Agricultural Economics Report

NO. 561 JUNE 1992

IMPACT OF MICHIGAN DAIRY MANURE HANDLING ALTERNATIVES

By

James D. Garsow
Larry J. Connor
Sherrill B. Nott

Department of
Agricultural Economics
MICHIGAN STATE
UNIVERSITY
East Lansing

Impact of Michigan Dairy Manure Handling Alternatives

James D. Garsow
Larry J. Connor
Sherrill B. Nott

Introduction

Winds have always moved across Michigan bringing the soothing sounds of growing corn and the aroma of new mown hay to towns and villages. In recent years, urban residents have noticed the winds also bring the sounds of insects and the odor of animal manure. These citizens have set up cross currents of complaints that have grown into winds of change. The message blowing in the wind is telling farmers it's time to clean up their manure act.

There is a recent history of tension at the rural-urban interface between livestock farmers who strive to continue traditional ways of handling manure plus fertilizers, and people concerned about air and water pollution. At the township level, ordinances and zoning constraints to farm expansion are being tried to limit situations that residential people find offensive. At the state level, Michigan is considering a variety of farming guidelines and new regulations of agriculture.[1]

Recent discoveries about the movement of plant nutrients through the soil have caused farmers to question what their fertility handling practices mean to the purity of their own water supplies. When presented with evidence of wasted plant nutrients, livestock managers realize costs can be reduced with better manure management.

Farmers, residents and legislators are starting to ask what can be done, and at what cost? This paper deals with those questions in a financial way.[2] Alternative dairy manure storage structures are listed. The financial impacts of investing in the least cost structure big enough for eight months storage are analyzed on a variety of representative dairy farms. The impacts are accumulated to the total state level to illustrate the cost burden the Michigan dairy industry would have to bear if new manure handling regulations were introduced.

Manure Handling Alternatives

It is assumed that future legislation, agency rulings and court cases will force dairy farms to do one or more of the following:

1. Control all barnyard runoff.
2. Prohibit winter application of manure.
3. Inject manure when applied to the soil.

---

[1] See J.D. Garsow (Chapter III) for a detailed review of national and state laws plus township ordinances pertaining to air and water pollution in Michigan.

[2] This publication is based on the M.S. thesis by J.D. Garsow titled "A Managerial Perspective of the Likely Economic Benefits and Costs of Environmental Regulations to the Michigan Dairy Industry."

The economic impact of having to comply with these actions will vary from farm to farm. Some dairy farms may already be in compliance with these projected actions. Others may already be in partial compliance. The Michigan State University Dairy Farm Survey indicated that in 1987, 73 percent of the responding farms had manure systems that would not meet any of the above three standards.

Three representative farm sizes were selected to illustrate the economic impact of investing in and operating adequate manure systems. They were 60, 120, and 250 cow herds.[3] These sizes are consistent with the earlier models developed by Nott, Garsow and Darling. The 60 cow farm can represent herd sizes from 30 to 90 cows with stanchion or tie stall barn technology when compared on a per cow basis. The two larger sizes can represent free stall and milking parlor technology. The unit costs on 120 cows represent free stall systems that have been in place several years as well as a common size goal for tie stall managers planning for expansion. The per unit characteristics of the 250 cow system represent Michigan's larger herds where milking parlor technology is being upgraded.

A preliminary review of survey data (Connor et al) indicated that part of the 60 cow herds would choose systems that handle manure as solids. The remaining herds with 60 cows would handle manure as liquids. Analyses were done on 60 cow herds with either tie stall barns or free stall barns with milking parlors. It was assumed management on the 120 and 250 cow herds would use liquid manure handling systems, free stall barns and milking parlors.

Investments Needed

Table 1 shows there are several real estate structures which can serve liquid manure systems. It is assumed managers of the representative farms will choose the structure needing the least investment. This is the unlined earthen pit for all sizes of farms. The pit is built for eight months of storage. Six months capacity might be adequate, but engineers generally design storage facilities with two months added capacity to allow room for extra runoff and future herd expansion.

The system to handle solids on the 60 cow tie stall farm in Table 1 is assumed to be a concrete slab with walls on three sides plus a mechanical stacker. The daily haul line in Table 1 indicates that if this alternative continues to be legally available, the added investment needed would be zero.

Machinery and equipment are needed for collection, agitation, and field application of the manure. The assumed investment levels of these plus the storage structures indicate the total investment needs by farm size and handling system; these are given in Table 2. Compare the investment differences in the right most column between the daily haul and long term

---

[3] Herd size is based on the number of cows that have freshened at least once, both milking and dry. Material volumes include allowances for milking center waste water. The detailed assumptions are given in this report for the manure systems with both the cows and replacements. J.D. Garsow also studied the impact of systems for only the milking herd, assuming no changes would be needed in heifer manure systems. The assumptions behind the latter are not printed in this report, but some of the results are.

Table 1. INVESTMENTS FOR ALTERNATIVE MANURE STORAGE STRUCTURES
Estimated for 1990, Cows and Heifers

	Number of Milk Cows		
	60	120	250
LIQUID SYSTEM:			
Steel Tank	$73,500	$129,800	$203,600
Concrete Tank above Ground	57,100	71,000	$107,800
Concrete Tank Partially in Ground	53,300	80,300	128,000
Earthen Pit with Concrete Liner	51,000	74,600	115,400
Earthen Pit with Membrane Liner	39,000	56,000	84,500
Earthen Pit with 3 ft. Clay Liner	28,300	39,500	57,100
Earthen Pit	20,700	27,700	37,300
SOLIDS SYSTEM			
Concrete Slab with 3 walls	31,700	N/A*	N/A*
DAILY HAUL	0	0	0

*N/A = not analyzed
Source:
T.J. Garsow, 1990a.

storage lines for a single herd size. These differences, after conversion to an annual cost basis, are a major reason why long term manure storage is more expensive then daily hauling.

The 60 cow free stall liquid system includes a buckwall. The tie stall barns have a gutter cleaner. The 60 cow daily haul and solid manure systems have a 205 bushel (bu) box spreader. The 60 cow systems with 8 month storage for liquids have no box spreaders, but do have 1,500 gallon (gal) spreader tankers.

All sizes of the liquid systems in Table 2 include both a piston pump and an agitation pump. The systems on the 120 and the 250 cow herds have 3,200 gal spreader tankers. For daily haul these 2 bigger herds have a 300 bu box spreader plus a buckwall. It is assumed farms have tractors adequate to power the modified systems, so no new tractor investments are

Table 2. INVESTMENT IN MANURE SYSTEMS BY REPRESENTATIVE FARM**
Cow and Heifer Manure Handled the Same

Farm and System	Storage Structure	Collection Equipment	Agitation, Application Equipment*	Total Investment
		dollars		
HANDLE MANURE AS SOLIDS:				
8 months storage				
60 Cows, tie stall	31,700	15,000	5,500	52,200
HANDLE MANURE AS LIQUID				
60 COWS, TIE STALL				
Daily haul	0	7,936	5,000	12,936
8 months storage	20,700	7,936	17,700	46,336
60 COWS, FREE STALL				
Daily haul	0	980	5,000	5,980
8 months storage	20,700	500	17,700	38,900
120 COWS, FREE STALL				
Daily haul	0	980	7,500	8,480
8 months storage	27,700	500	25,500	53,700
250 COWS, FREE STALL				
Daily haul	0	14,980	7,500	22,480
8 months storage	37,300	14,500	25,500	77,300

* Injectors would add $2,500 to investments
** Assumptions at 1990 prices.
Source: J.D. Garsow

needed. Tractor services are priced on an hourly basis in later sections of this report. These tractors range up in size to 95 horsepower to pull the 3,200 gal spreader tankers with injectors.

The investments needed per cow for manure storage structures are shown in Figure 1. Many farmers are expected to meet future regulations by changing only how the cow herd is handled. Other farmers will have to change both cow and heifer systems. The latter, changing how all manure is handled, is shown by the upper line in Figure 1. Slightly lower investment is needed if only the cow system is considered, as (not including the heifer system) shown by the lower line in Figure 1. Across the bottom of Figure 1 the "60 TSS" means 60 cow herd in tie stall barn with solids manure handling system. The next is tie stall with liquid (TSL) system and

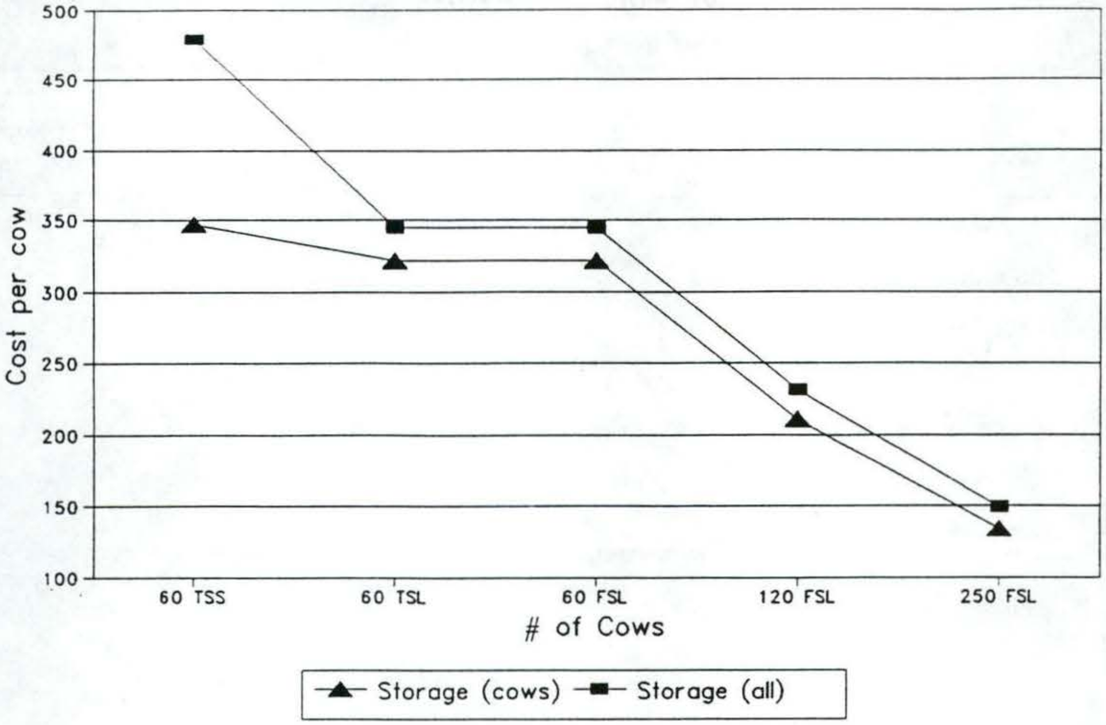

Figure 1. Investment per Cow for Manure Storage Structure by Herd Size, Housing Type and Solids Versus Liquid

the rest are free stalls with liquid systems (FSL).

Daily Haul Versus 8 Month Liquid Storage

Daily haul manure systems can use different amounts of annual inputs when compared to long term liquid storage. These in turn result in different levels of annual costs. Tables 3 through 6 give the assumptions used in this report about the amount of bedding, energy use, labor hours and manure nutrients per year.

Table 3 shows an 8 month liquid storage system will use less bedding per year than will daily hauling. A variety of bedding types is found in Michigan. Oat straw is used as representative because it is found throughout the state. Alternative bedding types were not considered in this study.

Energy use will be greater for long term liquid storage as shown in Table 4. The manure has to be agitated and pumped from the storage area before spreading on the land.

Table 3. TONS OF OAT STRAW BEDDING REQUIRED
Annually, Cows and Heifers

	Daily Haul, Tons	8 Months Storage, Tons
HANDLE MANURE AS SOLIDS		
60 Cows, tie stable	56.7	56.7
HANDLE MANURE AS LIQUID		
60 cows, tie stalls	56.7	32.4
60 cows, free stalls	28.4	16.2
120 cows, free stalls	56.8	32.4
250 cows, free stalls	118.2	67.6

Source: Midwest Plan Service

Table 4. KILOWATT HOURS OF ENERGY FOR MANURE HANDLING
Annually, Cows and Heifers

	Daily Haul, KWH	8 Months Storage KWH
HANDLE MANURE AS SOLIDS		
60 cows, tie stalls	6,212	6,635
HANDLE MANURE AS LIQUID		
60 cows, tie stalls	6,212	6,420
60 cows, free stalls	8,204	8,382
120 cows, free stalls	13,071	16,046
250 cows, free stalls	25,984	32,670

Source: J.D. Garsow

Table 5. HOURS OF LABOR FOR MANURE HANDLING
Annually, Cows and Heifers

	Daily Haul, (Hours)	8 Months Storage, (Hours)
HANDLE MANURE AS SOLIDS		
60 cows, tie stalls	310	291
HANDLE MANURE AS LIQUID		
60 cows, tie stalls	310	238
60 cows, free stalls	444	343
120 cows, free stalls	780	648
250 cows, free stalls	1,567	1,311

Source: J.D. Garsow

Table 5 gives the total hours per year to clean barns, store and spread manure by size and type of barn. The tie stall barn for 60 cows uses a gutter cleaner instead of the tractor scraper in the free stall system. This results in less total hours for the tie stall barn. Labor requirements decrease when one moves from a daily haul system to long term storage. However, for the daily haul system, labor needed is dispersed evenly throughout the year. The long term storage bunches labor needs into the spring and fall. This is when the manure management guidelines recommend that manure be spread and incorporated into the soil. The opportunity cost of labor during spring and fall can be high compared to other times of the year. More details on labor are given in Appendix Table 11.

The long term liquid storage will result in a larger portion of the total nutrients in the manure reaching the soil. Daily spreading results in losses during some of the year. Table 6 compares the two systems on an annual basis. The value per pound of nitrogen, phosphorous, and potassium were set at $.18, $.25, and $.12, respectively. Information on nutrient savings by manure system is given in Appendix Table 9.

Reducing Costs by Retaining Nutrients

Current systems can lose a large portion of manure nutrients, especially nitrogen, before they are incorporated in the soil. Managers who reduce these nutrient losses can achieve an incremental cost savings by having to buy less commercial fertilizer. The base handling system, to which all other systems are compared, is the daily haul system. Hence, in Figure 2, this

Table 6. VALUE OF MANURE NUTRIENTS RETURNED TO THE SOIL
Annually, Cows and Heifers

	Daily Haul	8 Months Storage
HANDLE MANURE AS SOLIDS		
60 cows, tie stalls	2,482	3,049
HANDLE MANURE AS LIQUID		
60 cows, tie stalls	2,482	3,374
60 cows, free stalls	2,482	3,374
120 cows, free stalls	4,963	6,748
250 cows, free stalls	10,340	14,058

Source: J.D. Garsow

system has zero incremental nutrient cost savings. The farm with 120 cows retains about $4,963 worth of nutrients the first year manure is spread by the daily haul method. See Table 6. By changing to long term liquid storage, the farm retains $6,748 of nutrients. This is an incremental cost savings of about $1,800 which is plotted in Figure 2.

Nutrient benefits represent minimum estimates, as only the first year of results are figured into the analyses. It is recognized that nutrients are released over several years from a given application of manure. Over half the nutrients are released in the first 12 months. This study did not attempt a discounted analysis over several years.

Annual Costs of Daily Haul Versus Liquid Storage

The individual elements in Tables 2 through 6 were converted to dollar values and combined into the net annual cost listings of Tables 7, 8 and 9. Table 7 shows the net annual cost per farm for daily haul manure systems on the 60 cow herds. The representative tie stall barn was assumed to use only solid manure. That is shown in the left column of numbers in Table 7. Free stall barns use only liquid manure systems. The top five rows of Table 7 are system cost components. The value of nutrients saved for incorporation into the soil is subtracted from total costs. The bottom value is the net annual cost for the manure handling system being analyzed. For 60 cow tie stall barns, considering the manure from cows and heifers, plus the milking center waste water, it is estimated that daily hauling costs $6,149 per year. Table 7 shows that a comparable herd in free stalls using a liquid system might have a net annual manure cost of $5,183.

The assumed prices were $40 per ton for straw bedding, $.08 per KWH for energy and $6.50 per hour for labor. Fuel, repairs, and other tractor expenses were estimated at $.20 per

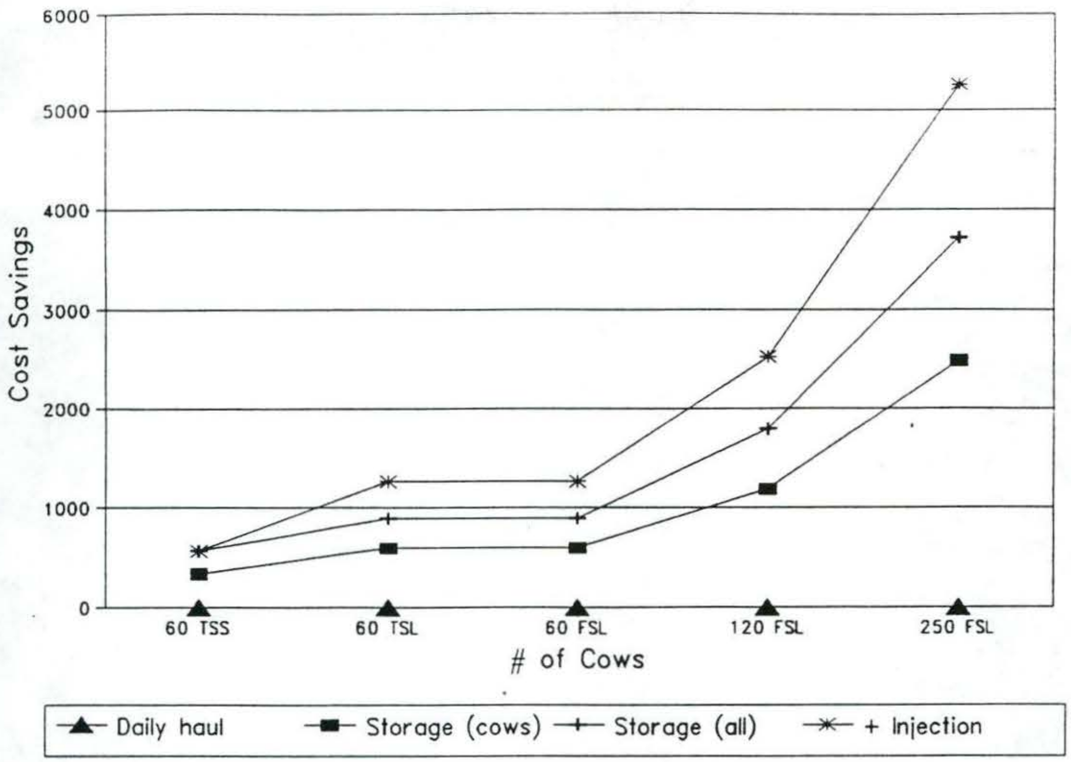

Figure 2. Incremental Cost Savings From Improved Nutrient Retention, Changing From a Daily Haul Manure System to Various Other Systems by Herd Size and Handling Practice

horsepower per hour used in the manure system. The fixed costs of depreciation, interest, repairs and insurance on the storage structure and equipment were estimated using the capital recovery charge procedure in Hunt. These annual fixed costs were calculated from the purchase price; insurance and shelter costs were 0.5 and two percent, respectively. The assumed useful life for equipment was 10 years, and for the storage structure was 20 years. In Tables 7, 8 and 9 the interest rate was 11.1 percent.[4]

Table 8 gives the net annual costs the representative 60 cow farms face if they are forced to have eight months of manure storage. The tie stall barn with a solids handling system would incur annual costs of $13,269 compared to $9,750 with a liquid system. For liquid systems, the free stall farm would have net costs about equal to a tie stall farm, but individual cost components are quite different. Bedding and fixed costs are less, but energy, fuel and labor cost are more on the free stall system. Comparing the bottom lines of Tables 7 and 8 shows how much more the eight month storage systems cost compared to daily haul, despite the extra value of nutrients saved in storage.

[4] In the thesis, Garsow presented results of similar calculations with 9.9 and 13.4 percent rates. These rates and debt to asset ratios were suggested by Henquinet, an executive with Farm Credit Services, as being representative of conditions that existed in 1990.

Table 7. NET ANNUAL COST FOR DAILY MANURE HAUL; 60 COW FARMS
Cows and Heifers

Cost Items	Tie Stall	Liquid Free Stall
Bedding	$ 2,267	$ 1,136
Energy	497	656
Fuel, repairs, tractor expense	1,330	1,169
Labor	2,015	2,886
Depreciation, interest, repairs, insurance*	2,522	1,818
Total Cost:	$ 8,631	$ 7,665
Less value of nutrients saved	(2,482)	(2,482)
Net Annual Cost:	$ 6,149	$ 5,183

* 11.1 percent interest used to calculate the capital recovery charge.
Source: J.D. Garsow

Table 9 shows the net annual cost of liquid systems on the two larger representative farms. The daily haul columns show lower annual costs than do the eight month storage ones. The major differences are in the fixed costs of depreciation, interest, repairs and insurance which flow from the larger investments needed for the storage structures and added equipment.

Whole Farm Impacts of Manure Regulations

A change in the way manure is handled would cause several changes to ripple across the whole farm operation. To assess the impact of moving to long term manure storage and liquid handling to comply with possible future regulations, a whole farm budgeting analysis was done on 45 situations using the "Financial Long Range Budgeting" (FINLRB) software (Hawkins et al). A variety of starting point situations in terms of debt to asset ratios, interest rates, and soil types were used. Results were measured in terms of farm profit, cash flow and breakeven milk

Table 8. NET ANNUAL COST FOR 8 MONTH MANURE STORAGE;
60 Cow Farms, Cows and Heifers

Cost Items	Solids Tie Stall	Liquid Tie Stall	Liquid Free Stall
Bedding	$2,267	$1,297	$ 648
Energy	531	514	671
Fuel, repairs, other, tractor, expense	1,453	922	1,999
Labor	1,892	1,547	2,230
Depreciation, interest, repairs, insurance*	10,175	8,844	7,586
Total Cost:	$ 16,318	$ 13,124	$ 13,134
Less value of nutrients saved	(3,049)	(3,374)	(3,374)
Net Annual Cost:	$ 13,269	$ 9,750	$ 9,760

* 11.1 percent interest used to calculate the capital recovery charge.
Source: J. D. Garsow

prices.[5] Farm profit (or loss) was before taxes and included revenue from milk plus cull livestock, minus cash operating expenses, minus depreciation. Cash flow was the net cash surplus (or deficit) left after debt service, family living expense, and any federal income tax paid by the dairy farm.

The FINLRB software allows one computer run to analyze a base situation and two alternatives. The base situations in this report were the representative farms before the onset of any manure handling regulations. The currently predominant daily haul system was set as the base situation. Alternatives one and two were the eight month storage system alone and the 8 month storage system plus injectors for soil application of the manure, respectively.

The whole farm budgeting assumptions are in Appendix Tables 1, 2 and 3. A milk price of $10.10 per hundredweight (cwt.) was used. The debt to asset ratios of low, medium and high were 0.0, .20 and .75, and the associated interest rates were 9.9, 11.1 and 13.4 percent,

[5] The first two measures were taken off the standard FINLRB output where they are called (E) Profit or Loss, and (S) Cash Surplus or Deficit, respectively. See (Hawkins et al) for the computation formulas. The break even milk price is that milk price at which accounted costs and revenues are exactly equal.

Table 9. NET ANNUAL COST OF LIQUID MANURE SYSTEMS BY HERD SIZE
Daily or Stored, Cows and Heifers

	120 Cows		250 Cows	
Cost Items	Daily Haul	8 Month Storage	Daily Haul	8 Months Storage
Bedding	$ 2,270	$ 1,297	$ 4,730	$ 2,702
Energy	1,046	1,284	2,079	2,614
Fuel, repairs, tractor expense	2,827	3,792	5,579	7,692
Labor	5,070	4,212	10,186	8,522
Depreciation, interest, repairs, insurance*	1,657	10,472	1,656	12,344
Total Cost:	$ 12,870	$ 21,057	$24,230	$ 33,874
Less Value of nutrients saved	(4,963)	(6,748)	(10,340)	(14,058)
Net Annual Cost:	$ 7,907	$ 14,309	$ 13,890	$ 19,816

* 11.1 percent interest used to calculate the capital recovery charge
Source: J.D. Garsow

respectively (Henquinet). To move from the base situation with daily hauling, it was assumed all representative farms borrowed the necessary investments with no down payments. Farms started out with no debt, then, had to take on debt to comply with the possible manure handling regulations. A 120 cow herd with no initial debt and a daily haul system went from 0.0 up to .055 debt to asset ratio after borrowing for an 8 month storage system. A 120 cow herd starting with .20 would increase to .244 debt to asset ratio. Equipment is financed with an intermediate term loan, and the storage facilities with a long term loan.

It was assumed the representative farms grew their feed on owned land, including corn for grain. No land was available for cash cropping. The roughage portion of the ration was half corn silage and half alfalfa on a dry matter basis.

Impacts on Farm Profitability

Two appendix tables deal with farm profitability impacts. Appendix Table 4 gives the annual profit by debt to asset ratio, by farm size, and by manure handling alternative. Appendix Table 5 gives the break even milk prices for the Appendix Table 4 alternatives. The break even milk prices for the base situation on the representative farms (cows only) are plotted in Figure 3. Across the bottom of Figure 3 the "60TSS" means 60 cow herd in tie stall barn with a solids

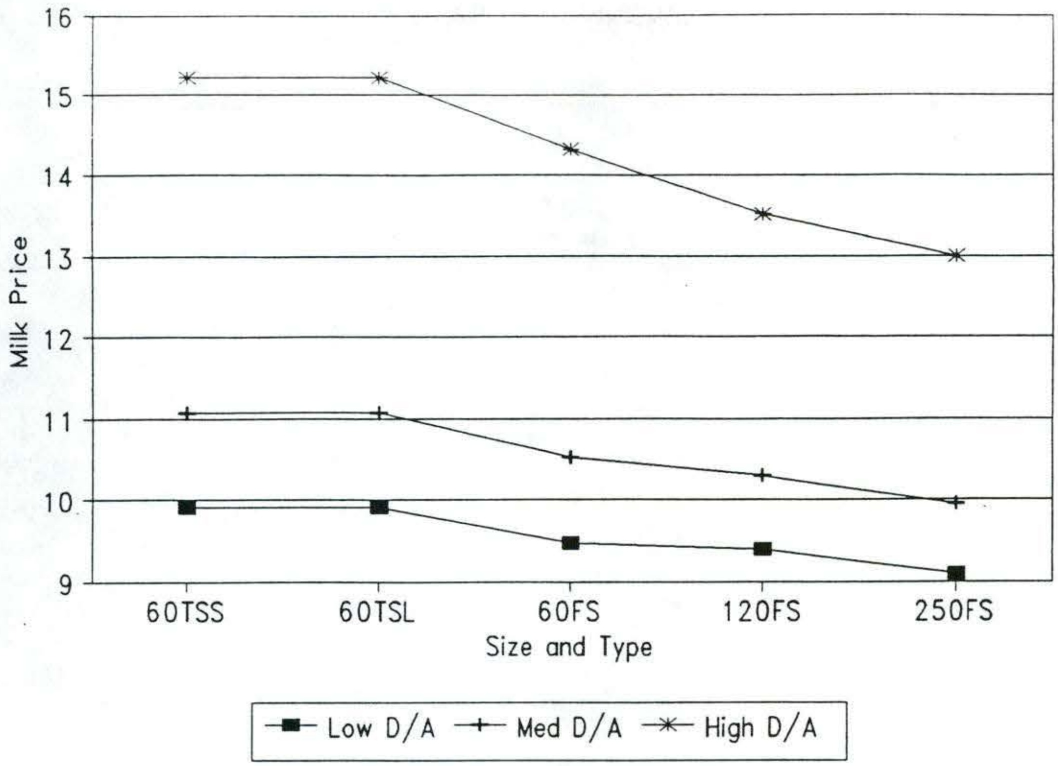

Figure 3. Profit Break-even Milk Price on Base Representative Farms using Daily Haul by Herd Size, Type of Housing Arrangement and Debt to Asset (D/A) Ratio

manure handling system. The next is tie stall with liquid (TSL) system and the rest are free stalls with liquid systems (FS).

For 60 cows in tie stall barns with solids handling systems, the breakeven milk price for daily hauling is just under $10 per cwt. if there is no debt. With a medium debt to asset ratio, the breakeven is about $11, or over a dollar more. For a high debt to asset ratio, the plotted breakeven price in Figure 3 is over $15 per cwt. This illustrates that the impact of new manure regulations on farm profitability will depend on the initial debt situation of the current dairy farms.

Figure 3 indicates economies of scale exist among the representative farms. The 60 cow free stall system could survive a lower milk milk than could a tie stall system. The bigger herds have progressively lower breakeven prices, which reflect lower unit costs.

The assumed base price of milk was $10.10 per cwt., which was the federal support price in 1991 when this study was done. This was pessimistically low, as farm blend prices received were higher than this. It was felt however, that future real prices for milk would more likely be below rather than above $11 per cwt. Many dairy farmers with medium debt to asset ratios would not like to compete at the $11 price shown in Figure 3. Those relatively low break even levels indicated the representative farm assumptions were optimistic in terms of management skills, cost control, and efficiency attained.

Table 10. PROFIT (OR LOSS) BREAK EVEN MILK PRICE
By Size and Manure System, Cows Only

	Solids, Daily Haul	Liquids, 8 Months Storage & Injection	Added Price Needed
Low Debt to Asset Ratio (0.0):		$'s per Cwt.	
Tie stalls:			
60 Cows	9.91	10.11	0.20
Free stalls:			
60 Cows	9.46	9.76	0.30
120 Cows	9.40	9.59	0.19
250 Cows	9.09	9.16	0.07
Medium Debt to Asset Ratio (.20)			
Tie stalls:			
60 Cows	11.08	11.35	0.27
Free stalls:			
60 Cows	10.53	10.91	0.38
120 Cows	10.30	10.55	0.25
250 Cows	9.96	10.04	0.08
High Debt to Asset Ratio (.75)			
Tie stalls:			
60 Cows	15.21	15.75	0.54
Free stalls:			
60 Cows	14.32	14.97	0.65
120 Cows	13.52	13.94	0.42
250 Cows	13.00	13.19	0.19

Source: J. D. Garsow

Table 10 compares the profit (or loss) break even milk price of the daily haul base system to the liquid system with injection. The daily haul column assumes the base situation handles manure as solids. The middle column assumes the representative farms invest in eight month liquid storage plus soil injectors only for cows. The right most column shows the added milk price that would be needed if profit (or loss) stays the same after the investment. The added price needed would probably stay about the same if the level of milk price moved up or down. Table 10 also illustrates the impact of size and initial debt status on the break even prices. The higher debt level situations need greater added prices because it is assumed they are paying higher interest rates on their loans.

Forcing dairy farmers to inject all manure into the soil is used in some town ordinances to reduce unpleasant odors. Alternative 2 in the FINLRB runs given in Appendix Table 5 shows the profit impact of using injectors in addition to the eight month liquid storage systems. Mandatory injection increases the break even milk price on 60 cow free stall systems by about six cents. On 250 cow systems this drops to one cent. Injection for a 60, 120, and 250 cow herd takes about 33, 65, and 101 hours more, respectively, when compared to a spread and cover option using a spreader tanker and incorporating with a disk within 24 hours. Despite some nutrient savings with injection, added costs of labor, capital recovery charge, and energy caused a negative return to injector investments.

Impacts on Farm Cash Flow

The cash flows by debt levels and system types are given in Appendix Table 6 with the associated break even prices in Appendix Table 7. Cash surplus or deficit, after subtracting family living expenses, principal payments and tax outflows, usually shows a different reaction to capital investment changes than does the profit or loss measure. Low debt levels allow farmers to balance their cash inflows and outflows at a lower milk price than is needed to break even on a profit basis. But with high debts, the cash flow breakeven price is even higher than with the profit measure. This can be seen comparing Appendix Tables 5 and 7.

All but the largest farms in Appendix Table 6 were thrown into a negative cash flow position by long term manure storage requirements if their initial debt position was in the medium range. With no debt before having to borrow and invest in eight month liquid handling systems, all farms would probably maintain a positive cash flow position.

Sensitivity Analysis

Table 11 ranks selected variables from the whole farm analysis from most to least sensitive in the daily haul column.

If the price of milk had increased by ten percent, the farm profit would have gone up by $22,107, holding all other variables constant. A ten percent improvement in an expense related variable such as fertilizer cost should be viewed as a decrease in the expenditures for that item.

Table 11 shows the importance of variables under a particular manure handling alternative and the change in importance of some variables if storage and injection regulations are enacted. For instance, repairs, depreciation, interest paid, utilities, etc., become larger, while fertilizer, bedding, and manure system labor costs become smaller as investment in storage and injectors increases.

Alternative Storage and Application Systems

If long term storage is required, many dairy farmers who currently employ a daily haul system would be unable to construct a standard earthen basin system, due to various environmental constraints. They might have a porous soil type that would not support a pit, or

Table 11. PROFIT CHANGE BY IMPROVING THE VARIABLE 10 PERCENT
120 Cows, Medium Debt to Asset Ratio

Variable Improved	Daily Haul	Storage	Store with Injection
	Dollars per year		
Price per cwt. of milk sold	22,107	22,107	22,107
Hired labor	4,883	4,798	4,840
Depreciation	3,739	4,180	4,205
Hourly wage paid to workers	2,183	2,098	2,140
Interest paid, all loans	1,977	2,553	2,581
Initial percent in debt	1,978	1,978	1,978
Building, machine repairs	1,505	1,722	1,737
Intermediate interest rate	992	1,380	1,409
Fertilizer cost	938	759	685
Long term rate	900	1,092	1093
Utilities	816	840	866
Farm taxes	800	830	830
Manure system labor cost	507	421	463
Manure nutrient savings	496	615	675
Bedding cost	227	130	130
Short term interest rate	105	105	105

Source: J.D. Garsow

be on rolling terrain where a pit would not be adequate, They would then have to invest in more expensive storage facilities. It is expected farmers would study an investment list like Table 1 and successively choose the minimum investment necessary according to their particular situation.

Figure 4 shows the reduced profits on representative 120 cow free stall herds for three storage systems where needed investments are greater than an earthen pit. The left set of bars represent an earthen pit with a three foot clay liner given starting debt to asset retios that were low, medium or high. The middle set of bars is for a pit with a concrete liner. The right set of bars represent a concrete tank partially buried in the ground. Profit decreases shown are additional losses beyond those expected from constructing an earthen basin system.

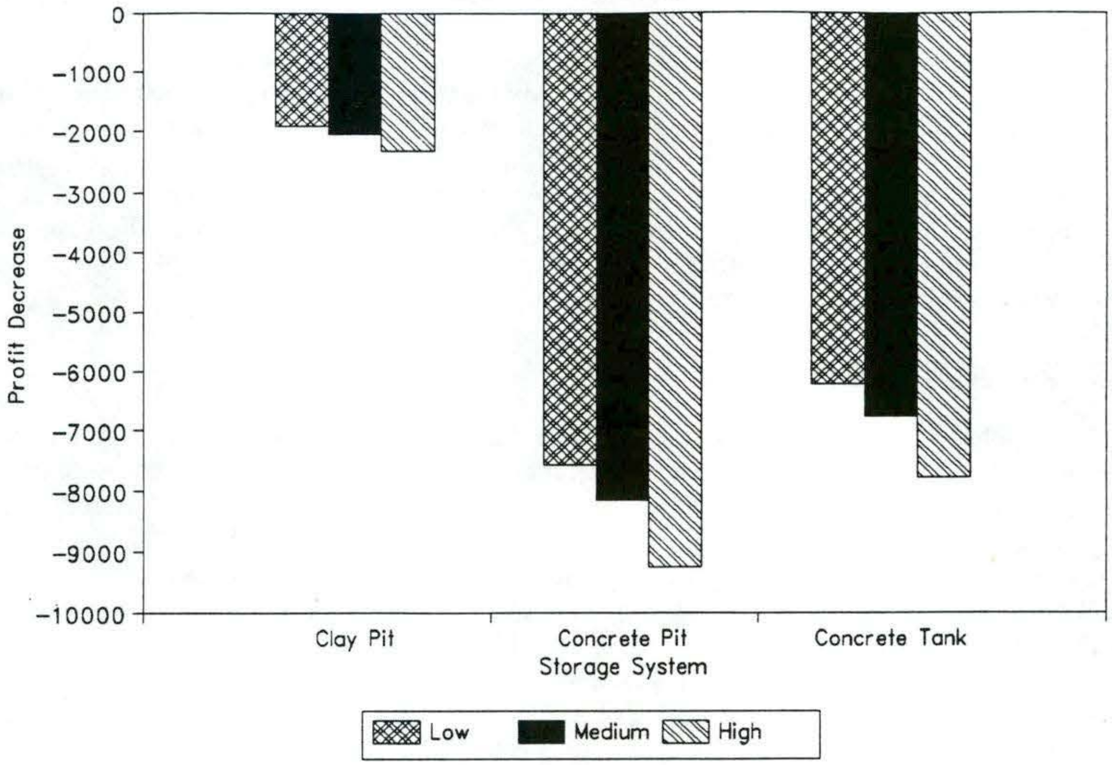

Figure 4. Incremental Profit Decreases Going From Earthen To Alternative Storage Systems on 120 Cow Herds by Low, Medium and High Debt to Asset Ratio

Appendix Table 8 gives the budgeted profit, cash flow, and break even milk prices for the three systems in Figure 4 for 60 and 120 cow herds. Profitability decreases rapidly for a 60 cow herd as the needed investment in the storage system increases or as the initial debt load of the farm is raised. The break even milk price for the base farms with low debt varied from $10.02 per cwt with a standard earthen pit to $10.55 per cwt with an above ground concrete tank. The break even price on base farms with 70 percent debt ranged from a low of $15 to a high of $15.75. The 120 cow farms with a low debt to asset ratio kept a positive profit margin when larger investments were assumed. The 120 cow herds with medium and high debt ratios had larger losses than the 60 cow herds when the storage investments increased.

Irrigation systems are sometimes used on larger farms to reduce costs by using the efficiency of these types of systems for moving manure longer distances. In this study, a pump with spreader tanker system was assumed for all liquid manure systems. Total annual costs for an irrigation system for the 120 and 250 cow farms were calculated to be $8,372 and $12,814 compared with $10,119 and $15,263 respectively, for a tanker system. Farmers should also consider alternative manure transport and application systems that have been researched by Crane and Person (1991).

Statewide Impact on Michigan Dairy Farms

The aggregate impacts on the Michigan dairy industry of different regulatory actions has been an area of concern for many parties. The Michigan dairy industry has been shown in the Animal Industry Initiative of Michigan State University to be a valuable contributor to the Michigan economy. Any regulations that compel farmers to adopt alternative, more costly production practices may put them at a competitive disadvantage with farmers who do not have the same restrictions to follow, and ultimately may force some out of business. For example, Michigan environmental policies may raise production costs in this state, yet if Ohio does not have similar laws, Ohio farmers could produce milk at a lower cost.

Approach to Aggregation of Financial Impacts

Aggregation of the whole farm budget results to the State's dairy industry was completed by weighing the financial impact of the pollution abatement policies on each representative farm by the number of farms in the Michigan State University Dairy Farm Survey (Connor, et al). Surveyed farms were grouped by debt to asset ratio with zero debt, medium (20 percent) debt, and high (75 percent) debt to match the representative farm models. Finally, one-half of the tie-stall operations were assumed to install long term storage facilities handling manure as solids. With these limitations, the resulting distribution table from the Michigan State University Dairy Farm Survey (see Appendix Table 14) was combined with the impact tables in the whole farm budget analysis and multiplied by a factor of ten (the survey represents approximately ten percent of the Michigan herds). This resulted in estimates of particular group impacts plus total impacts on the Michigan dairy industry of requiring long term storage for all animals and for injection of manure.

This study represents a sizable majority (340 out of 489) of the surveyed Michigan dairy farms. Of the 149 herds from the Michigan Dairy Survey not covered by this study, 78 have less than 30 cows, 37 have a combination of housing arrangements, 11 have dry lots, 10 have bedded pack barns, and 13 have "other" types of housing. The aggregation results that follow are also subject to the following qualifications:

1. Results are based on all farms complying to uniform standards (no adjustment for farm size)

2. Herd sizes below 30 cows are not included. The 60 cow tie stall system is assumed to represent all tie stall systems with 30-89 cows. The 120 cow free stall system represents 90-149 cow farms, and the 250 cow free stall system represents all operations with more than 149 cows.

3. Locational specifics that may allow daily haul to continue in some areas are omitted.

4. Whole farm budget assumptions get magnified. For example, all farms changing to a liquid system are expected to use a basic earthen basin system.

5. Bedded pack barns can be regarded as a system for long-term storage.

6. Farms are not expected to change their milk production technology or herd size because of particular regulations.

Policy analysts should exercise considerable restraint when using the results presented in this section for several reasons. Aggregation from microeconomic budget models is not an exact science. Since this study is a static analysis, its assumption may get out of date in the future. As Bonnen (1989) argues,

> "One cannot accept one-shot static or comparative static analysis as if it were adequate for policy analysis. When working to support policy makers, you are likely to have to redo analysis with different assumptions and variables several times before a policy decision is final."

Impact on Investment, Nutrients, Labor and Annual Costs

Four variables were deemed worthy of summing up to totals for all dairy farms in Michigan; capital requirements, nutrient savings, labor hours, and annual costs. Approximately two-thirds of the total industry capital requirements were found to be needed by 30-89 cow operations. Total industry capital requirements for two regulatory alternatives were found to be

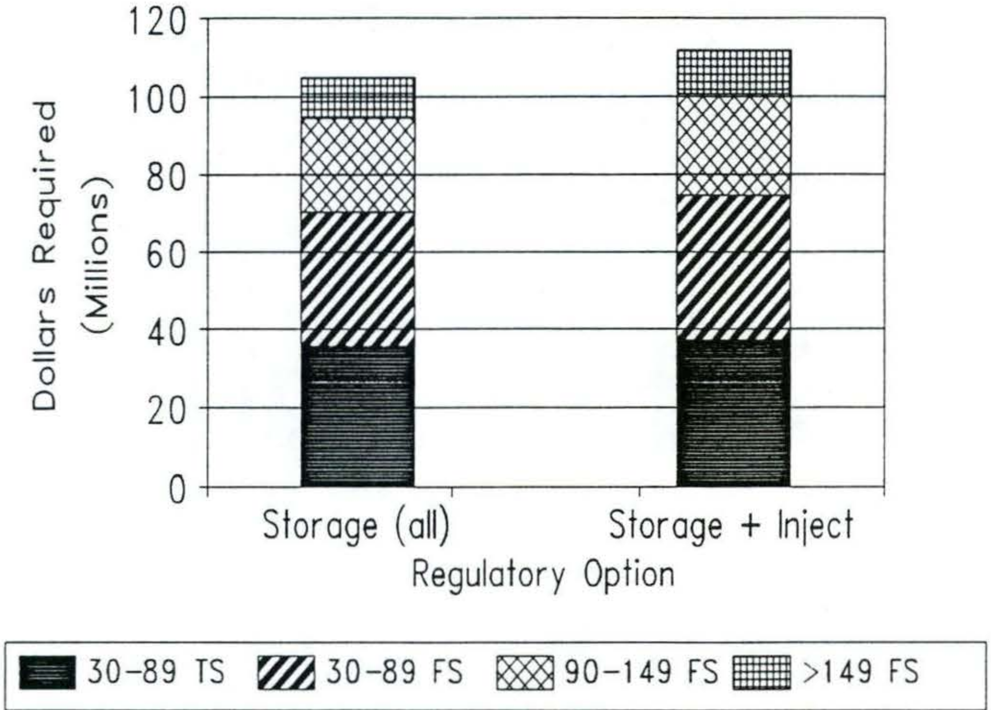

Figure 5. Estimated Michigan Dairy Industry Investment Needed to Comply with Eight Month Storage and Injection Requirements

$105 million and $111.7 million. The proportions by farm size are shown in Figure 5. The alternatives were long term storage for both cows and heifers, or the same plus the use of injectors. In figure 5, the TS is for tie stalls, and the FS is for free stalls.

Yearly nutrient savings were expected to increase if mandatory storage and injection were implemented for the state. They could be worth at least $3,424,655; only first year benefits from nutrients were calculated. Appendix Table 10 summarizes the results of first-year nutrient savings. Labor requirements showed an overall decrease in the Michigan dairy industry. Appendix Table 12 indicates the aggregate difference in yearly labor hours going from daily haul to the proposed changes in manure storage and handling system. They could be as much as 143,715 hours less for the total state. The industry labor savings in dollar terms is difficult to assess because of problems with valuing unpaid farm family contributions. The change in fixed and variable costs due to changes in regulations that may be imposed on the dairy industry was calculated, net of nutrient and hired labor savings. Figure 6 depicts these results. Under the assumptions employed in this study, the total annual costs on Michigan dairy farms with storage (all) and storage plus injection would increase $16.5 million and $18.1 million per year, respectively. Nearly 70 percent of these costs would be borne by farms with herds of less than 90 cows.

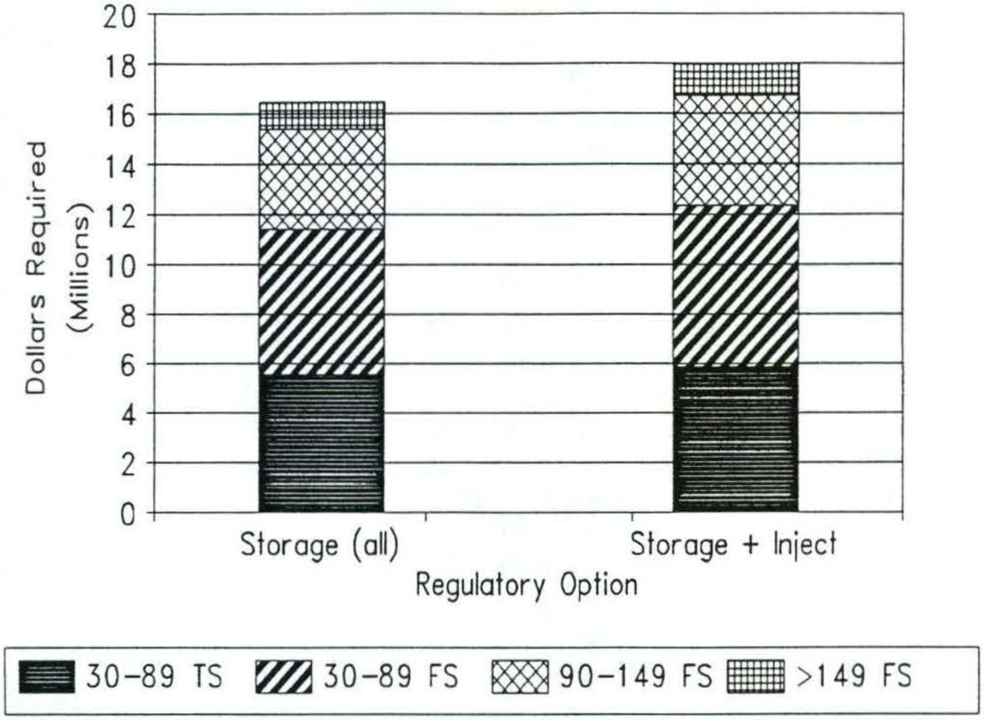

Figure 6. Estimated Increase in Michigan Dairy Industry Annual Costs to Comply with Eight Months Storage and Injection Requirements by Herd Size

How sound are these results, and what are their implications for the Michigan dairy industry? Although many assumptions are employed in this aggregation procedure, the use of generally accepted microeconomic analytical methods and primary survey data validates these results as informed "guesses." Also, many important variables were set at minimal levels. For example, the cost of earthen basin systems was determined on the assumption that a basic "hole in the ground" could be dug on each farm. Crop yield assumptions for the base models were a consensus arrived at by an interdisciplinary committee of extension specialists and researchers assuming they represented what better managers attained. Because they are well above state average yield levels, it could be argued the yields in this study were too high. Therefore, the actual industry costs in terms of capital, labor, etc., may be higher than shown here.

Certain conditions could reduce the actual impacts of compliance. It is possible that many farms are not polluting the environment and would not be required to invest in new facilities or to change their management practices. A long compliance period (period between enactment of regulations and the date on which all farmers must be in compliance) and subsidies could also lessen the financial impact.

Summary

Agriculture is no longer exempt from environmental issues. Agricultural trends toward fewer dairy farms and larger herds have increased the concentration of animal manure on Michigan farmland. Farmers may be told to stop polluting, or else pay for cleaning up the air, soil and water around them. To date, these costs have been external to farmers; they have not had to pay. This report explores the financial obstacles and opportunities facing Michigan dairy managers as they seek to comply with increasingly strict manure management guidelines. In order to assess the impact of compliance with particular regulations, 45 representative dairy farm situations were developed. Costs of various dairy manure systems were developed. Initial investment, labor, and total annual costs were compared for different sized herds and manure handling systems. For instance, total annual costs on representative 120 cow farms with free stall housing and liquid storage were found to be $5,183 for daily haul, $16,297 for long-term storage (cows only), and $14,309 for long-term storage (cows and heifers) assuming an 11 percent interest rate.

Whole farm budget analysis indicated the impacts on the representative farms, and on the Michigan dairy industry, of complying with long-term storage plus injection regulations. Investments in manure storage facilities were found to yield a negative return of 2.9 to 6.6 percent. Investment in injection equipment generated negative returns of 12 to 13 percent, depending upon herd size. Results indicate that per farm profitability of 60, 120, and 250 cow herds, currently using daily haul and having a medium debt to asset ratio, would decline by $7,100, $9,900, and $9,200 per year, respectively. Under the strict assumptions of this study, aggregate capital investment needed to comply with possible manure management regulations for the Michigan dairy industry would be approximately $118 million. Total annual costs of dairy production in Michigan would increase about $18 million per year.

Benefits to society at large were not specifically analyzed in this study, but they could be substantial if livestock operations made the assumed investments. Clean water would be assured, which would benefit consumers and industry throughout Michigan. Water would continue to attract recreational users. Insects and odor would be minimized, which would decrease tension on the rural-urban interfaces. Benefits would likely be broad enough to justify subsidizing farmers for investing in improved manure handling systems.

LIST OF REFERENCES

Abeles-Allison, M. and L.J. Connor. 1990. An analysis of local benefits and costs of Michigan hog operations experiencing environmental conflicts. Agricultural Economics Report 536. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Bonnen, J.T. 1989. Relevancy of the social sciences in the policy arena: Implications for agricultural economics. South. Jrl. Ag. Econ., July, pp. 45.

Connor, L.J. et al. 1989. Summary of the 1987 Michigan State University dairy farm survey. Research Report 498, Agricultural Experiment Station, Michigan State University, East Lansing, Michigan.

Crane, S. and H.L. Person. 1991. Energy conservation through innovative manure transport/application technology. Research Update. Michigan Energy Conservation Program, Michigan State University, East Lansing, Michigan.

Garsow, J.D. 1991. A managerial perspective of the likely economic benefits and costs of environmental regulations to the Michigan dairy industry. M.S. Thesis, Michigan State University, East Lansing, Michigan.

Garsow, T.J. 1990a. Nutrient balance template. Wisconsin Soil Conservation Spreadsheet Program, Oconto, Wisconsin.

Garsow, T.J. 1990b. Storage system estimates and verification of Halifax Dairy Waste Management data inputs. Personal communication.

Hawkins, R.O. et al. 1987. FINPACK, A computerized farm financial planning and analysis package. Version 7.0, Center for Farm Financial Management, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul MN.

Hengnirun, S. 1987. Network model for the selection of dairy waste management systems. M.S. Thesis, Technical University of Nova Scotia, Halifax, Nova Scotia.

Henquinet, W. 1990. Current interest rates. Lansing Farm Credit Services. Personal communication.

Hunt, D. 1983. Farm Power and Machinery Management. 8th Ed. Ames: Iowa State University Press.

Michigan Manure Management Task Force. Utilizing Michigan's animal manure resources. Report in progress in Dept of Agricultural Engineering, Michigan State University, East Lansing, Michigan.

Midwest Plan Service. 1985. Livestock waste facilities handbook, 2nd Ed. MWPS-18, Iowa State University, Ames, Iowa.

Nott, S.B. 1989. Business analysis summary for specialized Michigan dairy farms, 1988 Telfarm Data. Agricultural Economics Report No. 528, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Nott, S.B. et al. 1990. Michigan 1990 estimates for crop and livestock budgets. Agricultural Economics Report No. 539, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Nott, S.B., J.D. Garsow, and D. Darling. 1990. Projected profitability of Michigan dairy farms in the 1990's. Agricultural Economics Report No. 530, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Warncke, D.D., D.R. Christenson, and M.L. Vitosh. 1985. Fertilizer recommendations: Vegetable and field crops in Michigan. Extension Bulletin E-550, Michigan State University, East Lansing, Michigan.

Appendix Tables

Appendix Table 1. Selected General Whole Farm Budget Assumptions

VARIABLE	UNIT	AMOUNT ASSUMED
Income related variables		
Cows	head	$1,100.00
Bred heifers	head	$1000.00
Heifers 6 - 15 months	head	$500.00
Calves under 6 months	head	$200.00
Cull cow sold	head	$574.00
Herd cull rate	%	30.00
Bull calf at birth	head	$110.00
Calf death loss	%	5.00
Milk per cow	Lbs.	19,200.00
Percent of milk sold	%	95.00
Price of milk sold	Cwt.	$10.10
Land and feed related variables		
Land price	Acre	$697.00
Land tax rate, % of value	%	2.30
Crop yields (loam soil), as fed		
Hay and haylage	Ton per acre	5.00
Corn silage	Ton per acre	20.00
High moisture corn	Bu. per acre	130.00
Annual expense variables		
Hired labor cost *	hour	$6.50
Cost of herdperson	year	$27,000.00
Debt/asset ratios		0/.20/.75
Short and intermediate debt	Annual %	9.9/11.1/13.4
Long-term debt	Annual %	9.2/10.7/12.7
Purchased supplements	Per Cow / Year	$337.74
Soybean meal	Ton	$350.00
Corn grain	Bu.	$2.50
Alfalfa hay	Ton	$65.00
Corn silage	Ton	$18.00

* Owner and family labor = $12,000 + 5% of gross sales

Source: Nott, Garsow, and Darling. 1990, except for the interest rates on debt, crop yields, and debt/asset ratios.

Appendix Table 2. Dollars of Investment in Fixed Technology on Representative Dairy Farms by Farm Size, Housing Type, and Manure Handling System

Description	Daily Haul	L-term Storage (cow)	L-term Storage (all)
60 Cows (tie stall barn)	195,889	195,889	195,889
Field equipment	79,595	79,595	79,595
Milking and feeding	113,350	113,350	113,350
Manure collection	7,936	7,936	7,936
Man. transfer & storage	0	19,300	20,700
Man. agitate & applicate	5,000	22,700	17,700
Totals:	**401,770**	**438,770**	**435,170**
60 Cows (free stall barn)	155,075	155,075	155,075
Field equipment	79,595	79,595	79,595
Milking and feeding	99,550	99,550	99,550
Manure collection	980	980	500
Man. transfer & storage	0	19,300	20,700
Man. agitate & applicate	5,000	22,700	17,700
Totals:	**340,200**	**377,200**	**373,120**
120 Cows (free stall barn)	267,124	267,124	267,124
Field equipment	118,020	118,020	118,020
Milking and feeding	113,868	113,868	113,868
Manure collection	980	980	500
Man. transfer & storage	0	25,300	27,700
Man. agitate & applicate	7,500	30,500	25,500
Totals:	**507,492**	**555,792**	**552,712**
250 Cows (free stall barn)	531,800	531,800	531,800
Field equipment	257,700	257,700	257,700
Milking and feeding	147,300	147,300	147,300
Manure collection	14,980	14,980	14,500
Man. transfer & storage	0	33,500	37,300
Man. agitate & applicate	7,500	30,500	25,500
Totals:	**959,280**	**1,015,780**	**1,014,100**

Appendix Table 3. Base Farm Budgeting Assumptions by Herd Size and Housing Type (Daily Haul Manure System, 20:100 Debt/Asset Ratio)

HERD SIZE VARIABLE	60 COWS Tie stall	60 COWS Free stall	120 COWS Free stall	250 COWS Free stall
Crop acres				
Corn grain	29.0	29.0	58.0	121.4
Corn silage	27.1	27.1	58.5	121.3
Alfalfa haylage	34.6	34.6	74.6	154.9
Alfalfa hay	8.0	8.0	17.9	37.5
New seeding	8.8	8.8	19.1	39.7
Balance sheet, dollars				
Current assets	23,163	23,163	47,370	97,560
Interm. assets	308,982	288,225	446,848	859,680
L-term assets	260,811	231,397	428,201	867,266
Current liabilities	4,633	4,633	9,474	19,512
Interm. liabilities	61,796	57,645	89,374	171,936
L-term liabilities	52,162	46,279	85,640	173,453
Operating costs per year*				
Labor hr/cow	67	67	53	46
Labor hr-manager	2,560	2,560	2,400	2,144
Bedding costs, $	2,267	1,136	2,270	4,730
Hired labor, $	16,665	17,537	48,833	97,543
Seed, $	1,566	1,566	3,281	6,830
Fertilizer, $	4,339	4,339	9,379	19,856
Crop chemicals, $	1,752	1,752	3,695	7,688
Farm insurance, $	1,536	1,536	2,535	4,926
Farm taxes, $	4,726	4,252	8,005	16,278
Utilities, $	4,006	4,165	8,164	16,966
Fuel and oil, $	1,806	1,806	3,762	7,830
Repairs, $	8,226	7,414	15,045	32,244
Miscellaneous, $	897	897	1,656	3,640
Other costs, dollars per year				
Depreciation	29,813	26,266	37,393	69,338
Family living expense	18,693	18,693	25,385	39,886

* Labor hours for the milk production and cropping enterprise were estimated using equations formulated by Nott (1989). Insurance for cows and crops, real estate taxes, and miscellaneous costs were sourced from Nott (1988). Seed, fertilizer, and crop chemical requirements were obtained from Nott et al (1990).

Appendix Table 4. Farm Profit or (Loss) by Herd Size, Debt/Asset Ratio, Housing Type, and Initial Manure System (Standard Earthen Storage, Loam Soil, $10.10 Per Cwt.)

	Debt/asset	Low (0:100)			Medium (20:100)			High (75:100)		
Size	Initial System	Base	Storage	Inject	Base	Storage	Inject	Base	Storage	Inject
60 TSS	Solid-daily	2,059	(4,247)	(4,247)	(10,675)	(17,450)	(17,450)	(55,973)	(63,646)	(63,646)
	Solid-cow*	(72)	(1,645)	(1,645)	(13,395)	(15,097)	(15,097)	(60,797)	(62,748)	(62,748)
	Solid-all*	(1,645)	(1,645)	(1,645)	(15,097)	(15,097)	(15,097)	(62,748)	(62,748)	(62,748)
60 TSL	Solid-daily	2,059	(3,085)	(3,636)	(10,675)	(16,281)	(16,862)	(55,973)	(62,465)	(63,103)
	Liquid-cow*	(389)	442	(108)	(13,907)	(13,104)	(13,685)	(61,982)	(61,235)	(61,874)
	Liquid-all*	1,210	1,210	659	(12,236)	(12,236)	(12,806)	(60,013)	(60,013)	(60,651)
60 FS	Solid-daily	6,992	908	357	(4,677)	(11,223)	(11,804)	(46,174)	(53,606)	(54,244)
	Liquid-cow*	3,548	4,334	3,711	(8,926)	(8,169)	(8,823)	(53,278)	(52,576)	(53,287)
	Liquid-all*	5,157	5,157	4,606	(7,224)	(7,224)	(7,805)	(51,250)	(51,250)	(51,888)
120 FS	Solid-daily	15,313	6,700	6,120	(4,460)	(13,714)	(14,324)	(74,830)	(85,313)	(85,980)
	Liquid-cow*	10,997	11,671	11,092	(9,822)	(9,191)	(9,800)	(83,906)	(83,357)	(84,023)
	Liquid-all*	12,591	12,591	12,012	(8,156)	(8,156)	(8,765)	(74,202)	(81,988)	(74,869)
250 FS	Solid-daily	45,989	38,190	37,619	6,387	(2,253)	(2,854)	(132,185)	(142,193)	(142,851)
	Liquid-cow*	42,365	43,589	43,018	2,074	3,213	2,612	(141,344)	(140,368)	(141,027)
	Liquid-all*	45,699	45,699	45,128	5,452	5,452	4,851	(137,818)	(137,818)	(138,477)

* Cow = System only for cows. All = System for cows plus replacements.

Appendix Table 5. Break Even Milk Prices by Herd Size, Debt/Asset Ratio, Housing Type and Initial Manure System. Break-even Milk Price--Impact of Eight Months Storage and Injection
(Standard Earthen Storage, Loam Soil, Accounting Measure = Profit or Loss.)

	Debt/asset	Low (0:100)			Medium (20:100)			High (75:100)		
Size	Initial System	Base	Storage	Inject	Base	Storage	Inject	Base	Storage	Inject
60 TSS	Solid-daily	$9.91	$10.49	$10.49	$11.08	$11.69	$11.69	$15.21	$15.92	$15.92
	Solid-cow*	10.11	10.25	10.25	11.32	11.48	11.48	15.66	15.83	15.83
	Solid-all*	10.25	10.25	10.25	11.48	11.48	11.48	15.83	15.83	15.83
60 TSL	Solid-daily	9.91	10.38	10.43	11.08	11.59	11.64	15.21	15.81	15.87
	Liquid-cow*	10.14	10.06	10.11	11.37	11.30	11.35	15.76	15.70	15.75
	Liquid-all*	9.99	9.99	10.04	11.22	11.22	11.27	15.58	15.58	15.64
60 FS	Solid-daily	9.46	10.02	10.07	10.53	11.13	11.18	14.32	15.00	15.06
	Liquid-cow*	9.78	9.70	9.76	10.92	10.85	10.91	14.97	14.90	14.97
	Liquid-all*	9.63	9.63	9.68	10.76	10.76	10.81	14.78	14.78	14.84
120 FS	Solid-daily	9.40	9.79	9.82	10.30	10.73	10.75	13.52	14.00	14.03
	Liquid-cow*	9.60	9.57	9.59	10.55	10.52	10.55	13.93	13.91	13.94
	Liquid-all*	9.52	9.52	9.55	10.47	10.47	10.50	13.49	13.85	13.52
250 FS	Solid-daily	9.09	9.26	9.28	9.96	10.15	10.16	13.00	13.22	13.23
	Liquid-cow*	9.17	9.14	9.16	10.05	10.03	10.04	13.20	13.18	13.19
	Liquid-all*	9.10	9.10	9.11	9.98	9.98	9.99	13.12	13.12	13.14

* Cow = System only for cows. All = system for cows plus replacement.

Appendix Table 6. Cash Surplus (Deficit) by Herd Size, Debt/Asset Ratio, Housing Type, and Initial Manure System (Standard Earthen Storage, Loam Soil, $10.10 Per Cwt.).

	Debt/asset	Low (0:100)			Medium (20:100)			High (75:100)		
Size	Initial System	Base	Storage	Inject	Base	Storage	Inject	Base	Storage	Inject
60 TSS	Solid-daily	12,779	8,038	8,038	(8,624)	(13,753)	(13,753)	(75,862)	(81,762)	(81,762)
	Solid-cow*	12,410	11,270	11,270	(9,696)	(10,943)	(10,943)	(79,284)	(80,744)	(80,744)
	Solid-all*	11,270	11,270	11,270	(10,943)	(10,943)	(10,943)	(80,744)	(80,744)	(80,744)
60 TSL	Solid-daily	12,779	9,106	8,647	(8,624)	(12,646)	(13,126)	(75,862)	(80,574)	(81,096)
	Liquid-cow*	13,442	14,373	13,915	(9,070)	(8,164)	(8,644)	(79,841)	(78,985)	(79,507)
	Liquid-all*	14,611	14,611	14,153	(7,772)	(7,772)	(8,241)	(78,107)	(78,107)	(78,628)
60 FS	Solid-daily	14,165	9,552	9,093	(5,886)	(10,847)	(11,327)	(68,680)	(74,332)	(74,853)
	Liquid-cow*	13,931	14,817	14,286	(7,262)	(6,401)	(6,954)	(73,694)	(72,883)	(73,447)
	Liquid-all*	15,062	15,062	14,604	(5,975)	(5,975)	(6,454)	(71,930)	(71,930)	(72,452)
120 FS	Solid-daily	26,201	20,358	19,871	(8,233)	(15,285)	(15,794)	(118,070)	(126,090)	(126,640)
	Liquid-cow*	26,471	27,259	26,798	(9,964)	(9,181)	(9,690)	(124,458)	(123,751)	(124,300)
	Liquid-all*	27,563	27,563	27,103	(8,663)	(8,663)	(9,172)	(115,733)	(122,758)	(116,283)
250 FS	Solid-daily	67,888	64,487	64,121	8,280	3,022	2,576	(200,219)	(206,601)	(207,090)
	Liquid-cow*	69,844	71,010	70,718	4,220	5,661	5,161	(219,711)	(218,417)	(218,959)
	Liquid-all*	71,784	71,784	71,491	7,300	7,300	6,800	(216,337)	(216,337)	(216,879)

*Cow = System only for cows. All = System for cows plus replacements.

Appendix Table 7. Break Even Milk Prices by Herd Size, Debt/Asset Ratios, Housing type and Initial Manure System.
Break-even Milk Price--Impact of Eight Months Storage and Injection
(Standard Earthen Storage, Loam Soil, Accounting Measure = Cash Surplus).

	D/A Ratio		Low (0:100)			Medium (20:100)			High (75:100)	
Size	Initial System	Base	Storage	Inject	Base	Storage	Inject	Base	Storage	Inject
60 TSS	Solid-daily	$8.93	$9.37	$9.37	$10.89	$11.36	$11.36	$17.03	$17.57	$17.57
	Solid-cow*	8.97	9.07	9.07	10.99	11.10	11.10	17.34	17.48	17.48
	Solid-all*	9.07	9.07	9.07	11.10	11.10	11.10	17.48	17.48	17.48
60 TSL	Solid-daily	8.93	9.27	9.31	10.89	11.26	11.30	17.03	17.46	17.51
	Liquid-cow*	8.87	8.79	8.83	10.93	10.85	10.89	17.40	17.32	17.36
	Liquid-all*	8.76	8.76	8.81	10.81	10.81	10.85	17.24	17.24	17.28
60 FS	Solid-daily	8.81	9.23	9.27	10.64	11.09	11.13	16.38	16.89	16.94
	Liquid-cow*	8.83	8.75	8.79	10.76	10.68	10.74	16.83	16.76	16.81
	Liquid-all*	8.72	8.72	8.77	10.65	10.65	10.69	16.67	16.67	16.72
120 FS	Solid-daily	8.90	9.17	9.19	10.48	10.80	10.82	15.49	15.86	15.89
	Liquid-cow*	8.89	8.85	8.88	10.56	10.52	10.54	15.79	15.75	15.78
	Liquid-all*	8.84.	8.84	8.86	10.50	10.50	10.52	15.39	15.71	15.41
250 FS	Solid-daily	8.61	8.69	8.69	9.92	10.03	10.04	14.49	14.63	14.64
	Liquid-cow*	8.57	8.54	8.55	10.01	9.98	9.99	14.92	14.89	14.90
	Liquid-all*	8.53	8.53	8.53	9.94	9.94	9.95	14.84	14.84	14.86

*Cow = System only for cows. All = System for cows plus replacements.

Appendix Table 8. Annual Accounting Measure by Herd Size, Type of Manure Structure and Debt/Asset Ratios, In Dollars.

Storage System	Profit			Cash Flow			Break Even Milk Price		
D/A Ratio	Low	Med	High	Low	Med	High	Low	Med	High
60 Cows									
Standard Earthen Pit	908	(11,223)	(53,606)	9,552	(10,847)	(74,332)	10.02	11.13	15.00
Pit w/3 ft Clay Liner	(321)	(12,544)	(55,104)	8,639	(11,841)	(75,484)	10.13	11.25	15.14
Pit w/Concr. Liner	(3,993)	(17,491)	(60,578)	5,911	(15,808)	(79,928)	10.46	11.70	15.64
Above Ground Concr. Tank	(4,979)	(18,454)	(61,781)	5,178	(16,508)	(79,607)	10.55	11.79	15.75
120 Cows									
Standard Earthen Pit	6,700	(13,714)	(85,313)	20,358	(15,285)	(126,090)	9.79	10.73	14.00
Pit w/3 ft Clay Liner	4,791	(15,766)	(87,639)	18,940	(16,828)	(127,880)	9.88	10.82	14.10
Pit w/Concr. Liner	(886)	(21,869)	(94,558)	14,721	(21,417)	(133,206)	10.14	11.10	14.42
Above Ground Concr. Tank	460	(20,501)	(93,108)	14,911	(21,207)	(132,911)	10.08	11.04	14.35

Appendix Table 9. Increase in Dollar Nutrient Savings on Representative Michigan Dairy Farms--Impact of Required Eight Months Storage and Injection compared to Daily Haul, Standard Earthen Storage, Loam Soil.

		Storage (all)		Storage + Injection	
Size and Type	Initial System	Total	Per Cow	Total	Per Cow
60 cows (solid)	Daily haul	567	9	567	9
	L-term (cow)	231	4	231	4
	L-term (all)	0	0	0	0
60 cows (liquid)	Daily haul	892	15	1,264	21
	L-term (cow)	298	5	670	11
	L-term (all)	0	0	372	6
120 cows (liquid)	Daily haul	1,785	15	2,528	21
	L-term (cow)	595	5	1,338	11
	L-term (all)	0	0	743	6
250 cows (liquid)	Daily haul	3,718	15	5,266	21
	L-term (cow)	1,239	5	2,787	11
	L-term (all)	0	0	1,548	6

Appendix Table 10. Estimated Increase in Nutrient Savings on Michigan Dairy Farms from Complying with Eight Month Storage and Injection Requirements by Herd Size, Total State Of Michigan, First Year, in Dollars.

	System*	
Herd Size	Storage (all)	Storage + Injection
30-89 cows (tie stall)	685,645	886,525
30-89 cows (free stall)	841,560	1,247,040
90-149 cows (free stall)	464,100	835,820
> 149 cows (free stall)	200,790	455,270
Total	2,192,095	3,424,655

*Storage = Earthen pit for liquid manure. All = For cows plus replacements.

Appendix Table 11. Increase (Decrease) in Labor Hours on Representative Michigan Dairy Farms--Impact of Required Eight Months Storage and Injection

Debt/Asset Ratio:		Low (0:100)		Medium (20:100)		High (75:100)	
Size and Type	Initial System*	Storage	Inject	Storage	Inject	Storage	Inject
60 cows	Daily Haul	(19)	(19)	(19)	(19)	(19)	(19)
(solid)	L-term (cow)	(9)	(9)	(9)	(9)	(9)	(9)
Tie-stall	L-term (all)	0	0	0	0	0	0
60 cows	Daily Haul	(72)	(39)	(72)	(39)	(72)	(39)
(liquid)	L-term (cow)	(52)	(19)	(52)	(19)	(52)	(19)
Tie-stall	L-term (all)	0	33	0	33	0	33
60 cows	Daily Haul	(101)	(68)	(101)	(68)	(101)	(68)
(liquid)	L-term (cow)	(94)	(61)	(94)	(61)	(94)	(61)
Free-stall	L-term (all)	0	33	0	33	0	33
120 cows	Daily Haul	(132)	(67)	(132)	(67)	(132)	(67)
(liquid)	L-term (cow)	(77)	(12)	(77)	(12)	(77)	(12)
Free-stall	L-term (all)	0	65	0	65	0	65
250 cows	Daily Haul	(233)	(122)	(233)	(122)	(233)	(122)
(liquid)	L-term (cow)	(120)	(19)	(120)	(19)	(120)	(19)
Free-stall	L-term (all)	0	101	0	101	0	101

*L - term = 8 months liquid manure storage. Cows = cows only. All = cows plus replacements.

Appendix Table 12. Estimated Decrease in Labor Hours for all Michigan Dairy Farms from Complying with Eight Month Storage and Injection Requirements by Herd Size

		System*
Herd Size	Storage (all)	Storage + Injection
30-89 cows (tie stall)	44,305	26,485
30-89 cows (free stall)	104,930	68,960
90-149 cows (free stall)	77,330	30,530
> 149 cows (free stall)	50,550	17,740
Total	277,115	143,715

*Storage = Earthen pit for liquid manure. All = For cows plus replacements.

Appendix Table 13. Increase (Decrease) in Annual Costs on Representative Michigan Dairy Farms--Impact of Required Eight Months Storage and Injection (Standard Earthen Storage, Loam Soil, $10.10 Per Cwt.)

Debt/Asset Ratio:		Low (0:100)		Medium (20:100)		High (75:100)	
Type	Initial System*	Storage	Inject	Storage	Inject	Storage	Inject
60 cows	Daily Haul	6,306	6,306	6,775	6,775	7,673	7,673
(solid)	L-term (cow)	1,573	1,573	1,702	1,702	1,951	1,951
Tie-stall	L-term (all)	0	0	0	0	0	0
60 cows	Daily Haul	5,144	5,694	5,606	6,187	6,493	7,131
(liquid)	L-term (cow)	(831)	(281)	(803)	(222)	(747)	(108)
Tie-stall	L-term (all)	0	551	0	581	0	638
60 cows	Daily Haul	6,084	6,635	6,546	7,127	7,432	8,070
(liquid)	L-term (cow)	(786)	(163)	(757)	(103)	(702)	(9)
Free-stall	L-term (all)	0	551	0	581	0	638
120 cows	Daily Haul	8,613	9,193	9,254	9,864	10,483	11,150
(liquid)	L-term (cow)	(674)	(95)	(631)	(22)	(549)	117
Free-stall	L-term (all)	0	579	0	609	0	667
250 cows	Daily Haul	7,799	8,370	8,640	9,241	10,008	10,666
(liquid)	L-term (cow)	(1,224)	(653)	(1,139)	(538)	(976)	(317)
Free-stall	L-term (all)	0	571	0	601	0	659

*L - term = 8 months liquid manure storage. Cow = cows only. All = cows plus replacements.

Appendix Table 14. Distribution of Michigan Dairy Farms by Debt/Asset Ratio, Housing Arrangement and Manure Handling Practice
(Farms With < 30 Cows Not Included)

		Debt/Asset Ratio							
		Low		Medium		High		Totals	
Type	Initial System*	No.	Percent	No.	Percent	No.	Percent	No.	Percent
30-89 cows	Short-term	44	13.8%	32	10.0%	14	4.4%	90	28.1%
Tie	L-term (cow)	3	0.9%	6	1.9%	2	0.6%	11	3.4%
Stall	L-term (all)	1	0.3%	2	0.6%	4	1.3%	7	2.2%
30-89 cows	Short-term	23	7.2%	34	10.6%	32	10.0%	89	27.8%
Free	L-term (cow)	3	0.9%	7	2.2%	6	1.9%	16	5.0%
Stall	L-term (all)	0	0.0%	3	0.9%	1	0.3%	4	1.3%
90-149 cows	Short-term	18	5.6%	13	4.1%	13	4.1%	44	13.8%
Free	L-term (cow)	5	1.6%	13	4.1%	7	2.2%	25	7.8%
Stall	L-term (all)	0	0.0%	2	0.6%	1	0.3%	3	0.9%
> 149 cows	Short-term	7	2.2%	6	1.9%	2	0.6%	15	4.7%
Free	L-term (cow)	3	0.9%	9	2.8%	1	0.3%	13	4.1%
Stall	L-term (all)	1	0.3%	1	0.3%	1	0.3%	3	0.9%
	Totals	108	33.8%	128	40.0%	84	26.3%	320	100.0%

* Short-Term = daily haul. L-Term = 8 month storage. Cow = Cows only. All = Cows plus replacements
Source: MSU Dairy Farm Survey, 1987, Connor, et al.