waste management systems. All the various aspects of waste handling systems were netted out in this calculation, providing one number per system which could be used as a comparative tool. It was this figure, more than any other, that determined which waste system (and variation of that system) was most "economical."

No one system dominated other modeled systems (with regard to being the least net annual cost system) consistently as herd size and/or confinement system varied. Generally however, the DH system was least cost for herd sizes utilizing partial confinement. On herds using total confinement, DH tied for the second least cost system at best. EP (EP/3 and EP/6) systems tended to be least cost on modeled dairy herds incorporating total confinement. However, lagoon systems, especially the SSL/FC system, became quite competitive at the 320-cow

herd size. On the modeled 320/TC herd size/confinement system, the SSL/FC system cost only $1 per cow more annually than the least cost waste system (EP/6).

AGT systems, specifically SAGT systems, were consistently the most costly systems, and by a significant margin. At no herd size/confinement system did AGT systems even become competitive. In some cases, an SAGT system cost over $100 per cow more annually than the corresponding least cost system.

Increasing storage capacity appeared economically feasible only for EP systems. Modeled EP/3 systems incurred lower net annual cost than EP/6 systems in all but one instance (on the 320/TC system). However, no more than $3 per cow per year separated the two EP systems in any instance.

Significant economies of herd size were incurred on all modeled waste systems. However, the greatest economies of size tended to accrue to SSL, TSL, and EP systems (especially when total confinement was used).

Sensitivity Analysis

Certain critical parameters were varied to test the stability of the results of the net annual cost analysis. Parameters deemed to be critical included manurial nutrient loss rates, manurial nutrient value (per unit), and labor cost (per hour).

Varying Nutrient Loss Rates (During Storage)

Nutrient losses during storage are highly variable. A sensitivity analysis was performed to observe the effect on relative net annual

costs due to alteration of these parameters. Nutrient loss rates (during storage) were varied from the lower to upper extreme of ranges commonly reported.

Each waste system was compared at the extreme points of storage loss rates. It was assumed that environmental conditions affected all systems similarly i.e. if conditions existed that promoted increased nutrient loss in one system, all systems would experience increased nutrient losses.

In general, variation of nutrient loss rates did not impact significantly on relative net annual costs. The relative ranking of systems were not greatly affected. However, net annual costs for a particular dairy waste system was significantly affected in some cases, in absolute terms. Significant effects on relative net annual costs may occur if nutrient losses for the different systems were impacted differently by environmental conditions.

Varying Nutrient Values (Prices)

To test for sensitivity to valuation of manurial nutrients, the effect of an increase in nutrient values of 25% and 50% were analyzed. This test was also conducted to observe at what level of nutrient valuation would positive returns (negative net annual costs) accrue to any of the systems.

Generally, increases in manurial nutrient values did not significantly affect relative net annual costs of systems modeled for the 80-cow herd size. However, as herd size increased, greater impact was evident, especially on systems associated with total confinement.

DH systems (nutrient inefficient systems) generally were impacted unfavorably; nutrient-saving systems were generally affected the most favorably. DS systems were often affected adversely.

Only when nutrient values were increased by 50%, and on 320/TC systems, did positive returns accrue to any dairy waste management system. Increases of this magnitude in prices of manurial fertilizer nutrients exceed commonly held price expectations for the near future.

Varying Labor Costs (Hourly)

Dairy waste management systems are typically considered to be labor intensive. Variations in opportunity costs of labor may therefore impact upon the choice of an optimal dairy waste system. Labor costs were varied by 40% (increase and decrease) on each modeled dairy waste management system to test for possible sensitivity to this parameter. This technique was used as a proxy for a more detailed and complete analysis of labor value variation. Opportunity costs of labor vary according to seasonal labor constraints, environmental conditions, as well as quality of labor assigned to waste management. However, these factors are predominantly farm-specific and thus cannot adequately be incorporated into a general analysis.

Relative net annual costs of modeled dairy waste management systems were not acutely sensitive, generally, to even substantial changes in labor costs. Obviously, the more labor intensive systems were impacted greater in absolute terms. Indeed, a 23% change in net annual cost was effected for the 320/TC/DH system due to the variation in labor cost. However, in relative terms, labor cost variation did not impact net annual costs as greatly as was perhaps anticipated.

Therefore, the results of the base analysis appear quite stable, in relative terms, to possible swings in the price of labor.

Implications for the Dairy Industry

Results of this study tend to support the notion that significant economies of herd size are evident on U. S. dairy farms. Although waste management system costs may not represent a majority of total annual costs for individual dairy farms, these costs are likely to be significant. Reduction in average total costs on dairy farm firms attributable to economies of herd size with regard to waste management provides further incentive for increases in dairy herd size.

Additionally, imposition of stringent environmental regulations on the dairy farm sector could impact significantly upon individual dairy farm firms and the dairy industry. Because waste management on dairy farms is a costly process, increased regulations would result in increases in total costs for the dairy industry (on individual farms and in the aggregate)

Implications for Further Research

Although this study included the most typical types of dairy waste management systems found in Tennessee dairy farms, similar research should perhaps be conducted for less-than-typical systems. Dairy waste technology, only recently proven technically feasible or acceptable, could be included. Examples include methane generation, solids-liquids separation, refeeding, and using dried wastes as bedding. Through the development of budgets and economic research, these possibly-

significant waste management systems could be evaluated relative to alternative methods and techniques.

Analyses such as this study, in which economic modeling is the foundation, can potentially be developed within a mathematical programming framework. Considerably more technically-detailed and accurate models could thereby be compiled. Greater numbers of alterations in the base model (sensitivity analysis) could be performed to test the model more fully. In addition, with the advent and overwhelming infusion of micro-computers, such a model could potentially be developed as a decision aid for dairy farmers.

However, in order for mathematical programming models to be effective tools, considerable technical research is needed. More complete data on nutrient losses during storage (and inter-relationships with environmental parameters), nutrient losses after application (in a format conducive to modeling), and nutrient utilization (e.g. uptake by pasture vegetation as opposed to side-dressed corn) are required.

Dynamic type modeling is also needed to incorporate the entire dairy farm firm for completeness. Upper limits on the amount of labor available and degree of competition for labor for other farm tasks are important aspects in determining the "real" or opportunity cost of labor used for waste management. Incorporating these considerations into a mathematical, computerized model would aid in providing more precise estimates of the most economical dairy waste management system for a given dairy farm setting.

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APPENDICES

APPENDIX A

Technical Data Necessary for Synthesizing Dairy Waste Management Systems

Table A-1. Daily Manure Production by Dairy Cattle.[1]

Size	Total Manure Production			Water	Density	Nutrient Content (#/day)		
lbs	lb/day	ft^2/day	gal/day	%	lb/ft^3	N	P	K
150	12	0.19	1.5	87.3	62	0.06	0.010	0.04
250	20	0.32	2.4	87.3	62	0.10	0.020	0.07
500	41	0.66	5.0	87.3	62	0.20	0.036	0.14
1000	82	1.32	9.9	87.3	62	0.41	0.073	0.27
1400	115	1.85	13.9	87.3	62	0.57	0.102	0.38

[1]Midwest Plan Service (42)

Table A-2. Assumed Percentage of Herd Time Spent on Feeding/Housing Lots by Waste Production Period and Confinement System.

Confinement System	Waste Production Period	Percent of Herd Time Spent on Feeding/Housing Lots
Partial confinement	Jan.-Feb.	80
	Mar.-Apr.	65
	May-June	45
	Jul.-Aug.	45
	Sep.-Oct.	45
	Nov.-Dec.	65
Total confinement	Jan.-Feb.	95
	Mar.-Apr.	95
	May-June	90
	Jul.-Aug.	90
	Sep.-Oct.	90
	Nov.-Dec.	95

Table A-3. Daily Production of Milking Parlor Wastes by Herd Size.[1]

Parlor Waste Source	Daily Waste Production (Gal.) 80 Cows	160 Cows	320 Cows
Bulk tank	25	27.5	30
Pipeline	150	160	200
Udder wash	40	80	320
Parlor floor	40	50	70
Milkhouse floor	10	15	20
Misc.	30	30	30
Total	295	362.5	670
	(2463.25 lbs)	(3026.88 lbs)	(5594.501bs)
Nutrient production lbs/day			
N	0.6158	0.7560	1.3985
P	0.3658	0.4490	0.8307
K	0.4543	0.5583	1.0318

[1]Adapted from 5, 39, 41, 42, and 75.

Table A-4. Mean Monthly Precipitation and Evapotranspiration Rates Used for the Analysis.[1]

Climatic Month	Mean Monthly Precipitation (Inches)	Mean Monthly Evapotranspiration (Inches)
January	5.33	0.2818
February	4.97	0.4014
March	5.46	1.0564
April	4.35	2.2032
May	3.94	3.4300
June	3.89	4.5100
July	4.48	5.2700
August	3.55	5.1100
September	3.16	3.9300
October	2.62	2.3600
November	3.82	0.9662
December	4.56	0.3700
Yearly totals	50.13	29.89

[1]Calculated from data presented in 16, 17, 62, and 66.

Table A-5. Estimated Nutrient Loss During Storage (Prior to Land Application) From Various Dairy Waste Management Systems.[1]

Category/System	Estimated Nutrient Loss (%)		
	N	P	K
Solid/			
Daily haul	30-40	5-15	5-15
Dry stack	15-30	5-20	5-15
Slurry/			
Above-ground tank	5-20	0-10	0-10
Earthen pit	15-25	5-20	5-15
Liquid/			
Two stage lagoon	60-80	50-65	35-50
Single stage lagoon	40-60	10-30	5-25

[1]Adapted from 12, 25, 35, 46, 58, and 59.

Table A-6. Nitrogen Lost at Ground Surface as Free Ammonia, by Soil Moisture/Temperature Type.[1]

Days Between Application and Incorporation	Nitrogen Loss (%)		
	Warm Dry Soil	Warm Moist Soil	Cool Moist Soil
1	30	10	0
4	40	20	5
7 or more	50	30	10

[1]From Appendix table 3 in 12.

APPENDIX B

Example Collection Budgets For Modeled Dairy Waste Management Systems

Table B-1. Collection Budget for the 80/PC/DH System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Jan.-Feb.						
Total manure collectible[1]	542800	65600	87.3	2690	480	1795
Total manure collected[2]	434240	52480	87.3	2152	384	1436
+Bedding and feed wastes[3]	28320	10592	15	120	28	85
+Rainfall collected[4]	428878	51363	100			
+Parlor wastes[5]						
-Runoff losses[6]	(366691)	(43915)	97.2	(400)	(77)	(718)
-Evaporation losses[7]	(15931)	(2130)	100			
+Water added[8]						
Total wastes collected	508816	68390	86.45	1872	335	803
Mar.-Apr.						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	364780	44090	87.3	1808	324	1205
+Bedding and feed wastes	24400	9126	15	103	25	73
+Rainfall collected	408475	48919	100			
+Parlor wastes						
-Runoff losses	(367628)	(44027)	97.7	(330)	(65)	(603)
-Evaporation losses	(61755)	(7396)	100			
+Water added						
Total wastes collected	368272	50712	84.08	1581	284	675

Table B-1 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
May-June						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	252540	30524	87.3	1252	224	834
+Bedding and feed wastes	9760	3650	15	41	10	29
+Rainfall collected	326030	39046	100			
+Parlor wastes						
-Runoff losses	(309729)	(37093)	98.4	(193)	(45)	(417)
-Evaporation losses	(104143)	(12472)	100			
+Water added						
Total wastes collected	174458	23655	79.7	1100	189	446
Jul.-Aug.						
Total manure collectible	570400	68945	87.3	2827	506	1885
Total manure collected	256680	31025	87.3	1272	228	848
+Bedding and feed wastes	9920	3710	15	42	10	30
+Rainfall collected	334359	40043	100			
+Parlor wastes						
-Runoff losses	(317641)	(38041)	98.4	(198)	(46)	(424)
-Evaporation losses	(136146)	(16305)	100			
+Water added						
Total wastes collected	147172	20432	75.57	1116	192	454

Table B-1 (continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	252540	30524	87.3	1252	224	834
+Bedding and feed wastes	9760	3650	15	41	10	29
+Rainfall collected	240672	28823	100			
+Parlor wastes						
-Runoff losses	(228638)	(27382)	98.4	(143)	(45)	(417)
-Evaporation losses	(82501)	(9880)	100			
+Water added						
Total wastes collected	191833	25735	80.86	1150	189	446
Nov.-Dec.						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	364780	44090	87.3	1808	324	1205
+Bedding and feed wastes	24400	9126	15	103	25	73
+Rainfall collected	348932	41788	100			
+Parlor wastes						
-Runoff losses	(314039)	(37609)	97.7	(282)	(65)	(241)
-Evaporation losses	(25315)	(3032)	100			
+Water added						
Total wastes collected	398758	54363	84.99	1629	284	1037

[1]Calculated from data presented in 31.

[2]Total manure collectible x %TOL.

Table B-1 (continued)

[3]8, 7, 6, 5, and 2 lbs/day for 95, 90, 80, 65, and 45 %TOL respectively. (Adapted from 21, 24, and 25.)

[4]Total rainfall for the period that falls directly on the housing/feeding lot surface. (See table A-4.)

[5]Slurry and liquid systems only (from table A-1).

[6]80-95% total rainfall at 3.5% total solids by weight x %TOL. (Adapted from 12, 25, and 36.)

[7]Evapotranspiration rate (Table A-4) x .7 x housing/feeding lot size x %TOL.

[8]Water added at reception pit (CAGT and SAGT systems) to raise moisture content of waste (for pumping).

Table B-2. Collection Budget for the 80/TC/DS/6 System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Jan.-Feb.						
Total manure collectible[1]	542800	65600	87.3	2690	480	1795
Total manure collected[2]	515660	62320	87.3	2556	456	1705
+Bedding and feed wastes[3]	37760	14122	15	160	38	113
+Rainfall collected[4]	428878	51363	100			
+Parlor wastes[5]						
-Runoff losses[6]	(349536)	(41861)	96.7	(449)	(96)	(853)
-Evaporation losses[7]	(18918)	(2266)	100			
+Water added[8]						
Total wastes collected	613844	83678	85.98	2267	398	965
Mar.-Apr.						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	533140	64439	87.3	2643	473	1761
+Bedding and feed wastes	39040	14601	15	166	39	117
+Rainfall collected	408475	48919	100			
+Parlor wastes						
-Runoff losses	(332907)	(39869)	96.7	(429)	(95)	(881)
-Evaporation losses	(90257)	(10809)	100			
+Water added						
Total wastes collected	557221	77281	83.87	2380	417	997

Table B-2 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
May-June						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	505080	61047	87.3	2504	448	1669
+Bedding and feed wastes	34160	12776	15	145	34	102
+Rainfall collected	326030	39046	100			
+Parlor wastes						
-Runoff losses	(270605)	(32408)	96.9	(327)	(90)	(835)
-Evaporation losses	(208285)	(24944)	100			
+Water added						
Total wastes collected	386380	55517	78.05	2322	392	936
Jul.-Aug.						
Total manure collectible	570400	68945	87.3	2827	506	1885
Total manure collected	513360	62051	87.3	2544	445	1697
+Bedding and feed wastes	34720	12985	15	147	35	104
+Rainfall collected	334359	40043	100			
+Parlor wastes						
-Runoff losses	(277518)	(33236)	96.9	(336)	(91)	(849)
-Evaporation losses	(272292)	(32610)	100			
+Water added						
Total wastes collected	332629	49233	74.11	2356	399	952

Table B-2 (continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	505080	61047	87.3	2504	448	1669
+Bedding and feed wastes	34160	12776	15	145	34	102
+Rainfall collected	240672	28823	100			
+Parlor wastes						
-Runoff losses	(199758)	(23923)	96.9	(242)	(90)	(835)
-Evaporation losses	(165002)	(19761)	100			
+Water added						
Total wastes collected	415152	58962	79.05	2407	392	936
Nov.-Dec.						
Total manure collectible	561200	67830	87.3	2782	498	1854
Total manure collected	533140	64439	87.3	2643	473	1761
+Bedding and feed wastes	39040	14601	15	166	39	117
+Rainfall collected	348932	41788	100			
+Parlor wastes						
-Runoff losses	(284380)	(34058)	96.7	(366)	(95)	(881)
-Evaporation losses	(36999)	(4431)	100			
+Water added						
Total wastes collected	599733	82339	84.74	2443	417	997

1/ Calculated from data presented in 31.

2/ Total manure collectible x %TOL.

Table B-2 (continued)

[3]8, 7, 6, 5, and 2 lbs/day for 95, 90, 80, 65, and 45 %TOL respectively. (Adapted from 21, 24, and 25.)

[4]Total rainfall for the period that falls directly on the housing/feeding lot surface. (See table A-4.)

[5]Slurry and liquid systems only (from table A-1).

[6]80-95% total rainfall at 3.5% total solids by weight x %TOL. (Adapted from 12, 25, and 36.)

[7]Evapotranspiration rate (Table A-4) x .7 x housing/feeding lot size x %TOL.

[8]Water added at reception pit (CAGT and SAGT systems) to raise moisture content of waste (for pumping).

Table B-3. Collection Budget for the 160/PC/EP/3 System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Jan.-Feb.						
Total manure collectible[1]	1085600	131216	87.3	5380	960	3590
Total manure collected[2]	868480	104973	87.3	4304	770	2870
+Bedding and feed wastes[3]	56640	21184	15	240	57	170
+Rainfall collected[4]	857757	102725	100			
+Parlor wastes[5]	178590	21388	99.5	45	26	33
-Runoff losses[6]						
-Evaporation losses[7]	(31861)	(3816)	100			
+Water added[8]						
Total wastes collected	1929606	246454	91.74	4589	853	3073
Mar.-Apr.						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	729560	88182	87.3	3616	647	2411
+Bedding and feed wastes	48800	18251	15	207	49	146
+Rainfall collected	816951	97838	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(123510)	(14792)	100			
+Water added						
Total wastes collected	1656445	211592	91.85	3869	723	2591

Table B-3 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
May-June						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	505080	61049	87.3	2503	448	1669
+Bedding and feed wastes	19520	7300	15	83	20	59
+Rainfall collected	652062	78091	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(208285)	(24944)	100			
+Water added						
Total wastes collected	1153021	143609	92.92	2632	495	1762
Jul.-Aug.						
Total manure collectible	1140800	137888	87.3	5654	1012	3770
Total manure collected	513360	62050	87.3	2544	445	1697
+Bedding and feed wastes	19840	7420	15	84	20	60
+Rainfall collected	668717	80086	100			
+Parlor wastes	187666	22475	99.5	47	28	35
-Runoff losses						
-Evaporation losses	(272292)	(32610)	100			
+Water added						
Total wastes collected	1117291	139421	92.57	2675	503	1792

Table B-3 (continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	505080	61049	87.3	2503	448	1669
+Bedding and feed wastes	19520	7300	15	83	20	59
+Rainfall collected	481343	57646	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(165002)	(19761)	100			
+Water added						
Total wastes collected	1025585	128347	92.04	2632	495	1762
Nov.-Dec.						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	729560	88182	87.3	3616	647	2411
+Bedding and feed wastes	48800	18251	15	207	49	146
+Rainfall collected	697864	83577	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(50630)	(6064)	100			
+Water added						
Total wastes collected	1610238	206059	92.08	3869	723	2591

[1]Calculated from data presented in 31.

[2]Total manure collectible x %TOL.

Table B-3 (continued)

[3]8, 7, 6, 5, and 2 lbs/day for 95, 90, 80, 65, and 45 %TOL respectively. (Adapted from 21, 24, and 25.)

[4]Total rainfall for the period that falls directly on the housing/feeding lot surface. (See table A-4.)

[5]Slurry and liquid systems only (from table A-1).

[6]80-95% total rainfall at 3.5% total solids by weight x %TOL. (Adapted from 12, 25, and 36.)

[7]Evapotranspiration rate (Table A-4) x .7 x housing/feeding lot size x %TOL.

[8]Water added at reception pit (CAGT and SAGT systems) to raise moisture content of waste (for pumping).

Table B-4. Collection Budget for the 160/TC/CAGT/6 System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Jan.-Feb.						
Total manure collectible[1]	1085600	131216	87.3	5380	960	3590
Total manure collected[2]	1031320	124655	87.3	5111	912	3411
+Bedding and feed wastes[3]	75520	28244	15	320	76	227
+Rainfall collected[4]	857757	102725	100			
+Parlor wastes[5]	178590	21388	99.5	45	26	33
-Runoff losses[6]						
-Evaporation losses[7]	(37835)	(4531)	100			
+Water added[8]						
Total wastes collected	2105352	272481	90.69	5476	1014	3671
Mar.-Apr.						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	1066280	128881	87.3	5285	946	3524
+Bedding and feed wastes	78080	29203	15	331	78	234
+Rainfall collected	816951	97838	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(180515)	(21619)	100			
+Water added	66374	7949	100			
Total wastes collected	2031814	264365	90.02	5662	1051	3792

Table B-4 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
May-June						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	1010160	122098	87.3	5006	896	3338
+Bedding and feed wastes	68320	25552	15	290	68	205
+Rainfall collected	652062	78091	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(416570)	(49889)	100			
+Water added	413250	49491	100			
Total wastes collected	19118668	247456	90.20	5342	991	3577
Jul.-Aug.						
Total manure collectible	1140800	137888	87.3	5654	1012	3770
Total manure collected	1026720	124099	87.3	5089	911	3393
+Bedding and feed wastes	69440	25971	15	294	69	208
+Rainfall collected	668717	80086	100			
+Parlor wastes	187666	22475	99.5	47	28	35
-Runoff losses						
-Evaporation losses	(544584)	(65220)	100			
+Water added	550841	65969	100			
Total wastes collected	1958800	253380	90.28	5430	1008	3636

Table B-4 (continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	1010160	122098	87.3	5006	896	3338
+Bedding and feed wastes	68320	25552	15	290	68	205
+Rainfall collected	481343	57646	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(330003)	(39521)	100			
+Water added	505175	60500	100			
Total wastes collected	1919639	248388	90.26	5342	991	3577
Nov.-Dec.						
Total manure collectible	1122400	135664	87.3	5563	996	3709
Total manure collected	1066280	128881	87.3	5285	946	3524
+Bedding and feed wastes	78080	29203	15	331	78	234
+Rainfall collected	697864	83577	100			
+Parlor wastes	184644	22113	99.5	46	27	34
-Runoff losses						
-Evaporation losses	(73998)	(8862)	100			
+Water added	80887	9687	100			
Total wastes collected	2033757	264599	90.03	5662	1051	3792

[1] Calculated from data presented in 31.

[2] Total manure collectible x %TOL.

Table B-4 (continued)

[3]8, 7, 6, 5, and 2 lbs/day for 95, 90, 80, 65, and 45 %TOL respectively. (Adapted from 21, 24, and 25.)

[4]Total rainfall for the period that falls directly on the housing/feeding lot surface. (See table A-4.)

[5]Slurry and liquid systems only (from table A-1).

[6]80-95% total rainfall at 3.5% total solids by weight x %TOL. (Adapted from 12, 25, and 36.)

[7]Evapotranspiration rate (Table A-4) x .7 x housing/feeding lot size x %TOL.

[8]Water added at reception pit (CAGT and SAGT systems) to raise moisture content of waste (for pumping).

Table B-5. Collection Budget for the 320/TC/SSL/SC System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Jan.-Feb.						
Total manure collectible[1]	2171200	262432	87.3	10762	1926	7174
Total manure collected[2]	2062640	249310	87.3	10222	1830	6815
+Bedding and feed wastes[3]	151040	56489	15	640	151	453
+Rainfall collected[4]	1286634	154088	100			
+Parlor wastes[5]	330076	39530	99.5	83	49	61
-Runoff losses[6]						
-Evaporation losses[7]	(56753)	(6797)	100			
+Water added[8]						
Total wastes collected	3773637	492620	89.61	10945	2030	7329
Mar.-Apr.						
Total manure collectible	2244800	271328	87.3	11126	1991	7418
Total manure collected	2132560	257762	87.3	10570	1892	7047
+Bedding and feed wastes	156160	58403	15	662	156	469
+Rainfall collected	1003076	120129	100			
+Parlor wastes	341265	40870	99.5	85	51	63
-Runoff losses						
-Evaporation losses	(270772)	(32428)	100			
+Water added						
Total wastes collected	3362289	444736	87.95	11317	2099	7579

Table B-5 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
May-June						
Total manure collectible	2244800	271200	87.3	11126	1991	7418
Total manure collected	2020320	244195	87.3	10013	1792	6676
+Bedding and feed wastes	136640	51103	15	579	137	410
+Rainfall collected	978092	117137	100			
+Parlor wastes	341265	40870	99.5	85	51	63
-Runoff losses						
-Evaporation losses	(624885)	(74833)	100			
+Water added						
Total wastes collected	28514628	378472	86.87	10677	1980	7149
Jul.-Aug.						
Total manure collectible	2281600	275776	87.3	11309	2024	7539
Total manure collected	2053440	248498	87.3	10178	1822	6785
+Bedding and feed wastes	138880	51941	15	589	139	417
+Rainfall collected	1003076	120129	100			
+Parlor wastes	346859	41540	99.5	87	52	64
-Runoff losses						
-Evaporation losses	(816876)	(97829)	100			
+Water added						
Total wastes collected	2725379	363979	86.04	10854	2013	7266

Table B-5 (continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.						
Total manure collectible	2244800	271328	87.3	11126	1991	7418
Total manure collected	2020320	244195	87.3	10013	1792	6676
+Bedding and feed wastes	136640	51103	15	579	137	410
+Rainfall collected	722015	86469	100			
+Parlor wastes	341265	40870	99.5	85	51	63
-Runoff losses						
-Evaporation losses	(495005)	(59282)	100			
+Water added						
Total wastes collected	2725235	422637	86.26	10677	1980	7149
Nov.-Dec.						
Total manure collectible	2244800	271328	87.3	11126	1991	7418
Total manure collected	2132560	257762	87.3	10570	1892	7047
+Bedding and feed wastes	156160	58403	15	662	156	469
+Rainfall collected	1046796	125365	100			
+Parlor wastes	341265	40870	99.5	85	51	63
-Runoff losses						
-Evaporation losses	(110997)	(13293)	100			
+Water added						
Total wastes collected	3565784	469107	88.63	11317	2099	7579

[1]Calculated from data presented in 31.

[2]Total manure collectible x %TOL.

Table B-5 (continued)

[3]8, 7, 6, 5, and 2 lbs/day for 95, 90, 80, 65, and 45 %TOL respectively. (Adapted from 21, 24, and 25.)

[4]Total rainfall for the period that falls directly on the housing/feeding lot surface. (See table A-4.)

[5]Slurry and liquid systems only (from table A-1).

[6]80-95% total rainfall at 3.5% total solids by weight x %TOL. (Adapted from 12, 25, and 36.)

[7]Evapotranspiration rate (Table A-4) x .7 x housing/feeding lot size x %TOL.

[8]Water added at reception pit (CAGT and SAGT systems) to raise moisture content of waste (for pumping).

APPENDIX C

Example Storage and Application Budgets For Modeled Dairy Waste Management Systems

Table C-1. Storage and Application Budget for the 80/TC/DH System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N[8] (lbs)	NH_4-N[9] (lbs)	Total P (lbs)	Total K (lbs)
Jan.-Feb.							
Total wastes collected[1]	613844	83678	85.98	2267		398	965
-Storage nutrient loss[2]				(793)		(40)	(97)
+Rainfall on storage[3]							
+Water added[4]							
Total wastes applied		83678	85.98	1427	793	358	868
-N loss (irrigation)[5]							
-Volatilization loss[6]				(143)	(143)		
-Runoff losses[7]				(128)	(70)	(57)	(260)
Total nutrients in-soil				1156	580	301	608
Mar.-Apr.							
Total wastes collected	557221	77281	83.87	2380		417	997
-Storage nutrient loss				(833)		(42)	(100)
+Rainfall on storage							
+Water added							
Total wastes applied		77281	83.87	1547	859	375	897
-N loss (irrigation)							
-Volatilization loss				(464)	(464)		
-Runoff losses				(33)	(18)	(28)	(135)
Total nutrients in-soil				1050	377	347	762

Table C-1 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	NH_4-N (lbs)	Total P (lbs)	Total K (lbs)
May.-June							
Total wastes collected	386380	55517	78.05	2322		392	936
-Storage nutrient loss				(813)		(39)	(94)
+Rainfall on storage							
+Water added							
Total wastes applied		55517	78.05	1509	838	353	842
-N loss (irrigation)							
-Volatilization loss				(453)	(453)		
-Runoff losses				(32)	(18)	(26)	(126)
Total Nutrients in-soil				1024	367	327	716
Jul.-Aug.							
Total wastes collected	332629	49233	74.11	2356		399	952
-Storage nutrient loss				(825)		(40)	(95)
+Rainfall on storage							
+Water added							
Total wastes applied		49233	74.11	1531	851	359	857
-N loss (irrigation)							
-Volatilization loss				(459)	(459)		
-Runoff losses				(32)	(18)	(27)	(129)
Total nutrients in-soil				1040	374	332	728

Table C-1 (continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	NH_4-N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.							
Total wastes collected	415152	58962	79.05	2407		392	936
-Storage nutrient loss				(842)		(39)	(94)
+Rainfall on storage							
+Water added							
Total wastes applied		58962	79.05	1565	869	353	842
-N loss (irrigation)							
-Volatilization loss				(470)	(470)		
-Runoff losses				(33)	(18)	(26)	(126)
Total nutrients in-soil				1062	381	327	716
Nov.-Dec.							
Total wastes collected	599733	82339	84.74	2443		417	997
-Storage nutrient loss				(855)		(42)	(100)
+Rainfall on storage							
+Water added							
Total wastes applied		82339	84.74	1588	882	375	897
-N loss (irrigation)							
-Volatilization loss				(476)	(476)		
-Runoff losses				(111)	(61)	(60)	(269)
Total nutrients in-soil				1001	345	315	628

Table C-1 (continued)

[1]Source: Collection Budgets.

[2]Sources: 35, 42, 45, and 46. The fertilzer nutrient and organic matter losses were assumed to insignificantly affect the volume, weight, and moisture content of the wastes applied.

[3]Net rainfall on open (un-roofed) storage facilities.

[4]Water required to facilitate pumping or treatment of wastes in slurry or lagoon systems.

[5]N loss accruing to the irrigation process (movement of wastes through the air). Source: 42.

[6]N lost at ground surface as free ammonia after application and before incorporation (< 4 days). Source: Table 3 in 12.

[7]Nutrient loss due to runoff after field application. (Adapted from sources: 43, 40, and 41.)

[8]Ammonical N plus orgainc N which must be mineralized before crop uptake.

[9]Ammonical N, the N that is potentially 100% available to crops following land application.

Table C-2. Storage and Application Budget for the 80/TC/DS/3 System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N[8] (lbs)	NH_4-N[9] (lbs)	Total P (lbs)	Total K (lbs)
Mar.-Apr.							
Total wastes collected[1]	925043	126412	85.56	3536		615	1484
-Storage nutrient loss[2]				(796)		(77)	(148)
+Rainfall on storage[3]							
+Water added[4]							
Total wastes applied		126412	85.56	2740	1522	538	1336
-N loss (irrigation)[5]							
-Volatilization loss[6]				(548)	(548)		
-Runoff losses[7]							
Total nutrients in-soil				1156	580	301	608
May.-June							
Total wastes collected	723808	101249	82.48	3393		588	1404
-Storage nutrient loss				(763)		(74)	(140)
+Rainfall on storage							
+Water added							
Total wastes applied		101249	82.48	2630	1461	514	1264
-N loss (irrigation)							
-Volatilization loss				(789)	(789)		
-Runoff losses				(55)	(30)	(39)	(190)
Total nutrients in-soil				1786	642	475	1074

Table C-2 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	NH_4-N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.							
Total wastes collected	750180	108890	76.58	4821		820	1959
-Storage nutrient loss				(1085)		(103)	(196)
+Rainfall on storage							
+Water added							
Total wastes applied		108890	76.58	3736	2076	717	1763
-N loss (irrigation)							
-Volatilization loss				(747)	(747)		
-Runoff losses							
Total Nutrients in-soil				2989	1329	717	1763
Nov.-Dec.							
Total wastes collected	505928	70459	82.37	2425		392	936
-Storage nutrient loss				(546)		(49)	(94)
+Rainfall on storage							
+Water added							
Total wastes applied		70459	82.37	1879	1044	343	842
-N loss (irrigation)							
-Volatilization loss				(564)	(564)		
-Runoff losses				(132)	(73)	(55)	(253)
Total nutrients in-soil				1183	407	288	589

[1]Source: Collection Budgets.

Table C-2 (continued)

[2]Sources: 35, 42, 45, and 46. The fertilzer nutrient and organic matter losses were assumed to insignificantly affect the volume, weight, and moisture content of the wastes applied.

[3]Net rainfall on open (un-roofed) storage facilities.

[4]Water required to facilitate pumping or treatment of wastes in slurry or lagoon systems.

[5]N loss accruing to the irrigation process (movement of wastes through the air). Source: 42.

[6]N lost at ground surface as free ammonia after application and before incorporation (< 4 days). Source: Table 3 in 12.

[7]Nutrient loss due to runoff after field application. (Adapted from sources: 43, 40, and 41.)

[8]Ammonical N plus orgainc N which must be mineralized before crop uptake.

[9]Ammonical N, the N that is potentially 100% available to crops following land application.

Table C-3. Storage and Application Budget for the 160/PC/EP/6 System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N[8] (lbs)	NH_4-N[9] (lbs)	Total P (lbs)	Total K (lbs)
Mar.-Apr.							
Total wastes collected[1]	4218655	539233	91.89	10044		1874	6726
-Storage nutrient loss[2]				(2009)		(234)	(673)
+Rainfall on storage[3]	1762118	207308	100				
+Water added[4]							
Total wastes applied		746531	94.28	8035	4018	1640	6053
-N loss (irrigation)[5]							
-Volatilization loss[6]				(1607)	(1607)		
-Runoff losses[7]							
Total nutrients in-soil				6428	2411	1640	6053
Sept.-Oct.							
Total wastes collected	4273531	536259	92.37	10222		1920	6845
-Storage nutrient loss				(2044)		(240)	(685)
+Rainfall on storage	452411	54181	100				
+Water added							
Total wastes applied		590440	93.10	8178	4089	1680	6160
-N loss (irrigation)							
-Volatilization loss				(1636)	(1636)		
-Runoff losses							
Total nutrients in-soil				6542	2453	1680	6160

[1]Source: Collection Budgets.

Table C-3 (continued)

[2]Sources: 35, 42, 45, and 46. The fertilzer nutrient and organic matter losses were assumed to insignificantly affect the volume, weight, and moisture content of the wastes applied.

[3]Net rainfall on open (un-roofed) storage facilities.

[4]Water required to facilitate pumping or treatment of wastes in slurry or lagoon systems.

[5]N loss accruing to the irrigation process (movement of wastes through the air). Source: 42.

[6]N lost at ground surface as free ammonia after application and before incorporation (< 4 days). Source: Table 3 in 12.

[7]Nutrient loss due to runoff after field application. (Adapted from sources: 43, 40, and 41.)

[8]Ammonical N plus orgainc N which must be mineralized before crop uptake.

[9]Ammonical N, the N that is potentially 100% available to crops following land application.

Table C-4. Storage and Application Budget for the 320/TC/SAGT/3 System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N[8] (lbs)	NH_4-N[9] (lbs)	Total P (lbs)	Total K (lbs)
Mar.-Apr.							
Total wastes collected[1]	6362240	827446	90.00	17624		3269	11802
-Storage nutrient loss[2]				(2644)		(163)	(590)
+Rainfall on storage[3]	508148	60856	100				
+Water added[4]							
Total wastes applied		888302	90.69	14980	7490	3106	11212
-N loss (irrigation)[5]							
-Volatilization loss[6]				(2996)	(2996)		
-Runoff losses[7]							
Total nutrients in-soil				11984	4494	3106	11212
May-June.							
Total wastes collected	5541688	718636	90.00	15307		2839	10251
-Storage nutrient loss				(2296)		(142)	(513)
+Rainfall on storage	190605	22827	100				
+Water added							
Total wastes applied		741463	90.31	13011	6506	2697	9738
-N loss (irrigation)							
-Volatilization loss				(3903)	(3903)		
-Runoff losses				(364)	(164)	(270)	(1948)
Total nutrients in-soil				8744	2439	2427	7790

Table C-4 (Continued)

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N (lbs)	NH_4-N (lbs)	Total P (lbs)	Total K (lbs)
Sept.-Oct.							
Total wastes collected	6898623	892142	90.00	19081		3534	12744
-Storage nutrient loss				(2863)		(177)	(639)
+Rainfall on storage	818	98	100				
+Water added							
Total wastes applied		892240	90.00	16218	8109	3357	12135
-N loss (irrigation)							
-Volatilization loss				(3244)	(3244)		
-Runoff losses							
Total Nutrients in-soil				12974	4865	3357	12135
Nov.-Dec.							
Total wastes collected	4987987	647190	90.00	13775		2554	9224
-Storage nutrient loss				(2066)		(128)	(461)
+Rainfall on storage							
+Water added	198822	23811	100				
Total wastes applied		671001	90.35	11709	5855	2426	8763
-N loss (irrigation)							
-Volatilization loss				(3513)	(3513)		
-Runoff losses				(820)	(369)	(388)	(2629)
Total nutrients in-soil				7376	1973	2038	6134

[1]Source: Collection Budgets.

Table C-4 (continued)

[2]Sources: 35, 42, 45, and 46. The fertilzer nutrient and organic matter losses were assumed to insignificantly affect the volume, weight, and moisture content of the wastes applied.

[3]Net rainfall on open (un-roofed) storage facilities.

[4]Water required to facilitate pumping or treatment of wastes in slurry or lagoon systems.

[5]N loss accruing to the irrigation process (movement of wastes through the air). Source: 42.

[6]N lost at ground surface as free ammonia after application and before incorporation (< 4 days). Source: Table 3 in 12.

[7]Nutrient loss due to runoff after field application. (Adapted from sources: 43, 40, and 41.)

[8]Ammonical N plus orgainc N which must be mineralized before crop uptake.

[9]Ammonical N, the N that is potentially 100% available to crops following land application.

Table C-5. Storage and Application Budget for the 320/PC/TSL/FC System.

	Total Wastes (lbs)	Total Wastes (gal)	Moisture %	Total N[8] (lbs)	NH_4-N[9] (lbs)	Total P (lbs)	Total K (lbs)
Mar.-Apr.							
Total wastes collected[1]	7251412	934247		19439		3619	13016
-Storage nutrient loss[2]				(13607)		(2171)	(5206)
+Rainfall on storage[3]	13665202	1636551					
+Water added[4]	444103	53182					
Total wastes applied		2623980		5832	3645	1448	7810
-N loss (irrigation)[5]				(1166)	(1166)		
-Volatilization loss[6]				(933)	(933)		
-Runoff losses[7]							
Total nutrients in-soil				3733	1546	1448	7810
Nutrients in sludge				1944		1448	3254
Sept.-Oct.							
Total wastes collected	7903733	997650		21098		3945	14092
-Storage nutrient loss				(24769)		(2367)	(5637)
+Rainfall on storage	4211646	504389					
+Water added	9368207	1121941					
Total wastes applied		2623980		6329	3956	1578	8455
-N loss (irrigation)				(1266)	(1266)		
-Volatilization loss				(1013)	(1013)		
-Runoff losses							
Total nutrients in-soil				4050	1677	1578	8455
Nutrients in sludge				2110		1578	3523

Table C-5 (continued)

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[1]Source: Collection Budgets.

[2]Sources: 35, 44, 45, and 42. The fertilzer nutrient and organic matter losses were assumed to insignificantly affect the volume, weight, and moisture content of the wastes applied.

[3]Net rainfall on open (un-roofed) storage facilities.

[4]Water required to facilitate pumping or treatment of wastes in slurry or lagoon systems.

[5]N loss accruing to the irrigation process (movement of wastes through the air). Source: 42.

[6]N lost at ground surface as free ammonia after application and before incorporation (< 4 days). Source: Table 3 in 12.

[7]Nutrient loss due to runoff after field application. (Adapted from sources: 43, 40, and 41.)

[8]Ammonical N plus orgainc N which must be mineralized before crop uptake.

[9]Ammonical N, the N that is potentially 100% available to crops following land application.

APPENDIX D

Example Nutrient Mineralization And Valuation Budgets For Modeled Dairy Waste Management Systems

Table D-1. Nutrient Mineralization and Valuation Budget for the 80/-PC/EP/6 System.[1]

Nitrogen

Year	NH_4-N		Mineralized N[2]		Total N Available in Yr. X	Total Value of N[3]		Discount Factor[4]		Present Value
1	2454	+	1226	=	3680	1030	x	1.0000	=	1030
2			613	=	613	172	x	.9709	=	167
3			307	=	307	86	x	.9426	=	81
4			153	=	153	43	x	.9151	=	39
						Total annual value[5]				1317

Phosphorus

Year	Total P[6] Available in Yr. X	Total Value of P		Discount Factor		Present Value
1	1279	895	x	1.0000	=	895
2	171	120	x	.9709	=	117
3	82	57	x	.9426	=	54
4	17	12	x	.9151	=	11
		Total annual value				1077

Potsassium

Year	Total K Available in Yr. X	Total Value of K		Discount Factor		Present Value
1	4930	887	x	1.0000	=	887
2	493	89	x	.9709	=	86
3	308	55	x	.9426	=	52
4	62	11	x	.9151	=	10
		Total annual value				1035

[1]Determination of annual value of fertilizer nutrients in dairy wastes applied. Based upon data from Storage and Application Budgets.

[2]Source of mineralization rates for N: 67.

[3]Prices for elemental nutrients were derived from commercial fertilizer prices. N, P, and K were priced at $.28, $.70, and $.18/lb respectively.

[4]Discount factors were based upon a long-term real interest rate of 3%.

[5]Based upon the assumption that annual applications of dairy wastes are relatively constant i.e. valuation of an average year's application.

[6]Sources of mineralization rates for P and K: 25 and 45.

Table D-2. Nutrient Mineralization and Valuation Budget for the 320/-TC/DH System.[1]

Nitrogen

Year	NH_4-N		Mineralized N[2]		Total N Available in Yr. X	Total Value of N[3]		Discount Factor[4]		Present Value
1	10193	+	4091	=	14284	4000	x	1.0000	=	4000
2			2046	=	2046	573	x	.9709	=	556
3			1023	=	1023	286	x	.9426	=	270
4			511	=	511	143	x	.9151	=	131
						Total annual value[5]				4957

Phosphorus

Year	Total P[6] Available in Yr. X	Total Value of P		Discount Factor		Present Value
1	5864	4105	x	1.0000	=	4105
2	782	547	x	.9709	=	531
3	391	274	x	.9426	=	258
4	78	55	x	.9151	=	50
		Total annual value				4944

Potassium

Year	Total K Available in Yr. X	Total Value of K		Discount Factor		Present Value
1	13319	2397	x	1.0000	=	2397
2	1332	240	x	.9709	=	233
3	832	150	x	.9426	=	141
4	167	30	x	.9151	=	27
		Total annual value				2798

[1]Determination of annual value of fertilizer nutrients in dairy wastes applied. Based upon data from Storage and Application Budgets.

[2]Source of mineralization rates for N: 67.

[3]Prices for elemental nutrients were derived from commercial fertilizer prices. N, P, and K were priced at $.28, $.70, and $.18/lb respectively.

[4]Discount factors were based upon a long-term real interest rate of 3%.

[5]Based upon the assumption that annual applications of dairy wastes are relatively constant i.e. valuation of an average year's application.

[6]Sources of mineralization rates for P and K: 25 and 45.

Table D-3. Nutrient Mineralization and Valuation Budget for the 160/-PC/SSL/FC System.[1]

Nitrogen

Year	NH_4-N		Mineralized N[2]		Total N Available in Yr. X	Total Value of N[3]		Discount Factor[4]		Present Value
1	2685	+	1140	=	3825	3825	x	1.0000	=	1071
2			570	=	570	160	x	.9709	=	155
3			285	=	285	80	x	.9426	=	75
4			143	=	143	40	x	.9151	=	37
						Total annual value[5]				1338

Phosphorus

Year	Total P[6] Available in Yr. X	Total Value of P		Discount Factor		Present Value
1	2276	1593	x	1.0000	=	1593
2	303	212	x	.9709	=	206
3	152	106	x	.9426	=	100
4	30	21	x	.9151	=	19
		Total annual value				1918

Potassium

Year	Total K Available in Yr. X	Total Value of K		Discount Factor		Present Value
1	9228	1661	x	1.0000	=	1661
2	923	166	x	.9709	=	161
3	577	104	x	.9426	=	98
4	115	21	x	.9151	=	19
		Total annual value				1939

[1]Determination of annual value of fertilizer nutrients in dairy wastes applied. Based upon data from Storage and Application Budgets.

[2]Source of mineralization rates for N: 67.

[3]Prices for elemental nutrients were derived from commercial fertilizer prices. N, P, and K were priced at $.28, $.70, and $.18/lb respectively.

[4]Discount factors were based upon a long-term real interest rate of 3%.

[5]Based upon the assumption that annual applications of dairy wastes are relatively constant i.e. valuation of an average year's application.

[6]Sources of mineralization rates for P and K: 25 and 45.

Table D-4. Nutrient Mineralization and Valuation Budget for the 320/-TC/SAGT/6 System.[1]

Nitrogen

Year	NH_4-N		Mineralized N[2]		Total N Available in Yr. X	Total Value of N[3]		Discount Factor[4]		Present Value
1	16776	+	8388	=	25164	7046	x	1.0000	=	7046
2			4194	=	4194	1174	x	.9709	=	1140
3			2097	=	2097	587	x	.9426	=	553
4			1049	=	1049	294	x	.9151	=	269
						Total annual value[5]				9008

Phosphorus

Year	Total P[6] Available in Yr. X	Total Value of P		Discount Factor		Present Value
1	8693	6085	x	1.0000	=	6085
2	1159	811	x	.9709	=	787
3	580	406	x	.9426	=	383
4	116	81	x	.9151	=	74
		Total annual value				7329

Potsassium

Year	Total K Available in Yr. X	Total Value of K		Discount Factor		Present Value
1	33478	6026	x	1.0000	=	6026
2	3348	603	x	.9709	=	585
3	2092	377	x	.9426	=	355
4	418	75	x	.9151	=	69
		Total annual value				7035

[1]Determination of annual value of fertilizer nutrients in dairy wastes applied. Based upon data from Storage and Application Budgets.

[2]Source of mineralization rates for N: 67.

[3]Prices for elemental nutrients were derived from commercial fertilizer prices. N, P, and K were priced at $.28, $.70, and $.18/lb respectively.

[4]Discount factors were based upon a long-term real interest rate of 3%.

[5]Based upon the assumption that annual applications of dairy wastes are relatively constant i.e. valuation of an average year's application.

[6]Sources of mineralization rates for P and K: 25 and 45.

Table D-5. Nutrient Mineralization and Valuation Budget for the 80/-PC/TSL/SC System.[1]

Nitrogen

Year	NH_4-N		Mineralized N[2]		Total N Available in Yr. X	Total Value of N[3]		Discount Factor[4]		Present Value
1	812	+	345	=	1157	324	x	1.0000	=	324
2			173	=	173	48	x	.9709	=	47
3			86	=	86	24	x	.9426	=	23
4			153	=	153	43	x	.9151	=	11
	Sludge (annual value)[7]									92
						Total annual value[5]				497

Phosphorus

Year	Total P[6] Available in Yr. X	Total Value of P		Discount Factor		Present Value
1	584	409	x	1.0000	=	409
2	78	55	x	.9709	=	53
3	39	27	x	.9426	=	25
4	8	6	x	.9151	=	6
Sludge (annual value)						406
		Total annual value				898

Potsassium

Year	Total K Available in Yr. X	Total Value of K		Discount Factor		Present Value
1	3287	592	x	1.0000	=	592
2	329	59	x	.9709	=	57
3	205	37	x	.9426	=	35
4	41	7	x	.9151	=	6
Sludge (annual value)						232
		Total annual value				1035

[1]Determination of annual value of fertilizer nutrients in dairy wastes applied. Based upon data from Storage and Application Budgets.

[2]Source of mineralization rates for N: 67.

[3]Prices for elemental nutrients were derived from commercial fertilizer prices. N, P, and K were priced at $.28, $.70, and $.18/lb respectively.

[4]Discount factors were based upon a long-term real interest rate of 3%.

[5]Based upon the assumption that annual applications of dairy wastes are relatively constant i.e. valuation of an average year's application.

Table D-5 (continued)

[6]Sources of mineralization rates for P and K: 25 and 45.

[7]Derived by calculating the present (time of application) value of sludge nutrients applied in years 5, 10, 15, and 20 of the system's life, discounting these values to year 1, and amortizing the summed discounted values over the life of the system (26).

APPENDIX E

Example Annual Labor And Energy Cost Budgets For Modeled Dairy Waste Management Systems

Table E-1. Annual Labor and Energy Cost Budget for the 80/PC/EP/3 System.

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Jan.-Feb.						
Daily clean[1]	46.5		41.0	82.0		
Agit./loading[2]						
Hauling[3]						
Total	46.5	232.5	41.0	82.0		
Mar.-Apr.						
Daily clean	41.0		35.0	72.0		
Agit./loading	10.5		13.0	46.0		
Hauling	61.0		59.5	289.5		
Total	112.5	562.5	107.5	405.5		
May-June						
Daily clean	31.5		25.5	51.0		
Agit./loading						
Hauling						
Total	31.5	157.5	25.5	51.0		
July-Aug.						
Daily clean	30.5		24.5	49.0		
Agit./loading						
Hauling						
Total	30.5	152.5	24.5	49.0		
Sept.-Oct.						
Daily clean	32.0		26.0	52.0		
Agit./loading	10.0		12.5	44.0		
Hauling	59.0		57.5	280.0		
Total	101.0	505.0	96.0	376.0		
Nov.-Dec.						
Daily clean	42.0		36.0	72.0		
Agit./loading	6.5		8.0	28.0		
Hauling	37.0		35.5	173.0		
Total	85.5	427.5	79.5	273.0		

Table E-1 (continued)

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Yearly Totals	407.5	2038	374.0	1237		

[1]Labor and energy required to scrape the housing/feeding lot daily using a small scrape-tractor (37 hp).

[2]Labor and energy required to agitate the storage structure prior to and during the land application process, as well as transfer the agitated wastes to the tank spreader.

[3]Labor and energy required to haul and apply the stored dairy wastes on cropland.

Table E-2. Annual Labor and Energy Cost Budget for the 80/TC/CAGT/6 System.

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Jan.-Feb.						
Daily clean[1]	51.5		46.0	92.0		
Agit./trnsfer[2]	3.0		27.0		278.0	14.0
Agit./loading[3]						
Hauling[4]						
Total	54.5	272.5	73.0	92.0	278.0	14.0
Mar.-Apr.						
Daily clean	50.0		44.0	88.0		
Agit./trnsfer	3.0		25.5		262.5	13.0
Agit./loading	10.0		16.5	58.0		
Hauling	97.0		95.5	465.5		
Total	160.0	800.0	181.5	611.0	262.5	13.0
May-June						
Daily clean	42.5		36.5	73.0	21.5	1.0
Agit./trnsfer	2.5		23.0		237.0	12.0
Agit./loading						
Hauling						
Total	45.0	225.0	59.5	73.0	258.5	13.0
July-Aug.						
Daily clean	41.0		35.0	70.0	31.5	1.5
Agit./trnsfer	2.5		23.5		242.0	12.0
Agit./loading						
Hauling						
Total	43.5	217.5	58.5	70.0	273.5	13.5
Sept.-Oct.						
Daily clean	44.0		38.0	76.0	29.0	1.5
Agit./trnsfer	2.5		23.5		242.0	12.0
Agit./loading	9.0		14.5	51.0		
Hauling	85.5		84.5	409.0		
Total	141.0	705.0	160.0	536.0	271.0	13.5

Table E-2 (continued).

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Nov.-Dec.						
Daily clean	52.5		46.5	93.0		
Agit./trnsfer	3.0		25.5		262.5	13.0
Agit./loading						
Hauling						
Total	55.5	277.5	72.0	93.0	262.5	13.0
Yearly Totals	499.5	2498	604.5	1475	1606.0	80

[1]Labor and energy required to scrape the housing/feeding lot daily using a small scrape-tractor (37 hp).

[2]Labor and energy required to agitate (in collection sump) and transfer collected dairy wastes to the storage structure.

[3]Labor and energy required to agitate the storage structure prior to and during the land application process, as well as transfer the agitated wastes to the tank spreader.

[4]Labor and energy required to haul and apply the stored dairy wastes on cropland.

Table E-3. Annual Labor and Energy Cost Budget for the 160/TC/DS/3 System.

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Jan.-Feb.						
Daily clean[1]	81.0		75.5	151.5		
Loading[2]						
Hauling[3]						
Total	81.0	405.0	75.5	151.5		
Mar.-Apr.						
Daily clean	77.5		71.5	143.5		
Loading	10.0		9.5	19.0		
Hauling	66.0		65.0	411.0		
Total	153.5	767.5	146.0	573.5		
May-June						
Daily clean	62.0		56.0	112.0		
Loading	8.5		8.0	16.0		
Hauling	53.5		52.5	332.0		
Total	124.0	620.0	116.5	460.0		
July-Aug.						
Daily clean	58.0		52.0	104.0		
Loading						
Hauling						
Total	58.0	290.0	52.0	104.0		
Sept.-Oct.						
Daily clean	64.5		58.5	117.5		
Loading	9.0		8.5	17.0		
Hauling	57.0		56.0	354.0		
Total	130.5	652.5	123.0	488.5		
Nov.-Dec.						
Daily clean	81.0		75.0	150.5		
Agit./loading	6.0		5.5	11.0		
Hauling	38.5		37.5	237.0		
Total	125.5	627.5	118.0	398.5		

Table E-3 (continued)

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Yearly Totals	672.5	3363	631.0	2176		

[1]Labor and energy required to scrape the housing/feeding lot daily using a small scrape-tractor (37 hp).

[2]Labor and energy required to agitate the storage structure prior to and during the land application process, as well as transfer the agitated wastes to the tank spreader.

[3]Labor and energy required to haul and apply the stored dairy wastes on cropland.

Table E-4. Annual Labor and Energy Cost Budget for the 80/TC/TSL/FC System.

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Jan.-Feb.						
Daily clean[1]	10.0					
Recycle pump[2]			383.5		268.5	13.5
Irrigation[3]						
Total	10.0	50.0	383.5		268.5	13.5
Mar.-Apr.						
Daily clean	10.0					
Recycle pump			396.5		277.5	14.0
Irrigation	8.5		72.5	255.5		
Total	18.5	92.5	469.0	255.5	277.5	14.0
May-June						
Daily clean	10.0					
Recycle pump			396.5		277.5	14.0
Irrigation						
Total	10 0	50.0	396.5		277.5	14.0
July-Aug.						
Daily clean	10.5					
Recycle Pump			403.0		282.0	14.0
Irrigation						
Total	10.5	52.5	403.0		282.0	14.0
Sept.-Oct.						
Daily clean	10.0					
Recycle pump			396.5		277.5	14.0
Water Added					127.5	6.5
Irrigation	8.5		72.0	253.5		
Total	18.5	92.5	468.5	253.5	405.0	20.5
Nov.-Dec.						
Daily clean	10.0					
Recycle pump			396.5		277.5	14.0
Irrigation						
Total	10.0	50.0	396.5		277.5	14.0

Table E-4 (continued)

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Yearly Totals	77.5	388	2517.0	509.0	17880	90.0
					Equipment rental	
Sludge removal (annulized cost)[4]		26		66	92	
Total Annual Cost		414		575	92	90

[1]Labor required to flush (manual flush tanks) housing/feeding lots daily (2x/day if %TOL > 45, 1x/day otherwise).

[2]Energy required to power a 1/2 hp recycle pump associated with the system's flush collection system.

[3]Labor and energy required to irrigate collected wastes onto cropland.

[4]Annualized cost of sludge removal assumed to be required in years 5, 10, 15, and 20 of the system's life.

Table E-5. Annual Labor and Energy Cost Budget for the 320/TC/DH System.

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Jan.-Feb.						
Daily clean[1]	137.0		131.5	263.5		
Loading[2]	16.5		15.5	31.0		
Hauling[3]	84.0		80.0	674.5		
Total	237.5	1187.5	227.0	969.0		
Mar.-Apr.						
Daily clean	130.5		124.5	249.5		
Loading	16.0		15.0	30.0		
Hauling	79.5		75.5	636.5		
Total	222.5	1127.5	215.0	916.0		
May-June						
Daily clean	107.5		101.5	203.5		
Loading	13.5		12.5	25.0		
Hauling	64.5		60.5	510.0		
Total	185.5	927.5	174.4	738.5		
July-Aug.						
Daily clean	101.5		95.5	191.5		
Loading	13.0		12.0	24.0		
Hauling	61.0		57.0	480.5		
Total	175.5	877.5	164.5	696.0		
Sept.-Oct.						
Daily clean	111.0		105.0	210.5		
Loading	14.0		13.0	26.0		
Hauling	66.5		62.5	527.0		
Total	191.5	957.5	180.5	763.5		
Nov.-Dec.						
Daily clean	137.5		131.5	263.5		
Loading	16.5		15.5	31.0		
Hauling	84.5		80.5	679.0		
Total	238.5	1192.5	227.5	973.5		

Table E-5 (continued)

	Labor (hours)	Labor (cost)	Tractor/ Equipment (hours)	Fuel/Lubrication (cost)	Electricity (kwh)	Electricity (cost)
Yearly Totals	1254.0	6270	1189.0	5057		

[1]Labor and energy required to scrape the housing/feeding lot daily using a small scrape-tractor (37 hp).

[2]Labor and energy required to agitate the storage structure prior to and during the land application process, as well as transfer the agiated wastes to the tank spreader.

[3]Labor and energy required to haul and apply the stored dairy wastes on cropland.

APPENDIX F

Example Capital Recovery/Insurance/-Repairs/Housing Costs Budgets For Modeled Dairy Waste Management Systems

Table F-1. Capital Recovery/Insurance/Repairs/Housing Costs Budget for the 80/PC/SAGT/3 System.

	Initial Cost[1]	Insurance/ /Repairs/Housing Costs[2]	Life (yrs)	% of Time to Waste-handling[3]	Capital Recovery[4]
Scraper tractor (37 hp)	12500	55	8	23.5	611
Tractor for hauling (85 hp)	25700	79	10	17.0	815
Tractor for agit./-loading (65 hp)	20800	11	10	3.0	116
Box scrape (6 ft.)	700	22	10	100	131
Tank spreader (1500 gal.)	6300	205	8	100	1311
Concrete, curbing, etc.	1010	10	20	100	135
Collection sump (645 ft.^{3})	1060	11	20	100	142
Agitation/transfer pump (800 gpm)	6900	104	8	100	1584
Aboveground tank (42270 ft.^{3})	67400	674	20	100	8931
Totals		1171			13776

[1]For reference only. Some items of equipment used for waste handling are not included in the initial cost of the system ie. waste management is not the primary source of their annual use. See Initial Investment Budgets.

[2]Sources: 46 and 54.

[3]Based upon potential annual use e.g. tractors have a potential annual use of 800 hours.

[4]A substitute calculation for depreciation and interest on capital.

Table F-2. Capital Recovery/Insurance/Repairs/Housing Costs Budget for the 160/TC/SSL/SC System.

	Initial Cost[1]	Insurance/ /Repairs/Housing Costs[2]	Life (yrs)	% of Time to Waste-handling[3]	Capital Recovery[4]
Scraper tractor (37 hp)	12500	114	8	48.5	1261
Tractor for irrigation (85 hp)	25700	67	10	14.5	695
Tractor for agitation (105 hp)	38200	54	10	8.0	570
Box scrape (6 ft.)	700	22	10	100.0	131
Agitation pump	5600	204	8	100.0	1165
Irrigation pump (700 gpm)	7400	196	10	100.0	1380
Traveling big gun	15100	418	10	100.0	2817
Mainline 6-inch PVC (3000 ft.)	10800	108	15	100.0	1585
Concrete, curbing, etc.	1890	19	20	100.0	253
Fencing, gates, etc.	1170	18	20	100.0	157
Single stage lagoon ($571600 ft.^3$)	22450	225	20	100.0	3006
Totals		1445			13020

[1]For reference only. Some items of equipment used for waste handling are not included in the initial cost of the system ie. waste management is not the primary source of their annual use. See Initial Investment Budgets.

[2]Sources: 46 and 54.

[3]Based upon potential annual use e.g. tractors have a potential annual use of 800 hours.

[4]A substitute calculation for depreciation and interest on capital.

Table F-3. Capital Recovery/Insurance/Repairs/Housing Costs Budget for the 160/TC/DH System.

	Initial Cost[1]	Insurance/ /Repairs/Housing Costs[2]	Life (yrs)	% of Time to Waste-handling[3]	Capital Recovery[4]
Scraper tractor (37 hp)	16000	166	8	55.5	1847
Tractor for hauling (105 hp)	38200	211	10	31.0	2209
Box scrape (6 ft.)	700	22	10	100.0	131
Box spreader (275 bu.)	7200	239	5	100.0	1988
Concrete, curbing, etc.	1590	16	20	100.0	213
Totals		654			6388

[1]For reference only. Some items of equipment used for waste handling are not included in the initial cost of the system ie. waste management is not the primary source of their annual use. See Initial Investment Budgets.

[2]Sources: 46 and 54.

[3]Based upon potential annual use e.g. tractors have a potential annual use of 800 hours.

[4]A substitute calculation for depreciation and interest on capital.

Table F-4. Capital Recovery/Insurance/Repairs/Housing Costs Budget for the 320/TC/DS/6 System.

	Initial Cost[1]	Insurance/ /Repairs/Housing Costs[2]	Life (yrs)	% of Time to Waste-handling[3]	Capital Recovery[4]
Scraper tractor (37 hp)	16000	280	8	93.5	3112
Tractor for hauling (140 hp)	46400	385	10	47.0	4068
Box scrape (6 ft.)	700	22	10	100.0	131
Box spreader (450 bu.)	11200	347	8	100.0	2330
Concrete, curbing, etc.	4460	45	20	100.0	597
Dry stack (120960 ft.^{3})	103680	1037	20	100.0	13883
Totals		2116			24121

[1]For reference only. Some items of equipment used for waste handling are not included in the initial cost of the system ie. waste management is not the primary source of their annual use. See Initial Investment Budgets.

[2]Sources: 46 and 54.

[3]Based upon potential annual use e.g. tractors have a potential annual use of 800 hours.

[4]A substitute calculation for depreciation and interest on capital.

Table F-5. Capital Recovery/Insurance/Repairs/Housing Costs Budget for the 320/TC/TSL/FC System.

	Initial Cost[1]	Insurance/ /Repairs/Housing Costs[2]	Life (yrs)	% of Time to Waste-handling[3]	Capital Recovery[4]
Tractor for irrigation (125 hp)	42800	188	10	22.5	1977
Tractor for agitation (165 hp)[5]	49100	11	10	6.5	112
Recycle pump (1/2 hp)	350	9	8	100.0	73
Flush tanks (manual)	10800	108	20	100.0	1446
Irrigation pump (700 gpm)	7400	196	10	100.0	1380
Traveling big gun	20700	560	10	100.0	3861
Mainline 6-inch PVC (5000 ft.)	18000	180	15	100.0	2642
Concrete, curbing, etc.	4330	43	20	100.0	580
Fencing, gates, etc.	3233	48	20	100.0	433
Two stage lagoon ($1386600 ft.^3$)	49050	491	20	100.0	6568
Totals		1834			19072
Equipment rental for sludge removal[6]	191				

[1]For reference only. Some items of equipment used for waste handling are not included in the initial cost of the system ie. waste management is not the primary source of their annual use. See Initial Investment Budgets.

[2]Sources: 46 and 54.

[3]Based upon potential annual use e.g. tractors have a potential annual use of 800 hours.

[4]A substitute calculation for depreciation and interest on capital.

[5]Tractor is used only in years 5, 10, 15, and 20; % time used is for years in which sludge removal occurs, eg. the tractor is used only 6.5% of the potential annual hours in year 5, 10, 15, anbd 20. Capital recovery (insurance/repairs/housing costs) was computed by amortizing the present value of the calculated capital recovery (insurance/repairs/-housing costs) in years 5, 10, 15, and 20 over the life of the system.

[6]Rental of agitation pump in years of sludge removal (annualized cost).

VITA

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