RE-ENGINEERING FOR EFFECTIVE WASTE MANAGEMENT IN THE 90s

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It is usually a good idea to understand what the problem(s) or perceived problem(s) are before trying to determine appropriate solution approaches. This is particularly true for environmental issues associated with animal waste management. Therefore, the objective of this paper is to provide an introduction to the problems and a summary of re-engineered solutions these problems.

So what are the Environmental Problems Associated with Animal Waste?

The three most acute problems facing the livestock industry are odor, fly nuisance, and water quality impacts. Any manure management program in the future will have to fully address each of these issues. Odor and fly nuisance problems are directly influenced by manure management techniques as are potential water quality impacts. Therefore, no manure management system can be designed to address only one of these problems. The problems associated with odor and flies from manure are normally straightforward, i.e. complaints from nearby humans. However, the impacts of manure management on water quality are not always as obvious. Therefore, this paper will concentrate on when, where and how manure might contaminate water and what these contaminants might mean to the receiving waters. Solutions to the north Florida nitrate concerns will be the primary focus.

Water quality impacts.

The primary concern for water quality is the transport of manure or its by-products to either surface waters (streams, rivers, lakes, or estuaries) or ground water (drinking water aquifers). Both biological and chemical concerns arise from manure reaching water bodies in the state. The biological concerns are either human health related as in bacteria contamination or environmental as in BOD (biological oxygen demand). Bacterial contamination is a potential problem for surface and ground water, whereas BOD is primarily a surface water problem. BOD is a measure of how much a receiving water body's oxygen will be consumed to breakdown the organic material in the manure. Suppressed oxygen levels in water bodies can cause fish kills and other biological modifications which are normally associated with "poorer quality conditions".

The chemical constituents in manure that are of concern would be the nutrients which present a health hazard in potable ground water aquifers (primarily nitrates) or can accelerate the eutrophication process in surface waters. In Florida, the majority of our drinking and livestock water is withdrawn from ground water. The current maximum level of nitrates allowed in potable ground water is 10 milligrams of nitrate as nitrogen per liter (mg/l). The typical recharge rates in Florida would only require about 20 kg/ha (lbs/ac) of nitrogen to be leached to exceed this limit. Since animal manure is fairly rich in nitrogen, its nitrate leaching potential must be considered wherever it is placed.

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Both nitrogen and phosphorus can cause surface aquatic systems' plants and animals to grow faster (accelerated eutrophication). Because different plant and animal species respond differently to this enrichment, a change in biota diversity is likely. If undesirable species begin to dominate, then the water system is usually considered degraded. The nutrient most likely to cause a significant growth change depends on which of the nutrients is limiting current growth rates in the aquatic system. This implies each water body has a different sensitivity to nutrient changes, therefore the nutrient concentration standards for inflows to each water body must be independently determined. This is often a very difficult task because of the limited data for most aquatic systems around the state. Standards also change for the different classes of waters that exist as defined by the Department of Environmental Regulation, DER.

In Lake Okeechobee it was determined that phosphorus is the limiting nutrient, therefore P discharge limits became the water quality control criteria for the dairies in that basin. Using a eutrophication model for the Lake and in-stream assimilation factors, the discharge limit was set at 1.2 mg/l P for the surface drainage waters from dairies. As more information becomes available on the environmental response of water bodies it is likely that the nutrient limits will become more and more restrictive.

Activities to Solve Animal Waste Management Problems.

About twenty years ago Dr. Nordstedt and others at the University of Florida developed the first significant advances in waste management systems for Florida. These systems primarily consisted of treating only the dairy, swine and poultry (layers only) waste collected from the barns and chicken houses and passing it through anaerobic lagoons and seepage ditch overflows. However, for dairies this represented treatment of only about 20 percent of the total waste. Many of these systems have been advanced by the use of spray irrigation systems to spread the effluent more efficiently. These systems were designed to deal with only the point sources of waste from the barns or houses and did not address the nonpoint waste deposited on lands around the barns. Also the actual delivery of nutrients from these systems to the seepage or spray fields was not well known.

Current waste management practices which are sometimes called BMPs (Best Management Practices) are being designed to more fully utilize the nutrients in the waste for plant uptake. These systems are requiring more efficient manure collection and crop delivery systems. In basic terms the manure must be spread so that its nutrients can be taken up by crops for either re-feed or a marketable product. Often animal operations can be upgraded to these BMPs with minimal financial impacts because there is normally a significant cost benefit from the additional crop production, fertilizer saving and increased animal production. For example, cooling barns for dairy cows can significantly increase milk production while providing an efficient manure collection system. However, for some animal operations the owners do not have sufficient land to meet the maximum nutrient loading requirements or simply lack the capital to build the physical system. In these cases we need to be looking at a funding program to support the transition to the new BMPs. Innovative BMPs such as composting may be useful in some specific cases where the more conventional systems will not work.

BMPs for Controlling Nitrate Leaching to Groundwater from Daries

Best Management Practices (BMPs) for controlling the levels of nitrate migrating to the groundwater are discussed in this section. These BMPs are based on fundamental principles of nutrient budgeting where the amount of available nitrogen as nitrate is limited by the difference between inputs and outputs. The nitrogen inputs/outputs vary between different dairies and for different areas around a dairy. The nitrogen inputs that occur on a dairy are given below in descending order of relative N loading importance:

N Inputs (annual):

1. Imported animal feed (50 - 300 lbs/cow).
2. Crop fertilizer (50 - 500 lbs/Ac of cropped land)
3. Rainfall (10 - 20 lbs/Ac).
4. Animals transported on site as heifers or new cows (small N load).

Inputs 1 and 2 can be reversed in importance depending on the amount of feed grown on the dairy. The outputs of nitrogen from a dairy are given below in descending order of N loading importance:

N Outputs (annual):

1. Volatilization of ammonia (50 - 150 lbs/cow).
2. Export in milk (70 - 90 lbs/cow).
3. Leached to groundwater (5 - 100 lbs/Ac).
4. Losses in surface runoff (0 - 50 lbs/Ac).
5. Denitrification in soils (1 - 20 lbs/Ac).
6. Exported crops (presently very limited).
7. Liquid manure, scraped solids and lagoon sludge transported off the dairy (presently very limited).
8. Animals transported off site such as calves and culled cows (small N load).

The actual order of importance of the outputs can obviously vary tremendously from dairy to dairy depending on their operation.

Assuming a dairy will reach an equilibrium (inputs equal outputs) after a period of time, a rough first test to see if a dairy operation is causing a nitrate problem in groundwater can be done by summing all the N inputs and then subtracting all the outputs less leaching loss (#3 above). If the difference is greater than about 20 lbs of N per acre for the dairy then a problem is likely. Twenty lbs of N per acre is the amount of nitrogen it takes on the average to bring the annual groundwater recharge water to about 10 mg/l of nitrogen as nitrate. However not all nitrogen going to the groundwater is nitrate, so the above may be considered a conservative estimate. This assumes an average impact from the entire dairy, but in reality individual plumes of varied concentrations will be leaving the dairy. Therefore the above test should be done on all transects across the dairy in the direction of the groundwater flow.

It quickly becomes apparent that this test will be very difficult to do because neither the inputs or outputs can be easily delineated within a dairy. However, through modelling and basic assumptions, specific conditions on a dairy that are likely to create plumes of above standard nitrate levels can be predicted and therefore hopefully prevented through operational changes on a dairy.

The BMPs discussed below are therefore based on the simple premise that areas which have inputs minus outputs of N exceeding about 20 lbs/Ac need to be corrected and areas which can not be limited to this amount of excess N per acre will need areas of proportionally less excess N along its groundwater flow transect. To fully understand the benefit of the BMPs based on spatial groundwater impacts, the above nitrogen budget must be broken down further into a spatial budget (acre by acre). The basic budget remains the same but the importance becomes as follows:

N Inputs (annual):

1. Manure application after volatilization losses (50 - 100 lbs/Ac/cow).
2. Fertilizer (0 - 500 lbs/Ac).
3. Rainfall (10 - 20 lbs/Ac).

N Outputs (annual):

1. Harvested crops (0 - 450 lbs/Ac).
2. Leaching to groundwater (1 - 200 lbs/Ac).
3. Losses to surface waters (0 - 50 lbs/Ac).
4. Denitrification in soil (0 - 20 lbs/Ac).

Assuming negligible surface losses of N the test of a potential problem becomes:

Potential problem if: Leached N $\geq$ 20 lbs/Ac

where,

Leached N = (Manure+Fert.+rainfall N)-(Plant harvested N+Denitrified N)

This test quickly points out the potential problem with high intensity areas where plant harvested N is near zero and manure N applications are about 50 - 100 lbs of N per cow. Therefore a single cow/Ac on bare soil can cause nitrate levels to be significantly above the 10 mg/l standard. Indicating the extreme importance of crop uptake. Leaky lagoons can also result in a highly unbalanced budget situation.

The following specific BMPs will be presented as they apply to the overall dairy N budget categories given above.

<u>BMPs to reduce N Inputs:</u>

1. Reduce N levels in purchased feed. Watch the feed ration closely to keep the N levels in feed at or slightly below predicted optimum levels. Any excess N in feed will pass through the cow and increase the N in the manure, which will increase the requirements of the waste management system.

2. Use solid separator screens to filter undigested feed for immediate refeed. This reduces feed imports by increasing the percent of the feed digested by the cows. The reduced quality of the refeed material and the

relatively high cost of operation has limited its use but these systems have been used successfully throughout the country.

3. Offset purchased feed with feedstuff produced on the dairy. This is potentially the most effective BMP available to a dairy. This is only effective, however, if the feedstuff is grown utilizing a significant portion of the nitrogen in the manure and not by utilizing imported commercial fertilizer N. If imported fertilizer N for crop production is as large as the reduction of N in purchased feed then little is gained. However, some selective fertilization of crops at lower rates is important for optimum production and cost recovery. The general operations needed to obtain maximum manure N recovery in a crop are:

a) Manure collection systems to capture as much as possible of the manure N in a form which can be efficiently delivered to a crop. These collection systems will be covered in greater detail in the section on BMP facilities.

b) Manure distribution systems to spread the collected manure N as uniformly and economically as possible. These systems will also be covered in greater detail in the section on BMP facilities.

Because not all of the manure N is available upon application and it is usually necessary to apply it continuously throughout the year, it is not suggested to try to meet the entire crop N fertility needs by manure alone. Supplemental fertilizer N should be used to optimize, or "fine tune" crop production and N uptake by the crops. The optimal ratio of supplemental fertilizer N to manure N will vary according to the crop being grown and the rotation. The ratios in Table 1 are tentatively suggested and should be considered to be rough estimates since not all of the optimalization studies have been completed.

Table 1. Ratio of Fertilizer N to Manure N for various cropping systems.

Crop/Rotation	Fertilizer/Manure N Ratio
Hayland or pasture	.1 - .3
Hayland or pasture with winter crop of oats or ryegrass	.0 - .2
Single season corn or sorghum	.3 - .5
Double cropping (corn/sorghum or corn/winter wheat or ryegrass	.1 - .3

IFAS recommended N fertility rates should never be exceeded by either manure or fertilizer applied N or the combination of both.

Utilize the holding pasture grasses for nominal forage supplement to the milking cows. This is as much to balance the N budget in the pasture as it is to supply additional feed to the cows but every little bit of N recycled helps. To obtain the input/output balance of less than 20 lbs/Ac of N, cow densities of less than or equal to 2 cows per acre and supplemental N fertilization rates of 50 lbs/Ac or less are suggested in holding pastures.

4. Reductions in rainfall and animal N imports can not be effectively obtained - no BMPs available.

1. Enhance volatilization of ammonia. Though volatilization represents the major output of N from the dairy it is not necessarily an ideal way to lose N because it is a true loss which renders it unavailable for crop uptake and on-site feed production. Also, ammonia is a contributor to acid rain so atmospheric discharge is not necessarily pollution free. In Holland, ammonia from dairies is estimated to cause 40% of the acid rain in that country. Therefore the advantage of the increased N output by volatilization is to a large degree offset by increased need for imported N in feed or fertilizer and potential atmospheric problems. However if limited land area prevents the full use of the manure N for feed production then promotion of volatilization can be an effective BMP for groundwater nitrate control.

a) Volatilization can be promoted by rapid aeration or agitation of manure, particularly the urine. The thinner the manure is spread on the barn floors or pastures and the longer it is left before being flushed, the greater the volatilization will be. Also, once the manure is in the lagoon, additional volatilization can be generated by agitation. Finally, the smaller the atomization of the irrigated effluent and the greater the height of ejection, the greater will be the volatilization of ammonia.

It should be noted that promotion of volatilization can be energy intensive and somewhat of an inconvenience for barn manure management.

2. Increasing N in milk exports can be obtained by overall improved herd health and reduced stress factors (particularly heat stress) which increase milk production efficiency of the cows. The reduction of heat stress can be effectively coupled with manure collection systems as will be highlighted in the next section on BMP facilities. Follow recommended herd health management guidelines.

3. Losses to surface water should not be promoted for increasing N output because of potential environmental impacts downstream. Instead, the surface drainage system for pastures, croplands, haylands, and sprayfields should be designed to reduce concentrated surface flow and provide optimal soil moisture conditions. This will reduce the erosion of surface particles that are typically enriched with N. This N will then be available for later N uptake by the crops. Also the improved soil moisture condition will increase crop quality and also increase N uptake by the crop. Increased N uptake will increase crop yields thereby further reducing imported feed requirements.

4. Denitrification of N in the soil is the conversion of nitrate N to N_2 gas which is released to the atmosphere. This is a totally non-polluting release of N, however the denitrification process is quite limited in the well drained soils found in the basin. In fact the conditions that promote denitrification are high organic anaerobic (saturated) environments. Instead, the aerobic soils of the basin promote the opposite process, nitrification, which is the formation of nitrate. Though some denitrification does occur in these soils, it is not significant and can not be easily increased without other adverse effects.

The denitrification process could be used to remove significant amounts of nitrogen from the lagoon or waste storage ponds if the N in the lagoon is first converted to nitrate N. This could be accomplished by the use of a second pond which is held in an aerobic state by aeration to nitrify the ammonia and organic N to nitrate. This water would then be pumped back to the first lagoon where the nitrate N would be quickly denitrified to N_2 gas. This technique of N removal is not recommended as a BMP until all other options are exhausted because of the expense and loss of the valuable N resource. To get the second pond aerobic it would require very expensive aeration equipment and high energy cost or an extremely large pond which would need to be lined. Also, much of the converted ammonia could have been volatilized directly.

5. The exportation of crops off the dairy is as effective as using them for feed on the dairy. The major considerations would be to select crops with high N uptake efficiencies and high percentages of N removed in the harvested crop.

6. The transport of liquid manure, scraped manure or lagoon sludge off the dairy is a direct and obvious way to reduce N loading on-site. The primary limitation of this BMP is the economics of doing it. Manure is a very bulky form of N fertilizer and therefore can only be transported short distances before the transport cost exceeds the value of the nutrients. However, if nearby markets exist or are developed that offset the transportation cost then it may become viable. Current possible markets would be neighboring high value cropland such as specialized organic farms or fruit or vegetable farms and composting operations.

On-farm composting of manure for commercial sale is also a possibility for direct removal of N from a dairy but the feasibility is totally dependent on the market price of compost which would drop if many dairies did this. Therefore composting would be limited to only a few innovative/daring dairymen.

7. Nitrogen removed from a dairy due to animal removal is not very significant and this practice can not be changed to increase N removal. It should be noted, however, that dead animals should be disposed of properly and not buried on site.

BMP Facilities

Manure Collection Systems

When cows are held at stocking rates greater than the soil's ability to hold the N in their manure, a manure collection system is required to capture the excess manure so it may be delivered to systems that can handle the manure loads. The most common and effective collection system is a concrete floor where the manure can be either flushed or scraped off. Historically in Florida concrete floors were only used around and in the milking barn. Therefore only about 15 - 25 percent of the generated manure was collected and typically delivered to a lagoon. This left about 75 - 85 percent of the manure in holding pastures in forms that are difficult to collect. In high-water-table soils with limited deep seepage, perimeter ditches can be used to collect manure and nutrients washed from the manure by rainfall in the high intensity areas. This is the system used in the Okeechobee Basin Dairy Rule. Unfortunately, the soils in the Suwannee River basin are not suited to this method, therefore requiring collection systems to have concrete floors or be lined with some other sort of impermeable material either on or under the soil.

The limit of N uptake by pasture grasses is the loading from about two cows per acre. Therefore the sizing of supplemental manure collection systems (beyond current milking barn collection) should be based on the percentage of time the cows must be kept from the holding pastures to keep cow densities below the two cow per acre limit. Percent time to hold cows (CB) in the collection facility can be calculated based on the following relationship:

$$CB(\%) = \left[1 - \frac{(MB*HERD + AHP*2)}{HERD} \right] * 100$$

where, MB is percentage time cow spent in milking barn (as a decimal), HERD is the number of milking cows, and AHP is the size in acres of the available holding pastures. Therefore the larger the holding pastures the smaller the collection system requirements.

The cows can be encouraged to stay on the collection floors by forced enclosure or incentives such as shade, feed, and water or all three. Cows should be encouraged or forced to spend part or all of their day on the collection floors during the entire year. This is especially true in the winter when the permanent grass in loafing area is dormant. Many dairymen have built cooling/feed barns, which serve well as manure collection systems, strictly for the purpose of improved health, comfort and related increased milk production. Therefore manure collection systems of this nature are economical even without the consideration of the waste management benefits.

The manure collection system must be accompanied by appropriately sized transport and storage facilities, such as flush alleys, storage pads for solid waste (scraped manure) and storage ponds/lagoons for liquid waste. Since the concrete floor, flush alleys, and storage facilities contain concentrated manure it is important to design them so that no leakage can occur to the soil. Such leaks can create "hot spots" of nitrate leaching. Concrete is normally sufficient to prevent leakage from floors, flush alleys, and solid waste storage pads.

Research has determined that the organic matter in the waste does not always seal a lagoon/pond and that agitation may break some of the seals that have formed. Therefore unsealed lagoons/ponds (especially on sandy soils with deep water tables) are likely to leak nitrates into the surrounding soil. The actual leakage rates for various lagoons/ponds have not been well estimated. Concrete linings are usually the preferred choice to seal lagoons, but clay or plastic lining may also be used. If concrete is used it should also have a thin plastic lining under it or designed to such specification as to not develop significant cracks.

To reduce sand and solids build up in lagoons and storage ponds, sand and solids separators should be considered. Sand separators, "traps", are strongly recommended because sand accumulation reduces storage volume and is very abrasive to pumps and irrigation systems. Solid separators remove significant amounts of N which can reduce the required size of the sprayfields and also offers the opportunity for direct refeed as discussed earlier.

The sizing and construction requirements of cooling/feed barns, flush alleys, separators, and retention ponds/lagoons can be obtained from the Soil Conservation Service.

Waste Distribution Systems:

As mentioned earlier but worth repeating, the premise of a good waste management system is to spread the manure/waste at rates which allow nutrients to be taken up by crops for either refeed or transport off site. To meet this goal, a waste distribution system must accompany any manure collection system. The solid waste collected by either scraping or solid separators must be distributed at appropriate fertility rates by manure spreaders. The liquid manure in the storage lagoon/pond can be spread by either tank spreaders, "honey wagons", or spray irrigation systems. Spray irrigation systems are less expensive per acre-in of water applied and can provide higher uniformity of application. Table 2 highlights the advantages of spray irrigation systems.

Table 2. Relative cost of waste distribution systems.

System Name	Cost per 1000 lbs of N spread
Manure (solids) spreader	$ 120 - 500
Liquid manure (tank) spreader	$1000 - 2000
Spray Irrigation System	
Center Pivot	$ 100 - 200
Cable Tow	$ 150 - 300
Solid Set (guns)	$ 300 - 1000

The above costs include the installation, pumping, and operational costs. Considering the value of fertilizer N is between $.25 - $.30 per pound, the cost of spreading the manure is more than covered by the value of the N in it. This value of the N as fertilizer can be viewed another way. An average dairy cow produces about 100 pounds (after losses) of usable N per year. This amounts to an average output of 25 to 30 dollars worth of N per cow per year.

<u>Additional BMPs for Nitrate Control</u>:

<u>Prevention of High Intensity Areas</u>. High intensity areas are those areas where cow densities cause manure N loadings to significantly exceed vegetative N uptake capacity of the pasture grasses. Cow densities greater than three to four cows per acre can cause such areas. High intensity areas normally form around field entrances, feeders, waterers, and shaded areas. Therefore these areas may need to be paved for manure collection or moved at a sufficient frequency to prevent high intensity area development. Use of cooling/feed barns greatly reduces high intensity area development.

Some high intensity areas can not be prevented, especially at field entrances. High nitrate losses from these areas will need to be compensated by areas along the groundwater flow path that are proportionally lower in nitrate leaching potential, such as wooded, idle or low fertility cropland. Adverse impacts from localized very high intensity areas such as lanes or standing areas near gates can be controlled by placing an impermeable barrier about three to five feet below these areas and placing subsurface drainage tubing on top of the barrier. The leachate water can then be drained to the lagoon/waste pond. This will also keep these areas drier.

Other practices such as placing feeders, waterers, and shade in pasture to disperse cows can be important. Also, maintaining the pasture grasses in good quality and growth stage is important. This may require the addition of supplemental fertilizer such as potash or seasonal additions of nitrogen or phosphorus. It is important to keep live vegetation in the high intensity area all year long. This may require overplanting with ryegrass or some other cold tolerant vegetation in the winter. Grass should be cut or harvested (baled) in order to keep the grass in a state of high growth and reduce weeds.

Use a planned grazing system if land is available. This is a system in which two or more grazing units are alternately rested from grazing in a planned sequence to improve forage production, maintain vegetative cover, and retain animal waste.

Use Good Crop Management Techniques. When economically feasible or when sprayfield land is limited, irrigation is recommended to increase yields and N uptake. However, be sure to use proper irrigation techniques for controlling the rate, amount, and timing of irrigation water being applied in order to minimize runoff and movement of fertilizer, nutrients and pesticides. Perform routine soil, manure, and plant nutrient tests to avoid over-fertilization and subsequent losses of nutrients due to runoff or leaching. Adjust timing and placement of fertilizers and manure for maximum utilization by plants. A procedure for assessment is provided in a later section.

Reduce Water Use. Use water from the lagoon to flush the barn, and scrape barn before hosing. This will decrease the water use of the dairy, thus decreasing the required lagoon size. A smaller lagoon is more economical than a larger one.

Fencing. Exclude cows from sensitive areas such as open sinkholes, bogs, or surface waters with fences. However, depressional sinks, which have no open access to groundwater (soil is at least four feet thick throughout the sink) and are well drained (no boggy conditions), can be grazed or cropped normally. If trees or other conditions cause a sink to become a congregation point for cows then it should be fenced.

Buffer Strips. Vegetative buffer strips trap nutrient enriched soil and manure particles as water flows through them, thus keeping these constituents away from surface waters and sinkholes. Buffer strips are most effective in areas of high runoff potential.

Seal old wells. All wells that are no longer being used should be either permanently or temporarily sealed, depending on whether they will ever be used again. Abandoned wells can become direct conduits for surface waters to deep groundwater, thus eliminating soil reactions and plant uptake.

Water Conveyance. All nutrient rich water should be conveyed in either pipes or lined ditches. Unlined ditches and leaky pipes and valves could allow leaching of nitrates. Conveyance systems should be routinely checked for leaks.

Regulatory Programs

The future is here as far as how the government, particularly Florida's Department of Environmental Regulation, FDER, is planning to address the animal waste management - REGULATION. They are charged to assure the public that the environment is going to be protected. Incentive programs such as cost share program will still be part of the implementation strategy but will likely be backed up by a strong regulatory program. Rapid voluntary conversion of existing systems could hold off a lot of pending regulations but no one is optimistic this will occur because of the limited incentive program funding. We can expect more and more specific regulations to be developed for each type of animal operation. Dairies in the Okeechobee Basin as well as any new dairy in north Florida are already being regulated and must obtain a permit. It is likely that similar regulations will be developed for existing dairy operations, poultry and other animal operations in the future.

What should we be doing?

First we must understand and accept that animal waste does pose an environmental threat in many situations. We must then technically define the problem that is occurring. This can best be done by getting all the affected parties, which would include the farmers, environmentalists, regulators, politicians, and animal waste management experts, together to define the problem and discuss the most "reasonable" solutions. Issues of owner and community financial viability must be thoroughly addressed in addition to environmental issues and actual solution techniques.

The North Florida Dairy Fact Finding Committee formed by FDER is an attempt to have all the appropriate parties interested in dairies discussing the issues. Similar groups should be considered for each of the other animal operations, particularly poultry and swine. It is important that agriculture is organizing these discussions to assure their involvement. Otherwise groups with less understanding of farming systems are likely to take the lead and unfairly influence the outcome.

It is of course essential for any decision to be based on the best information. Unfortunately not all the answers are available. Therefore, a continued research effort will be needed to develop new or refine existing solutions for animal waste management.

The BOTTOM-LINE is that environmental problems can and are occurring with existing animal waste management systems, but the GOOD NEWS is that we have the technology to manage these wastes in an environmentally sound fashion.