ECONOMIC ASSESSMENT OF MANURE PHOSPHORUS REGULATIONS FOR MANITOBA's PIG INDUSTRY:

PART 1

COSTS OF ALTERNATIVE MANURE MANAGEMENT STRATEGIES

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EXECUTIVE SUMMARY

For the development of a sustainable agricultural industry, the Government of Manitoba has been continuously improving programs, policies and regulations aimed at the control of diffuse agricultural pollution. Manitoba's pig industry is one of the most important in Canada and is the most valuable agricultural sector in the Province. However, this industry has been under scrutiny for manure management and its potential implication for the eutrophication of several waterways and waterbodies.

One of the challenges of trying to implement regulations or recommendations to control agricultural pollution is to evaluate the economic impacts on the livestock sector. Therefore, the main objective of this project was to propose a framework for the economic evaluation of the impacts of the new phosphorus P regulations. To demonstrate the new regulations, manure application rates were assessed with the help of three different nutrient management options: N-based nutrient recommendations, up to two times crop P_2O_5 removal and up to one times crop P_2O_5 removal. Five nutrient management strategies were examined to acquire information on the economic impacts of these new regulations: current land base sufficient for N or P-based annual manure application, current land base sufficient for N-based annual or multi-year manure application with extra land available, current land base sufficient for N-based annual manure application and excess manure was transported over different distances, current land base sufficient for N-based annual manure and excess manure was treated and finally, additional storage capacity was constructed to comply with prohibition of winter application.

Costs per marketed pig allowed an effective comparison between the different strategies. The lowest average incremental costs of compliance were for annual application on land (up to two times P_2O_5 crop removal) and for the multi-year land application (up to one times P_2O_5 crop removal), averaging $0.15 in increased costs per marketed pig for farrowing and finishing operations. As for the strategies where no extra land was available and manure needed to be transported over a certain distance, increased cost per marketed pig averaged $1.11 per marketed pig for the two types of transport and distances assessed. Finally, for the strategy where no additional spreading land was available, incremental costs for manure treatment with solid-liquid separation technology averaged $1.08 per marketed pig and with aerobic technology, $3.50 per marketed pig. As for manure storage, incremental costs averaged $0.62 per marketed pig over a 10 year-period, using an interest rate of 7.5%.

To have a better appreciation of the effect of these incremental costs on the profitability of the pig industry, increased costs were calculated as a percentage of average annual returns. Decreases in profitability averaged 5.7% for farrow to 5 kg for annual and multi-year manure application and 2.3% for both finishing operations. As for the aerobic manure treatment, the decreases in profitability averaged 140% for farrow to 5 kg and 92% for both finishing operations. As for the impacts on the types of pig operations, the overall impacts on the farrow to 5 kg operations as a percentage of long term returns were considerably greater than those for the finishing operations.

Overall, the assessment of the impacts of the new proposed environmental regulations on the selected scenario farms presented the following results:

- Negative impacts on farrowing operations were larger than on finishing operations.
- Grain corn was the cropping system with the least increase in land required and pasture was the crop with the highest increase.
- In areas or on farms where there is not sufficient nearby land for manure application a P_2O_5 removal basis, the cost increases are substantial.
- Incorporation of phytase into finishing rations will pay substantial dividends in lowering costs of manure management.
- For operations with cropping enterprises, the impact of exporting manure N to other farms and replacing with synthetic fertilizer N is substantial, equivalent to a decrease in net returns of 22-54%.

These increased costs could have significant impacts on Manitoba's pork industry. For primary producers, this represents decreased profitability that will reduce further investment in this sector and an increased risk of losses during periods of low prices, threatening the viability of some existing operations. Beyond the farm gate, these increases in costs could also reduce investment and economic activity in other sub-sectors of the pork industry such as feed suppliers and pork processors.

More work will need to be done to be able to determine these economic impacts at a regional or provincial scale. More specific information on the pig industry will be needed, as well as more resources to expand the study. Such knowledge will be essential for assessment in a more accurate way the appropriate costs of the implantation of the new regulations on the pig industry in Manitoba.

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1. INTRODUCTION

Manitoba is Canada's third largest pig-producing province, with about 23 percent of national production and about 5% of total North American production in 2005[1]. Manitoba's 1,460 pig operations produced about 8.2 millions pigs in 2005 and about 60% of the total production was exported to the United States. Pig production is the most valuable agricultural sector in Manitoba with more than 24% of the total value of agricultural production in 2005 (about $900 million). Furthermore, Manitoba's vibrant pig production sector plays an essential role in supplying Manitoba's newly revitalized pork processing industry. However, with the success of this industry, the public is concerned about manure and nutrient management and their implications for the eutrophication of waterways and waterbodies, especially Lake Winnipeg. According to Tyrchniewicz et al. (2000), the challenge for everyone with an interest in the livestock sector, is to identify policies, guidelines and regulations that will enable the expansion of Manitoba's livestock sector while taking into account its economic viability, environmental stewardship, and social and equity issues. Thus, policy makers, livestock producers and the general public need to have a balanced view of livestock production including its economic and environmental impacts (CARC, 2003).

With the goal of sustainable agricultural development, the Government of Manitoba is continuously improving programs, policies and regulations aimed at the control of diffuse agricultural pollution. For example, Manitoba Conservation sought recommendations on amendments to the *Livestock Manure and Mortalities Management Regulation* to address the issue of phosphorus (P) application to land from manure. The concern is that long term regulation of manure application on the basis of nitrogen (N) could result in over-application of manure phosphorus and a build-up of soil P that threatens surface water quality. Recommendations were developed by the Manitoba Phosphorus Expert Committee[2]. The objective of the recommendations is to minimize the risk of P loss to surface water without harming crop productivity. Although it was acknowledged that the implementation of the new regulations for manure application would likely raise manure management costs for many farms, the Phosphorus Expert Committee did not evaluate the economic impact of their regulations on the livestock sector. The economic impacts of implementing the Committee's recommendations should be considered before any regulatory changes are made.

[1] Dr Ian Seddon (MAFRI), personal communication. Source of information : Statistics Canada (2006) Available on line at http://www.statcan.ca/bsolc/english/bsolc?catno=23-010-X (verified 25/04/2006).
[2] Report available on line at http://www.gov.mb.ca/conservation/regoperations/livestock/pdf/final_report_manitoba_phosphorus_expert_committee.pdf (verified 30/04/2006).

Manitoba Water Stewardship is also committed to reducing nutrient loads into Manitoba's surface and groundwater. As such, they have proposed a regulation for Water Quality Management Zones for Nutrients[3]. With respect to manure nutrients, the regulatory approach for this initiative is consistent with the overall recommendations for P management in the *Livestock Manure and Mortalities Management Regulation*.

Changes to manure management practices will likely mean additional costs for livestock and crop producers as well as for communities. For example, the ability of a pig producer to eliminate winter application of manure is dependant on whether or not the operation has enough manure storage capacity to contain the manure over the winter months. The recommended prohibition on winter application could be very expensive, especially for small producers. The cost of nutrient management depends on which nutrient is limiting. P-based manure management generally results in more restrictive manure application rates and is more costly than N-based management (Bonham et al., 2004; Yap et al., 2004). Several studies have shown that P-based management would decrease profits because of an increase in manure application costs (Schnitkey and Miranda, 1993; Boland et al., 1998; Fleming et al., 1998; Pratt et al., 1997; Unterschultz and Jeffrey, 2001). Therefore, prior to the implementation of this proposed regulation, the economic impacts of these recommendations should be assessed to ensure the sustainability of Manitoba's livestock industry.

1.1 Objectives of the project

This study proposes a multidimensional framework, based on farm-level, regional and provincial scale. The consistency of current land application decisions (referred to as baseline) will be evaluated, against the new incremental soil test P regulatory thresholds and the special management areas and measures proposed. Then, the cost of managing manure according to soil P thresholds while considering the availability of cropland will be estimated.

This report presents the new proposed environmental regulations from Manitoba Conservation and Manitoba Water Stewardship. The cost analysis framework developed for the purpose of this project is also presented. Afterwards, results of the cost assessment of the manure management strategies and their impacts on typical livestock operations and other related enterprises are discussed.

[3] Consultation document available on line at http://www.gov.mb.ca/waterstewardship/reports/wqmz_2005-07-20.pdf (verified 30/04/2006).

1.2 Principal investigators and technical advisory committee

Principal investigators are members of the Faculty of Agricultural and Food Sciences of the University of Manitoba: Departments of Soil Science and Agribusiness and Agricultural Economics (Table 1.1). The technical advisory committee is comprised of specialists from a variety of provincial or federal government departments and industry. Contacts and collaborations have been established with Manitoba Water Stewardship, Manitoba Agriculture, Food and Rural Initiatives, Manitoba Conservation, Manitoba Pork Council, Elite Swine Inc. and Agriculture and Agri-Food Canada. Those collaborations include sharing data, gathering information, expertise and consultation about scientific aspects of the project.

Table 1.1 Principal investigators and members of the technical advisory committee.

Member	Position	Organization
Dr Esther Salvano*	Research associate	University of Manitoba Dept. of Soil Science
Dr Don Flaten*	Associate professor	University of Manitoba Dept. of Soil Science
Dr Gary Johnson*	Associate professor	University of Manitoba Dept. of Agribusiness & Agricultural Economics
Charles Grant*	Senior instructor	University of Manitoba Dept. of Agribusiness & Agricultural Economics
Petra Loro	Livestock Environment Specialist	Manitoba Agriculture, Food and Rural Initiatives
Scott Dick	Manager, Land and Nutrient Resources	Elite Swine Inc.
Andrew Dickson	General Manager	Manitoba Pork Council
Dwight Williamson	Water quality manager	Manitoba Water Stewardship
Dave Green	Water quality specialist	Manitoba Water Stewardship
Gary Plohman	Regional Engineer	Manitoba Agriculture, Food and Rural Initiatives
Weldon Newton	Producer representative	Keystone Agricultural Producers
Al Beck	Manager	Manitoba Conservation
Dr Ian Seddon	Pork industry specialist	Manitoba Agriculture, Food and Rural Initiatives
Peter Blawat	Economist	Manitoba Agriculture, Food and Rural Initiatives

* Principal investigators.

2. NEW PROPOSED ENVIRONMENTAL REGULATIONS

To address public concern regarding water quality in Manitoba, two new sets of regulations have been proposed to regulate the application of nutrients onto agricultural land. The first regulation will control application of manure P through amendments to Manitoba Conservation's *Livestock Manure and Mortalities Management Regulation*. The second set of regulations is designed to prevent over-application of N and P from all nutrient sources on agricultural land, through the establishment of Water Quality Management Zones (WQMZ) under Manitoba Water Stewardship's *Water Protection Act*. The following sections present the main features of these regulations. A summarized description of the two proposed regulations and their associations is presented in the next chapter.

2.1 Manure phosphorus management recommendations (Manitoba Conservation)

Manitoba Conservation sought recommendations on proposed amendments to the *Livestock Manure and Mortalities Management Regulation* to address the issue of P application to land from manure (Manitoba Phosphorus Expert Committee, 2006). The concern is that long term regulation of manure application on the basis of N could result in over-application of manure P and a build-up of soil P that threatens surface water quality. The recommendations were developed by the Manitoba Phosphorus Expert Committee with the objective of minimizing the risk of P loss to surface water without harming crop productivity.

The proposed amendment is comprised of two main components to regulate manure phosphorus: regulatory thresholds to trigger a management response and special measures in Special Management Areas (SMAs). Four soil test P thresholds are part of this proposal. Each has a specific intent and triggers a specific rate of manure application: on the basis of crop N requirements, up to two and one times P crop removal rates and prohibition of manure application when soil test P is above a certain threshold (Table 2.1). As for the SMAs, two main types are defined: regular inundated areas including the Red River Valley SMA, corresponds to immediate prohibition on all winter application and incorporation within 48 hours or injection of fall applied manure on tilled soils: the second set of SMAs consists of different vegetated buffer strips and manure application setbacks from watercourses (Table 2.2).

Table 2.1 Recommended soil test P thresholds for regulating livestock manure application (Manitoba Phosphorus Expert Committee, 2006).

Soil Test P Threshold[1]	Intent of Threshold	Manure P Application
< 60 ppm	No restriction on P application	Apply on the basis of crop N requirements[2]
60 – 119 ppm	Control soil P accumulation rate	Apply P up to two times the crop P_2O_5 removal rate
120 – 180 ppm	Prevent further increases in soil P concentrations	Apply P up to one times the crop P_2O_5 removal rate
> 180 ppm	Depletion at a rate controlled by crop removal	No manure application without written consent of the Director

[1] Olsen P or equivalent.
[2] Soil nitrate concentrations are subject to Section 12 of the LMMMReg: The Livestock Manure and Mortalities Management Regulation MR 42/98, as amended March 30, 2004.

Table 2.2 Recommended livestock manure management practices for Special Management Areas (SMAs) (Manitoba Phosphorus Expert Committee, 2006).

SMA Type	Winter Application / Buffers	Manure Application Setbacks	
		Injection/low level application & incorporation	High level broadcast application / low level application with no incorporation
Red River Valley or Flood plains of other designated rivers	Immediate prohibition on all winter application; Incorporation within 48 hours or injection of fall applied manure on tilled soils		
Lakes	Permanently vegetated buffer strip of 15 m; no manure application	15 m setback	30 m setback
River, creeks and large unbermed drains (3rd order or higher)	Permanently vegetated buffer strip of 3 m; no manure application	3 m setback	10 m setback
Smaller watercourses[1] (1st and 2nd order) and wetlands	Permanently vegetated buffer strip of 1 m; no manure application	1 m setback	1 m setback

[1] Such as roadside ditches designated drains and other drains.

2.2 Water quality management zones for nutrients (Manitoba Water Stewardship)

On July 20 2005, Manitoba Water Stewardship released a consultation document on the Water Quality Management Zones for Nutrients (Manitoba Water Stewardship, 2005). The goal of this proposed regulation is to protect water quality by preventing the over-application of fertilizer, manure, or biosolids to the landscape and by minimizing the risk of loss to sensitive areas

(Manitoba Water Stewardship, 2006). According to this concept, the province is divided into four soil zones based on the principal factors that influence N leaching potential. Each zone has different residual soil test nitrate limits and N application rate caps. Factors taken into consideration include climate, moisture limitations, land slope topography, soil texture, permeability, salinity, stoniness, erosion potential, soil characteristics and crop yield potential (Manitoba Water Stewardship, 2005). Each zone is associated with limitations on application of N (Schedules A, B, C and D) and P (Schedule E). The consultation document also proposes to implement the soil test P thresholds and the buffer setbacks recommended by the Phosphorus Expert Committee for all sources of nutrients. Water Quality Management Zones 1, 2, and 3 regulate residual soil nitrate limits based on the Canadian Land Inventory (CLI). As for Zone 4, it defines areas where no application of nutrients should occur. Nitrogen application rates must be based on soil tests and realistic target crop yields. Nitrogen application rate maxima are also provided for each zone and crop type. According to Manitoba Water Stewardship (2006); these maxima may be removed in the new regulation.

3. MANURE MANAGEMENT IMPACTS ASSESSMENT

This chapter presents a brief literature review of some studies of nutrient management. Beneficial management practices are then discussed and the ones selected for this preliminary study are presented. Finally, the general impact assessment framework developed for this project is described.

3.1 Other relevant studies

Numerous studies have shown that P-based management would have an impact on all aspects related to nutrient management. Most of the previous research has demonstrated that a P-based regulation would decrease profits because of an increase in manure management costs (e.g. treatment, storage, transportation and application). Olson (2004) summarized the issues regarding switching maximum manure application rates from a N basis to a P basis. The main issues and challenges associated with a P-based approach concerned: land-base requirements, manure application technologies, livestock diets, manure processing, soil test P, economic and policy frameworks and soil P limits. According to his research, the primary challenge is that a larger land base is needed and this may be particularly difficult to achieve in areas with high livestock densities and high concentrations of soil P.

In Minnesota, the economic model developed by Koehler and Lazarus (2000) presented similar results. For a finisher operation, manured land requirement for corn was 400 acres for a N-based rate (2,500 us gal/ac) and 800 acres for a P-based agronomic rate (1,250 us gal/ac) versus 167 acres for a higher-than-agronomic rate (6,000 us gal/ac). Thus, these rates resulted in manure pumping and application costs that were 14% greater for the P-based rate than for the N-based rate. Comparison of the total cost to meet fertility needs with a combination of manure and commercial fertilizer gave an interesting result: total cost was lower for the P-based rate than for the N-based rate. This was explained by the higher cost of commercial fertilizer needed in addition to manure for the N-based rate.

Huang et al. (2003) assessed the economic impacts of three alternative regulations (baseline, P-restriction and P-restriction/phytase diet) on manure application in the Heartland region where seventy percent of U.S. hog farms were in 1998. The main finding was that more farms needed to lease land for manure application with the P-restriction than with the N-restriction and the use of phytase would reduce the additional acreage needed when compared with the P-restriction scenario. The calculation of the net cost to utilize manure per hog sold, showed higher estimates for the P-restriction scenario mainly because of differences in land restriction assumptions. Similar trends were assessed for the marginal cost of utilizing manure: P-restriction caused a large increase. For all hog operations examined, compliance with the new proposed P-restriction would cause most farms to have higher manure application costs and lower net crop returns. Similar indicators and scenarios were used by Huang and Magleby (2003) and equivalent assessments were obtained.

Similar results were also obtained by Lory et al. (2004) with their study of 39 pig productions in east-central United States to evaluate the effect of a P rule on manure management practices. According to their findings, manure type and application limit significantly affected land requirements for manure application and the interaction of these two effects was significant. Comparison between N-based and P-based land requirements showed an increase of 314% for the latter. This difference was translated in a manure management cost increase of 20% for the P-based scenarios.

Ribaudo et al. (2003) also found that most confined hog operations would need to increase the land receiving manure to meet the needs of P-based nutrient management plan. In the Western Cornbelt region of the United States, pig production with more than 1,000 AUs would have to increase the amount of land for manure application by a factor of six with a P-based nutrient management plan.

Yap et al. (2004) compared five different scenarios representing variations of manure land application based on a P standard with an N-based management for an 11,970 hog operation with a crop land base of 1,500 acres in Central Indiana. The P-based standard did not allow for manure P application to exceed the P needs of crops. Changes for some scenarios were about two times the land required for N-based manure application; this represented a reduction of about 42% of the pig production. Overall, estimates of compliance cost per unit of hog production capacity ranged between $US0.56 and $US21.74. These researchers concluded that farms with a relatively small land base relative to animal numbers faced a higher cost of compliance and the change from a N-based to a P-based application standard will likely support larger farms and those with a small land base may not remain cost competitive.

Olson and Paterson (2005) carried out an economic assessment of P limits in Alberta where they compared the impacts of four scenario cases on a farrow-to-finish pig operation. Manure application rates ranged widely from 13,172 imp gal/ac for the scenario where manure was applied at four times the annual P crop requirement (once every 4 year) to 3,293 imp gal/ac for the scenario where manure was applied to meet annual P crop requirement every year. Therefore, four times more annual area manured was estimated for the latter scenario compared to the previous one. Even though the management scenarios required more land for manure application, no increased costs were determined because the pig production unit had enough land to accommodate all scenarios.

In Ontario, Brethour et al. (2004) determined the economic impact that the *Nutrient management regulation*[4] (Province of Ontario Regulation 267/03) will have on the agricultural industry in Ontario. Comparison between costs and returns and estimated direct cost of compliance for farrow to finish operations were assessed. For medium farrow to finish operations (between 900 to 1,800 pigs), estimated cost of compliance ranged from 55% (low cost of compliance) to 110% (high cost of compliance) of their average net farm income ($78,112). As for the large operations (more than 1,800 head), percentages ranged from 33% (low cost of compliance) to 59% (high cost of compliance) of their average net farm income ($174,035). Thus, compliance for the medium size operations represented a loss if the high cost options were utilized.

3.2 Beneficial management practices (BMPs)

In order to conform to these new environmental regulations, livestock producers will need to implement BMPs that are appropriate for their operations. A preliminary set of BMPs for Manitoba has been developed by the Manitoba Phosphorus Expert Committee BMP Task Force (Manitoba Phosphorus Expert Committee, 2006). For the purpose of this assessment, the principal BMPs utilized to conform to the new P regulations were aimed at reducing the impacts of the main basic processes that result in the loss of agricultural P to surface water: loading, mobilization and delivery. According to Flaten (2006), BMPs for pig producers can be categorized in the following:

- Plan for P management in new and expanding operations
- Minimize the import of P (balancing on-farm P budget) and maximize P export (meat, milk, eggs and crops)
- Export P from the farm in manure where necessary
- Reduce mobilization and delivery of dissolved and particulate P
- Reduce the direct addition of fertilizer manure P to water

For the pig producers, these represent actions and measures like:

- Accessibility to sufficient spreading lands.
- Purchase, lease or rent additional crop land to increase P exported where the land base on the farm is insufficient.
- Appropriate animal diet to minimize P excretion and maximize animal production efficiency.
- Soil test to determine available soil P when establishing manure application rates.
- Soil test P thresholds
- Improve crop management practice to improve overall crop production
    - Select more productive lands and appropriate crops to maximize P removal.
    - Ensure adequate supply of N and other nutrients to optimize crop yields
    - Remove as much crop material as possible to maximize removal of P from the field
- Setbacks and buffers

[4] *Nutrient Management Act* (2002): provides province-wide regulation to address the effects of agricultural practices on the environment.

- Accurate calibration of manure application equipment.
- Injection or incorporation of manure
- No winter application
- Treat the manure on-farm and export treated manure (e.g. Solid-liquid separation)
- Export raw manure to other nearby farms
- Vegetative growth or wetlands

Although many of these BMPs show promise, in most cases their environmental effectiveness, technical feasibility and economic affordability has not been evaluated under Manitoba conditions (Flaten, 2006). Therefore, the most obvious and fundamentally sound BMPs, reducing net loading or surpluses of P by balancing its application with removal should be one of the first to implement. For that reason, the following BMPs were chosen to perform this preliminary economic impact assessment of the new proposed environmental regulations:

- Application onto sufficient spreading land
- Appropriate animal diet to reduce P excretion
- Monitor soil test P and respect soil test P thresholds
- Prohibition of winter application

3.3 General impact assessment framework

The impact assessment focused on two main components of the new environmental regulations: land application according to soil test thresholds and SMAs (Figure 3.1). As for land application, the first main element considered was WQMZ for nutrients for their agricultural productivity zones and type of soil. These parameters are important to establish the type of crops and expected yields. The next step is comprised of residual NO_3^- limits and manure management plans. For the purpose of this study, the focus was on the manure management plans. Parameters such as soil test P and crop target yield played a central role in the management simulations. To assess manure application rates, three management options were selected (simulations): N-based nutrient recommendations, up to two times crop P_2O_5 removal and up to one times crop P_2O_5 removal.

Concerning livestock operation, the choice of the size and the type of animal gives information on the nutrient content and volume of manure produced annually. With these two factors estimated, simulation of the manure management scenarios (application method, rate and timing) land area requirements may be estimated. Comparing that result to the farm's land area for spreading manure, two situations are probable: enough land available or not enough land. For the cases where enough land is available, the only costs are those associated with manure application; they are estimated in relation to the type of application and distance. In the cases of not enough land, two options are: manure transport or treatment. Even if manure transport is not currently popular in Manitoba[5], this option was still considered as possible means of

[5] Scott Dick (Elite Swine), personal communication.

complying with future regulations. As for manure treatment, several technologies were examined to present a variety of possibilities.

As for the SMAs component of this analysis, two parts were considered: buffer strips and prohibition of winter manure application in certain areas. The implementation of the buffer strips is beyond the scope of this study and will not be assessed. As for the prohibition of winter spreading, its impacts were represented by the costs of increasing the manure storage capacity of the livestock operation to meet the requirements of the new proposed regulation.

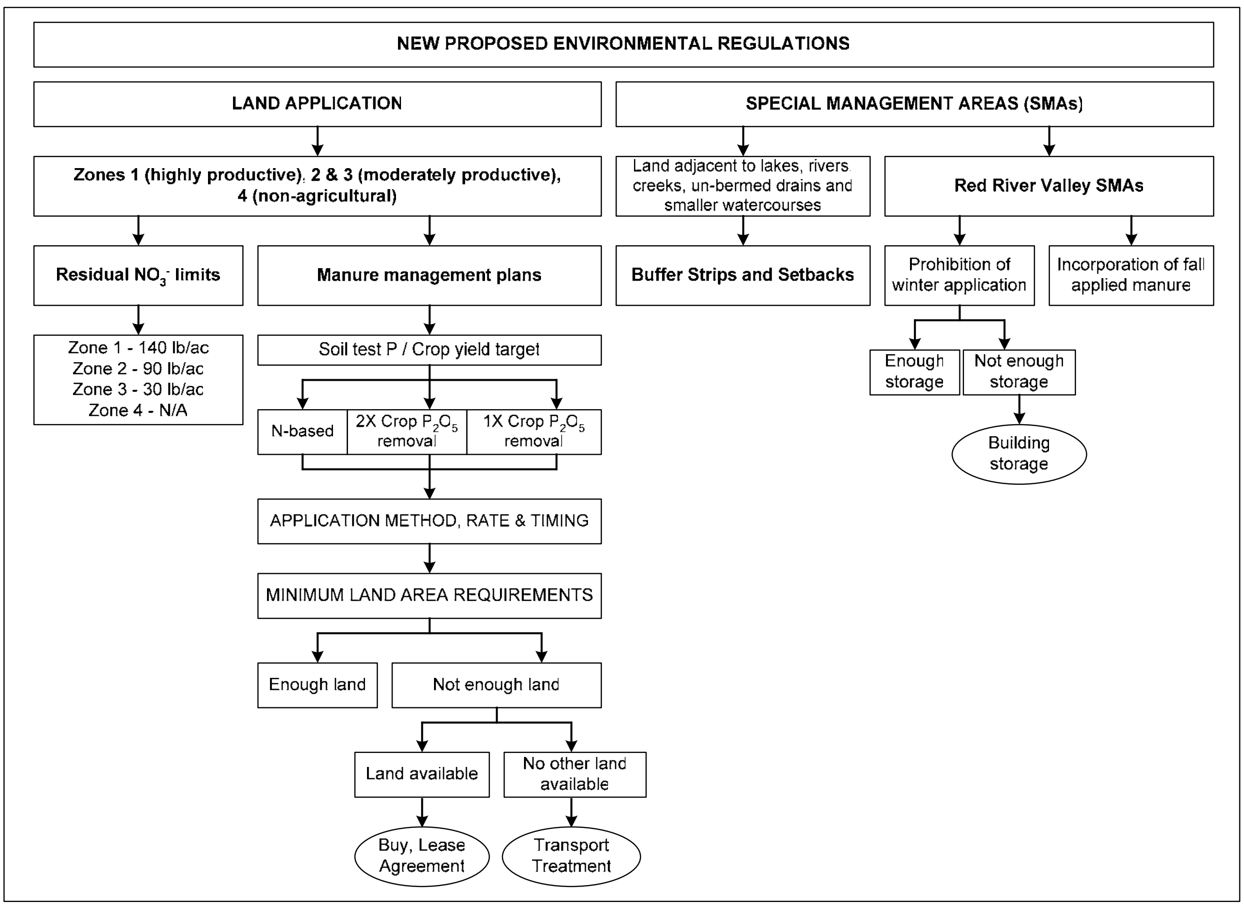

Figure 3.1 General framework for minimum land requirements and cost assessment.

4. MANURE MANAGEMENT STRATEGIES

For the purposes of this study, the economic impacts of the new environmental regulations were considered as site specific. Thus, to obtain a better understanding of the general impact, a series of manure management strategies was developed and examined. These strategies are part of a more elaborate management scheme to get a more accurate assessment of the importance of the new proposed P regulation. To achieve this goal, a number of assumptions were made to justify the data, management strategies and calculations.

For this economic assessment of the impacts of the new environmental regulations, the main focus was on costs of different manure management strategies: manure application and minimum land requirements, manure transport, manure treatment and manure storage building.

This chapter presents the assumptions, information and data used for the assessment of the impacts of the new proposed environmental regulations on a series of scenario farms. First, a description of the cropping systems and presentation of the pig operations chosen is provided. Next, a description of the nutrient management, manure transport, manure treatment technologies and building of manure storage facilities are offered. Figure 4.1 presents the general framework for the simulation of manure management strategies.

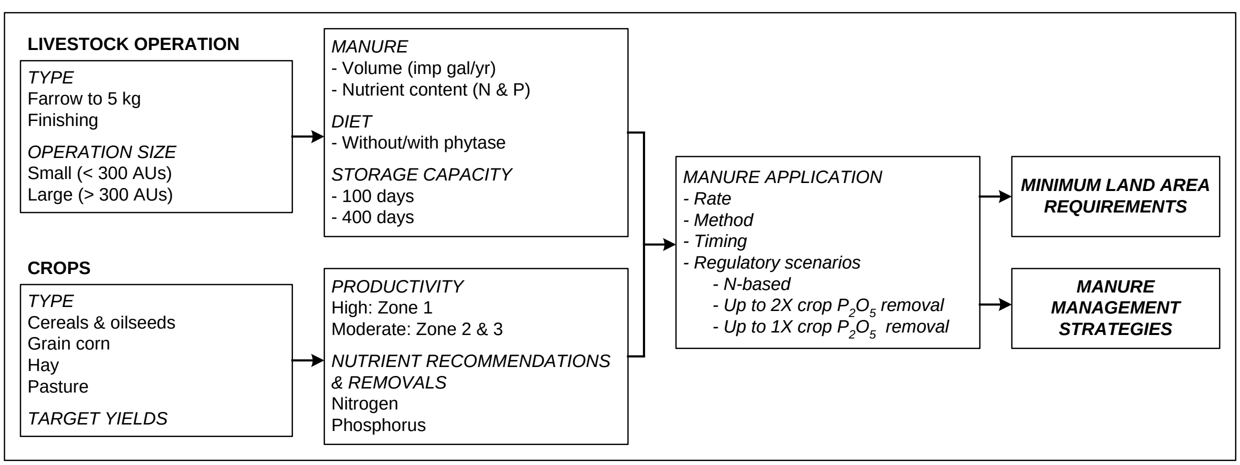

Figure 4.1 General framework for the assessment of manure management strategies.

4.1 Presentation of the model farms

For the assessment, four representative crop rotations for two different regions of the Province were chosen: annual crops in the R.M. of Hanover (cereals and oilseeds and grain corn) and perennial crops in the R.M. of La Broquerie (hay and pasture) (Table 4.1). In addition, farms in these areas were further differentiated by the type of livestock (farrow to 5 kg and finishing), the size of the operation (small and large) and the animal diet (without or with phytase) (Table 4.2).

Table 4.1 Description of the crop rotations, target yields, nutrient recommendations and removals and manure application method and timing.

Variables	Cropping systems			
Rural municipality	Hanover		La Broquerie	
Soil type	Clay (medium to heavy soils)		Sand (light soil)	
Agricultural productivity	High		Moderate	
Crop rotation	Cereals & oilseeds	Grain corn	Hay	Pasture
Crop target yield[1]	-	110 bu/ac	3 ton/ac	3 ton/ac
N recommendations (lb/ac)[2]	94	130	100	100
P_2O_5 removal (lb/ac)[3]	32	48	30	5
Application method	Injection	Injection	Broadcast	Broadcast
Application timing	Fall	Fall	Summer	Summer

[1] Rotation comprised of wheat (target yield of 50 bu/ac, 95 lb N/ac recommended, 29 lb P_2O_5/ac removed), canola (target yield of 40 bu/ac, 115 lb N/ac recommended, 41 P_2O_5/ac removed) and oats (target yield of 105 bu/ac, 72 lb N/ac recommended, 27 P_2O_5/ac removed).
[2] Recommendations for target yield according to the Soil Fertility Guide (MAFRI, 2001).
[3] Removals for grain crops are for harvested grain only; removal for hay is for entire forage harvest; removals for grain crops and hay are based on values from the Soil Fertility Guide (MAFRI, 2001). Removal from grazed pasture is in the form of liveweight gain (since most of the forage nutrients ingested are re-excreted by the animal) and is based on University of Manitoba research with liquid hog manure applied onto intensive beef cattle grazing pastures near La Broquerie (Kelwin Management Consulting, 2005).

Table 4.2 Description of the typical livestock operations.

Livestock type	Size of the operation	Typical number of pig places [1]	Animal units[2]	Manure production (imp gal/year)[3]
Farrow to 5 kg	Small	600	150	1,107,921
	Large	3,000	750	5,539,605
Finishing[4]	Small	2,000	286	1,138,800
	Large	8,000	1,144	4,555,200

[1] Scott Dick (Elite Swine), personal communication.
[2] Farrow to weanlings (5 kg), 0.25 animal unit and finishing, 0.14 animal unit.
[3] 5.06 imp gal/day/head for farrow to 5 kg and 1.56 imp gal/day/head for finishing (Manitoba Agriculture, 1998).
[4] For both finishing operations (without and with phytase).

4.1.1 Description of cropping systems

As mentioned, to represent adequately the selected regions, four different crop systems were selected (Table 4.1). The first system was defined as a cereals and oilseeds rotation. Three crops were part of that rotation: wheat, canola and oats. The crop selection was based on statistics of acreages and yields from Manitoba Agricultural Services Corporation[6] (MASC) (Tables A.1 to A.3 in Appendix A). For Hanover, the three crops with the most acreage for the past five years were canola (23% of the annual crop acreages), wheat (18% of the annual crop acreages), and oats (10% of the annual crop acreages). For this annual rotation, nutrient recommendations and removal were combined to determine the N and P crop rotation requirements. The second cropping system examined was continuous grain corn. Corn was the annual crop with the third most acreage (14%) in Hanover. The last two cropping systems were the most representative of La Broquerie: perennial forage used as hay or pasture.

Crop target yields were established with MASC data and the Manure Management Planner Manual (Racz et al., 2005). A rolling average plus 10% except for corn grain (rolling average only) was used to assess crop target yields. With these target yields, general recommendations from the Soil Fertility Guide (MAFRI, 2001) and best professional judgement were used to estimate nutrient recommendations and removal. Manure application rates were calculated using MARC2005[7] software. For the N recommendations, soil moisture category was “ideal”; fall NO_3-N rating was “medium” and fall applied manure was assumed to be 17% less available than spring applied manure. N recommendations varied from 94 lb N/ac (cereals and oilseeds) to 130 lb N/ac (grain corn) and P_2O_5 removal from 5 lb/ac (pasture) to 48 lb/ac (grain corn) (Table 4.1). As mentioned, P_2O_5 removal rate for pasture represented the net removal after taking into account the re-excretion by the grazing animal. The figure for estimating the P removed by grazing beef cattle is based on the P in the liveweight gain of the animals (live cattle contain 7 to 9 g P per kg or 15 -20 g P_2O_5 per kg or 15-20 lb P_2O_5 per 1,000 lb; Lynch and Caffrey, 1997). According to recent research conducted by the University of Manitoba on manured pastures near La Broquerie, typical weight gains have been approximately 250 lbs live weight per acre, which translates into only 4-5 lbs of P_2O_5 being removed.

4.1.2 Description of livestock operations

For this preliminary assessment, two types of pig operations were chosen to represent the Manitoba pig industry. For farrow to 5 kg, 600 and 3,000 sows (150 and 750 animal units) were considered as typical for small and large operations, respectively; for finishing (without and with phytase), the numbers of pig places were 2,000 and 8,000 (286 and 1,144 animal units) for small and large operations, respectively (Table 4.2). For each operation type, volumes of

[6] Manitoba Agricultural Services Corporation, http://www.mmpp.com/ (verified February 2, 2006)
[7] Manure Application Rate Calculator version 1.2.15 (available online at http://www.gov.mb.ca/agriculture/livestock/ , verified 11/10/2005)

manure produced per year were then calculated: approximately 1.1M and 5.5M imp gal for small and large farrow to 5 kg operations and 1.1M and 4.6M imp gal for small and large finishing operations[8].

Two different datasets were utilized to establish typical manure nutrient contents (Table 4.3). The first set was representative of a diet without phytase (Fitzgerald and Racz, 2001) and the second of a diet with phytase (Industry co-operators, 2005). Mean concentrations of total N in manure were 17.4 lb N/1,000 imp gal for farrow to 5 kg, 34.0 lb N/1,000 imp gal for finishing without phytase and 34.1 lb N/1,000 imp gal for both finishing with phytase (finishing-phy). As for P, mean concentrations in manure were 6.6 lb P/1,000 imp gal for farrow to 5 kg, 10.0 lb P/1,000 imp gal for finishing and 6.7 lb P/1,000 imp gal for finishing-phy. Average dry matter contents in manure ranged from 3.0 and 3.7 percent for all types of pigs.

Table 4.3 Description of nutrients and dry matter content for pig manure (Fitzgerald and Racz, 2001 and Industry co-operators, 2005).

Livestock	Total N	NH_4-N	Total P	Total K	Dry matter %
	(lb/1000 imp gal)				
Farrow to 5 kg[1] (n = 37)	17.4	12.4	6.6	10.1	3.0
Finishing[1] (n = 92)	34.0	25.9	10.0	15.3	3.7
Finishing-phy[2,3] (n = 181)	34.1	24.5	6.7	14.9	3.4

[1] Fitzgerald and Racz (2001).
[2] Industry co-operators (2005).
[3] With phytase incorporated in diets at commercial feeding rates.

4.2 Nutrient management

Among the different liquid manure application methods and timing, manure injection in fall was chosen for cereals, oilseeds, grain corn and broadcast in spring for grasses (hay and pasture). As for custom manure application, injection and broadcast, costs for rates greater than 3,500 imp gal/ac, varied between \$0.009 and \$0.012/imp gal for variable distances[9] (0 to 3.0 miles) (Table 4.4). These manure application costs compared very well with those presented by Khakbazan et al. (2004).

[8] This is an estimate for engineering of manure storage facility. Now, it is likely that barns are more efficient in the usage of water and this is likely an over-estimation of manure volume. Jennifer Shaykewich (Manitoba Conservation), personal communication.
[9] Scott Dick (Elite Swine Inc.), personal communication.

Table 4.4 Costs of custom liquid manure injection and broadcast.

Radius (miles)	Cost ($/imp gal)[1,2]
0 - 1.5	$0.009
1.5 - 2.0	$0.010
2.0 - 2.5	$0.011
2.5 - 3.0	$0.012

[1] For rates greater than 3,500 imp gal/ac.
[2] Scott Dick (Elite Swine Inc.), personal communication.

According to the best professional judgment of industry and government representatives, even if manure application rates lower than 3,500 imp gal/ac are now technically feasible[10], they are not practical in many areas in Manitoba. For example, preliminary assessment of an application rate of 200 imp gal/ac with a conventional drag hose system within one mile of the storage would cost about $0.0573/imp gal[11]. This cost is at least six times higher than those for application rates in excess of 3,500 imp gal/ac. Also, this cost could easily increase by 20-50% for application at greater distances which would probably be required given the low rates of application on nearby land. Therefore, ***for the purpose of this study, all manure management strategies with application rates lower than 3,500 imp gal/ac were regarded as impractical and were not financially assessed.***

4.3 Manure transport

In the case where there is not enough local land available, manure transport outside of the region can be one of the management strategies for excess manure. In Manitoba, this scenario is unlikely to become popular in the foreseeable future, mainly because the necessary infrastructure and equipment are not adequate or in place. Conversely, this is a common alternative in Ontario for 5 to 10 km distances[12]. Three plausible options were examined: transport with a tractor-drawn tanker over a 20-km distance, transport with a truck over a 20-km distance and with a truck over a 40-km distance. Transport costs ranged between $0.018/imp gal by truck (20 km) and $0.037/imp gal by tank (40 km) (Table 4.5).

[10] Some types of equipment can spread as low as 1,800 imp gal/ac (Marc Trudelle, Manitoba Conservation, personal communication).
[11] Scott Dick (Elite Swine Inc.), personal communication.
[12] Scott Dick (Elite Swine Inc.), personal communication.

Table 4.5 Cost of manure transport with different vehicles and diverse distances.

Transport mode	Distances (km)	Transport costs[1] ($/imp gal)
Tank	20	0.037
Truck	20	0.018
Truck	40	0.030

[1] Scott Dick (Elite Swine Inc.), personal communication.

4.4 Manure treatment

As for the previous strategy, manure treatment could be necessary when not enough land is available for manure application according to the new environmental regulations. There is a wide range of treatment methods available, although many of these treatment methods have not been fully evaluated under Manitoba conditions. A review and description of the principal treatment alternatives and systems was presented by Flaten et al. (2003). Most of these technologies can be classified in the following categories: mechanical separation, aerobic treatment (with or without nitrification and denitrification), anaerobic treatment, composting, filtration, drying and fertilizers production, biological treatment and finally, flotation processes. For the purpose of this project, five technologies from two treatment process categories were examined: solid-liquid separation with polymers (Vanotti et al. (2002), Filtramat® and, Lisox® separation process) and aerobic treatment (Biofertile® and Biosor® technologies).

4.4.1 Solid-liquid separation

Solid-liquid separation is a manure treatment technology to separate the liquid fraction from the solids. It has been generally used in the last few years as a physical treatment process for animal manure, mainly for the improvement of its handling properties by taking coarse solids and fibre out of slurry. The main advantages of this treatment are: reducing the initial size of the storage facility, increasing handling flexibility for ultimate disposal and use of the manure and extending time between solids cleanout (Tyson, 1997). Because most of the P in pig manure is in the solids, separating the liquids from the solids allows more precise management of the N:P ratio in the manure to be applied (Canadian Pork Council, 2005). The two main types of solid-liquid separators are mechanical and gravity systems. The basic problem with this manure treatment is that most of the organic nutrient elements (N and P) are contained in fine particles (Vanotti et al., 2002). Therefore, it is necessary to remove particles smaller than 0.25 mm in order to effectively reduce nutrient and odour-generating compounds contained in liquid manure. The range of efficiency can be really wide. To be more effective, chemicals are required to enhance the separation process. For example, organic polymers are added to increase separation of suspended solids and carbon compounds from liquid hog manure

(Vanotti et al. 2002). Consequently, only the solid-liquid separation technologies with polymer treatment were examined. Three technologies were chosen: LISOX®, FILTRAMAT® and the technology presented by Vanotti et al. (2002). Table 4.6 summarized the principal characteristics of each solid-liquid separation technologies; more information is presented in Appendix B.

Table 4.6 Manure solid-liquid separation with polymers treatment technologies.

Variable	LISOX®	FILTRAMAT® (v. C)	Vanotti et al. (2002)
Origin	Quebec	Quebec	North Carolina
Supplier	Corporation HET	Envirogain	USDA-ARS
Polymer	Agrifloc-EM	Flocculants agent	Polyacrylamide (PAM)
Capacity (imp gal/day)	1,100 to 5,500	Up to 17,500	Up to 6,600
N removal (%)	50	20	85
P removal (%)	80 - 95	30	92
Solid removal (%)	80 - 85	60	95
Ratio N:P in effluent	> 7	Not specified	12.1
Costs of operation	\$0.010/imp gal [1]	\$0.0085/imp gal [2] \$0.011/imp gal [3]	\$US1.27/finished pig [4]
Investment costs	\$200,000 - \$490,000	\$120,000 (approx.)	Not specified

[1] Estimated for a 2,000-head operation producing 4,000 m^3 (900,000 imp gal) of manure per year.
[2] Estimated for 17,600 imp gallons of manure per day and electricity cost of \$0.08/kwh. Flocculants agent cost of \$7.77 per 1,000 imp gallons of manure (2.5 lb/1,000 imp gal).
[3] Estimated for 4,400 imp gallons of manure per day and electricity cost of \$0.08/kwh. Flocculants agent cost of \$7.77 per 1,000 imp gallons of manure (2.5 lb/1,000 imp gal).
[4] Based on 2.8 groups of pigs per year for a 1000-head operation (\$US 4.41/kg PAM).

4.4.2 Aerobic manure treatment

The second type of manure treatment considered is more complex and sophisticated. Aerobic treatment is a natural degradation and purification process. These aerobic treatment systems accomplish water purification, nutrient management as solids and an overall pollution reduction (water, air and soil) with odours and pathogens control. Two technologies were selected for this study: Biofertile® and Biosor®. Principal characteristics of each technology are presented in Table 4.7; more information on these treatment systems is presented in Appendix B.

4.5 Storage building

As mentioned, this manure management strategy illustrates the impacts of the SMAs component concerning prohibition of winter manure application in certain areas. Building proper manure storage facilities will allow producers to store manure until application is permitted and conditions are optimum. New or expanding operations and operations with 400 animal units are already prohibited from applying manure between November 10 and April 10 of the following year. Existing operations with between 300 and 400 animal units have until November 10, 2010 to comply with this prohibition. Therefore, storage facilities need to be sufficient to store manure for a minimum of 180 days to allow sometime for spreading, for all large livestock operations. However, most of the permits for these earthen storage facilities require a capacity of 400 days of storage[13].

Table 4.7 Aerobic manure treatment technologies.

Variable	BIOFERTILE®	BIOSOR®
Origin	Quebec	Quebec
Supplier	Envirogain	H_2O Innovation
Advantages	Water purification with pathogens, contaminants, odours and GHG control	Simplicity, efficiency and robustness. Odour treatment
Capacity (imp gal/day)	85,500	2,200 – 110,000
N removal (%)	99	93.7
P removal (%)	99	90.0
Solid removal (%)	> 99	99.8
Nutrient status	3 – 7 – 2	
Total costs	$0.036/imp gal [1,2] - $0.068/imp gal [1] $0.027/imp gal [2,3] - $0.036/imp gal [3]	About $0.045/imp gal
Investment costs	$300,000 $0.014/imp gal [2] - $0.018/imp gal	$425,000

[1] Estimated for manure production ranged from 2,200 to 4,400 imp gal/day. Included financial and operation costs (energy, maintenance and operation).
[2] Total cost calculation included sale of solid end-product as fertilizer by the company.
[3] Estimated for manure production of about 18,000 imp gal/day. Included financial and operation costs.

According to the new proposed P regulation, prohibition of all winter manure application will also be in force for small pig operations (under 300 animal units) in the Red River Valley and regularly inundated areas. Therefore, these small operations will have to build sufficient manure storage to comply. The costs of manure storage will depend mostly upon the volume required for waste storage based on the size and the type of operation. Table 4.8 presents the construction costs of different manure storage. The initial cost of manure storage will depend greatly upon the volume required for waste storage based on the size and type of operation. The economies of scale indicate that the cost per gallon for larger operations will be less than those for smaller operations, and the total cost on a per pig basis should also be less for a larger operation (Canadian Pork Council, 2005). For the purpose of this study and based on best professional judgment of industry representatives, earthen manure storage was the

[13] Petra Loro (MAFRI), personal communication.

chosen type of storage and construction costs used for assessment were $0.02/imp gal for large operations and $0.05/imp gal for small operations.

Table 4.8 Construction cost for manure storage building.

Type of liquid manure storage	Costs ($ per imp gal)	Reference
Earthen	0.032 – 0.040	Brethour et al. (2004)
Concrete-covered, concrete tank	0.241	
Open concrete tank	0.209	
Earthen	0.02[1] – 0.05[2]	Gary Plohman (MAFRI)
Earthen	0.004 - 0.116	Canadian Pork Council (2005)
Concrete	0.055 – 0.261	
Steel tanks	0.132 – 0.264	

[1] For large hog operation: more than 2 million imp gallons (400 days).
[2] For small hog operation: about 0.5 million imp gallons (400 days).

5. QUANTITATIVE ASSESSMENT OF MANAGEMENT STRATEGIES

Under the new proposed regulation, many hog farmers will produce much more manure than they can apply on their current land base. Therefore, without substantial changes to land use or cropping systems, the industry will be left with four options: increase land base, reduce production, transport excess manure to non-surplus regions, or treat the manure. To assess the impact of the new environmental regulations, five manure management strategies were defined (Table 5.1). For all strategies, manure application rates were assessed according to three different nutrient management options (simulations): N-based nutrient recommendations, up to two times crop P_2O_5 removal and up to one times crop P_2O_5 removal. MARC2005 was used to determine the manure application rate for every simulation. This analysis supposed that all pig farms eventually will have to be in compliance and costs associated with compliance were assumed for a single year.

The first manure management strategy consisted of simulations where enough land was available for N or P-based annual manure application at the cost of $0.009/imp gal. Producers had a land agreement for manure application and no financial interest in the crop produced on the manured land. For the second manure strategy, multi-year manure P application (intermittent manure application on an N-basis) was examined. For this strategy, we also considered that pig producers had a land agreement. As for the third strategy, current land base available was sufficient for N-based annual manure application and any manure that could not be applied on this base needed to be transported out of the farm land over several distances. The fourth strategy explored the costs of manure treatment when not enough land was available for manure application. Finally, the last management strategy assessed the economic impacts of the SMAs on prohibition of winter manure application with the construction of adequate manure storage.

This chapter consists of the presentation of quantitative analysis of the selected manure management strategies defined to illustrate farm management strategies that could take place following the possible implementation of the new environmental regulations.

Table 5.1 Manure management strategies for the economic impact assessment of new proposed regulations.

Strategy	Description	Costs considered
1	Current land base sufficient for N or P-based **annual** manure application at the cost of $0.009/imp gal. Pig producers with land agreement, but no financial interest in crops produced on that land.	Manure application
2	Current land base sufficient for N-based annual manure application at the cost of $0.009/imp gal. Extra land available for annual manure application at the cost of $0.011/imp gal. **Multi-year manure application** for crop P requirements. Pig producers with land agreement but no financial interest in crops produced on that land.	Manure application
3	Current land base sufficient for N-based annual manure, no additional spreading land locally available. Excess manure for P-based application **transported over 20 or 40-km distance**.	Transport of manure Manure application
4	Current land base sufficient for N-based annual manure application, no additional spreading land locally available. Only option: **manure treatment**.	Manure treatment
5	No winter application, not enough **storage capacity**.	Construction of storage facility

5.1 Strategy 1: Current land base sufficient for N or P-based manure application

For this strategy, there was no restriction on the land base for manure application and the land was leased by the producer. The main objective for this strategy was to assess the manure application rates for all cropping systems and pig operations and also to determine the acres required to comply with the new environmental regulations. These strategy simulation results are regarded as baseline information and data throughout the present study. For farrow to 5 kg, annual application rates ranged from 8,550 to 11,820 imp gal/ac for N-based simulations, from 620 to 6,000 imp gal/ac for up to two times crop P_2O_5 removal and from 310 to 3,000 imp gal/ac for one times crop P_2O_5 removal (Table 5.2). For finishing, annual application rates for N-based varied between 4,090 and 5,650 imp gal/ac, between 450 and 4,360 imp gal/ac for up to two times crop P_2O_5 removal simulations and between 230 and 2,180 imp gal/ac for one times crop P_2O_5 removal. As for finishing-phy, annual application rates varied from 4,270 to 5,910 imp gal/ac for N-based, from 620 to 6,000 imp gal/ac for up to two times crop P_2O_5 removal and finally, from 310 to 3,000 imp gal/ac for one times crop P_2O_5 removal. Detailed results of all simulations are presented in Tables C.1 and C.2 Appendix C.

Table 5.2 Manure application rates for all pig operations and cropping systems for strategy 1.

Location	Livestock	Crop rotations	Manure application rates (imp gal/ac) N-based	2X crop P_2O_5 removal	1X crop P_2O_5 removal
Hanover	Farrow to 5 kg	Cereals & oilseeds	8,550	4,000	2,000*
		Grain corn	11,820	6,000	3,000*
	Finishing	Cereals & oilseeds	4,090	2,910*	1,450*
		Grain corn	5,650	4,360	2,180*
	Finishing-phy	Cereals & oilseeds	4,270	4,000	2,000*
		Grain corn	5,910	5,910	3,000*
La Broquerie	Farrow to 5 kg	Hay	11,110	3,750	1,880*
		Pasture	11,110	620*	310*
	Finishing	Hay	5,260	2,730*	1,360*
		Pasture	5,260	450*	230*
	Finishing-phy	Hay	5,560	3,750	1,880*
		Pasture	5,560	620*	310*

* Manure application rate not practical for this cropping system and manure type (see section 4.2).

As mentioned, for this study manure application rates lower than 3,500 imp gal/ac are not regarded as practical (section 4.2). It is assumed that land application costs at lower rates are greater than the costs of alternative manure management strategies. Moreover in some cases, limitations of the current application equipment and local infrastructures, exclude any lower application rates (Olson and Paterson, 2005). Therefore, all manure management strategy simulations with application rates lower than 3,500 imp gal/ac in this study were considered not practical for most areas of the Province and therefore, these simulations were not evaluated economically.

Overall, annual manure application rates were higher for N-based management simulation and lower for one and two times crop P_2O_5 removal. As for the lowest application rates, they were calculated for the grass pasture rotations where the net removal of nutrients is the lowest.

Manure application rates were used to calculate the minimum land requirements for each nutrient management option. As mentioned, the N-based minimum land requirement established the original land base used for all scenarios. This premise appeared to be the most representative of the actual situation where land requirements are usually determined according to the Farm Practices Guideline for Hogs (Manitoba Agriculture, 1998)[14].

As expected, for each pig operation, the most restrictive nutrient management option (up to one times crop P_2O_5 removal) required the largest land area (Tables 5.3 and 5.4). For small farrow to 5 kg operations, land requirements ranged from 369 acres (grain corn) to 3,574 acres

[14] Petra Loro (MAFRI), personal communication.

(pasture). For small finishing operations, land requirements varied between 522 acres (grain corn) and 4,951 acres (pasture) and for finishing-phy between 380 acres (grain corn) and 3,674 acres (pasture). As for large pig operations, land requirements for farrow to 5 kg varied from 1,847 acres (grain corn) to 17,870 (pasture), for finishing, from 2,090 acres (grain corn) to 19,805 acres (pasture) and for finishing-phy, from 1,518 acres to 14,694 acres (pasture).

Table 5.3 Minimum land area requirements for manure application for small pig operations for manure management strategy 1.

Location	Livestock	Crop rotations	Minimum land area (acres) N-based	2X crop P_2O_5 removal	1X crop P_2O_5 removal
Hanover	Farrow to 5 kg	Cereals & oilseeds	130	277	554*
		Grain corn	94	185	369*
	Finishing	Cereals & oilseeds	278	391*	785*
		Grain corn	202	261	522*
	Finishing-phy	Cereals & oilseeds	267	285	569*
		Grain corn	193	193	380*
La Broquerie	Farrow to 5 kg	Hay	100	295	589*
		Pasture	100	1,787*	3,574*
	Finishing	Hay	217	417*	837*
		Pasture	217	2,531*	4,951*
	Finishing-phy	Hay	205	304	606*
		Pasture	205	1,837*	3,674*

* Manure application rate not practical for this cropping system and manure type (see section 4.2).

Table 5.4 Minimum land area requirements for manure application for large pig operations for manure management strategy 1.

Location	Livestock	Crop rotations	Minimum land area (acres) N-based	2X crop P_2O_5 removal	1X crop P_2O_5 removal
Hanover	Farrow to 5 kg	Cereals & oilseeds	648	1,385	2,770*
		Grain corn	469	923	1,847*
	Finishing	Cereals & oilseeds	1,114	1,565*	3,142*
		Grain corn	806	1,045	2,090*
	Finishing-phy	Cereals & oilseeds	1,067	1,139	2,278*
		Grain corn	771	771	1,518*
La Broquerie	Farrow to 5 kg	Hay	499	1,477	2,947*
		Pasture	499	8,935*	17,870*
	Finishing	Hay	866	1,669*	3,349*
		Pasture	866	10,123*	19,805*
	Finishing-phy	Hay	819	1,215	2,423*
		Pasture	819	7,347*	14,694*

* Manure application rate not practical for this cropping system and manure type (see section 4.2).

Overall, management simulations of the new proposed regulations showed important increases especially for pasture. For simulations of up to one times crop P_2O_5 removal for cereals and oilseeds, increases in land requirement compared to N-based, ranged from 2.1 times for finishing-phy to 4.3 times for farrow to 5 kg (Table 5.5). As mentioned, P-based simulations for perennial forage presented the highest increases in land requirement, ranging from 3.0 times for finishing-phy and to 35.8 times for farrow to 5 kg and pasture. Grain corn was the cropping system that showed the lowest increases of the simulations: between 2.0 times (finishing-phy) and 3.9 times (farrow to 5 kg).

Manure application costs are dependent on manure volume and distance to the land where the manure is applied (Table 4.4). Since the land base needed is assumed to be sufficient for all cropping systems in this strategy and all manure is applied at the same cost, manure management is simply proportional to the volume of manure produced. Application costs for the nutrient management options where manure application rates were higher than 3,500 imp gal/ac, ranged from $9,971 (small operation) to $49,856 (large operation) for farrow to 5 kg and from $10,249 (small operation) to $40,997 (large operation) for finishing (without and with phytase) (Table 5.6). However, it is very important to note that all manure application rates for the most restrictive nutrient management option (up to one times crop P_2O_5 removal) were under 3,500 imp gal/ac. Therefore, costs were not assessed for these strategy simulations. In addition, the cropping systems with manure application rates lower than 3,500 imp gal/ac for simulation with up to two times crop P_2O_5 removal were hay (finishing operations) and pasture (all pig operations).

Table 5.5 Increase of minimum land required for manure application for strategy 1.

Location	Livestock	Crop rotations	Increase in land required[1] 2X crop P_2O_5 removal	1X crop P_2O_5 removal
Hanover	Farrow to 5 kg	Cereals & oilseeds	2.14	4.28*
		Grain corn	1.97	3.94*
	Finishing	Cereals & oilseeds	1.41*	2.82*
		Grain corn	1.30	2.59*
	Finishing-phy	Cereals & oilseeds	1.07	2.14*
		Grain corn	1.00	1.97*
La Broquerie	Farrow to 5 kg	Hay	2.96	5.91*
		Pasture	17.92*	35.84*
	Finishing	Hay	1.93*	3.87*
		Pasture	11.69*	22.87*
	Finishing-phy	Hay	1.48	2.96*
		Pasture	8.97*	17.94*

[1] Compared with land available (N-based minimum land requirements).
* Manure application rate not practical for this cropping system and manure type (see section 4.2).

Table 5.6 Costs for manure application for manure management strategy 1.

Livestock	Size	Manure volume (imp gal per year)	Application costs[1] ($)
Farrow to 5 kg	Small	1,107,921	9,971
	Large	5,539,605	49,856
Finishing [2]	Small	1,138,800	10,249
	Large	4,555,200	40,997

[1] For manure application rates higher than 3,500 imp gal/ac only.
[2] For both finishing operations (without and with phytase).

5.2 Strategy 2: Multi-year manure P-based application

The purpose of this strategy was to illustrate a multi-year application of manure-P followed by a determined number of years without manure application. In most cases, this manure management practice represents the most realistic way of dealing with low annual rates of manure application that are not physically or economical practical. Manure application rates were capped by the lower result of either the regulated N-based rates or rates for P removal for crops for up to five years (Manitoba Conservation, 2006). Therefore, N-based rate was used for the first year of the rotation and for the remaining years of the rotation, no manure was applied on that land. For all simulations, land base available was sufficient for N-based annual manure application at the cost of $0.009/imp gal and extra land available for annual manure application at the cost of $0.011/imp gal. For this strategy, it was assumed that the pig producer had a land agreement for manure application with no financial interest in any of the crops produced on that land.

First, the duration of the multi-year P application was determined by dividing N-based manure application rates by the application rates of the most restrictive nutrient management option (Table 5.7). Intervals between manure applications varied between 2 years to 5 years for annual crops and hay. The pasture cropping system was not evaluated economically because of the extremely low, impractical manure application rates, even with up to 5 years of removal. For the finishing operation, two crop systems, cereals and oilseeds and hay, were not evaluated economically, once again because of the impractical manure application rates under a P-based scenario.

Table 5.7 Duration of the multi-year manure P-based application period (strategy 2).

Location	Livestock	Crop rotations	Number of years
Hanover	Farrow to 5 kg	Cereals & oilseeds Grain corn	4 4
	Finishing	Cereals & oilseeds Grain corn	3 3
	Finishing-phy	Cereals & oilseeds Grain corn	2 2
La Broquerie	Farrow to 5 kg	Hay Pasture	5 [1] n.r. [2]
	Finishing	Hay Pasture	4 n.r.
	Finishing-phy	Hay Pasture	3 n.r.

[1] Manure application rates capped by removal rates for P up to 5 years.
[2] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

Manure application costs for small operations were quite similar for all cropping systems: for small pig operations; they varied on an annual basis between \$10,908 (up to two times crop P_2O_5 removal) and \$11,795 (multi-year application) for farrow to 5 kg, between \$10,760 (up to two times crop P_2O_5 removal) and \$11,957 (multi-year application) for finishing and finally between \$10,260 (up to two times crop P_2O_5 removal) and \$11,778 (multi-year application) for finishing-phy (Table 5.8). For large pig operations, annual average manure application costs ranged from \$55,310 (up to two times crop P_2O_5 removal) to \$59,131 (multi-year application) for farrow to 5 kg, from \$43,133 (up to two times crop P_2O_5 removal) to \$47,829 (multi-year application) for finishing and from \$40,997 (up to two times crop P_2O_5 removal) to \$47,072 (multi-year application) for finishing-phy. Detailed results are presented in Table C.3 (Appendix C).

Once again, the economic impacts on the pasture cropping system were not examined, since all manure application rates for the manure management strategies were lower than 3,500 imp gal/ac. For most pig operation and cropping systems, N-based manure application costs were the lowest; this option represented the baseline and the least restrictive manure management strategy. The costs of adjusting to a two times crop removal rate for P were greatest for farrow to 5 kg operation, but negligible for finishing operations where phytase is used (Table 5.9). For farrow to 5 kg, costs for the multi-year P-based application averaged 1.17 times N-based manure application cost over all cropping systems. For finishing, costs for multi-year P-based application averaged 1.16 times N-based application and for finishing-phy, 1.12 times. The average increase in costs was slightly greater for hay cropping systems than for annual cropping systems.

Table 5.8 Manure application costs for annual application and multi-year P-based application strategy for small and large pig operations (strategy 2).

Location	Livestock	Crop rotations	Manure application cost ($)			
			Small operations		Large operations	
			2X crop P_2O_5 removal	Multi-year	2X crop P_2O_5 removal	Multi-year
Hanover	Farrow to 5 kg	Cereals & oilseeds	10,908	11,635	55,816	58,165
		Grain corn	11,086	11,629	55,310	58,170
	Finishing	Cereals & oilseeds	n.r. [1]	11,766	n.r.	47,069
		Grain corn	10,760	11,770	43,133	47,069
	Finishing-phy	Cereals & oilseeds	10,393	11,388	41,573	45,552
		Grain corn	10,260	11,389	40,997	45,554
La Broquerie	Farrow to 5 kg	Hay	11,144	11,795	57,195	59,131
		Pasture	n.r.	n.r.	n.r.	n.r.
	Finishing	Hay	n.r.	11,957	n.r.	47,829
		Pasture	n.r.	n.r.	n.r.	n.r.
	Finishing-phy	Hay	10,990	11,778	43,964	47,072
		Pasture	n.r.	n.r.	n.r.	n.r.

[1] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

Table 5.9 Manure application cost increases for annual application and multi-year P-based application strategy for small and large pig operations (strategy 2).

Location	Livestock	Crop rotations	Manure cost increase	
			2X crop P_2O_5 removal	Multi-year
Hanover	Farrow to 5 kg	Cereals & oilseeds	1.12	1.17
		Grain corn	1.11	1.17
	Finishing	Cereals & oilseeds	n.r. [1]	1.15
		Grain corn	1.05	1.15
	Finishing-phy	Cereals & oilseeds	1.01	1.11
		Grain corn	1.00	1.11
La Broquerie	Farrow to 5 kg	Hay	1.12	1.18
		Pasture	n.r.	n.r.
	Finishing	Hay	n.r.	1.17
		Pasture	n.r.	n.r.
	Finishing-phy	Hay	1.07	1.15
		Pasture	n.r.	n.r.

[1] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

5.3 Strategy 3: Current land base sufficient for N-based annual manure, no additional spreading land locally available, transport of excess manure

As mentioned, the intent of this scenario was to assess the economic impacts of manure management when no extra land is available for manure application and the only option for the pig producer is to transport the manure where it could be applied on an N-basis. To assess the volume of manure that needs to be transported, only the nutrient management option of annually applying up to two times crop P_2O_5 removal was examined, because many of the one times crop P_2O_5 removal rates were considered impractical. Three possibilities were looked at: transport with a tractor-drawn tanker over a 20-km distance, transport with a truck over a 20-km distance and with a truck over a 40-km distance. Transport with a tractor-drawn tank was the costly option per gallon of manure (Table 4.5). For farrow to 5 kg operations, manure transport with a tractor-drawn tank over 20 km (plus application) cost[15] up to $37,128 for small operations and up to $185,639 for the large ones (Table 5.10). As for finishing operations, manure transport and application cost $19,870 for small operations and $79,478 for large operations, both for grain corn. Finally, for finishing-phy, manure transport and application cost up to $10,294 for small operations and up to $95,864 for large operations. Detailed results are presented in Table C.4 in Appendix C. These costs represented manure management cost increases of up to 3.7 times for farrow to 5 kg (hay), 1.9 times for finishing (grain corn) and 2.3 for finishing-phy (hay).

Table 5.10 Total manure management costs for strategy 3: transport with tractor-drawn tank for 20 km.

Location	Livestock	Crop rotations	Overall costs[1] ($)		Increased cost (ratio)[2]
			Small operation	Large operation	
Hanover	Farrow to 5 kg	Cereals & oilseeds	31,786	158,932	3.19
		Grain corn	30,156	150,778	3.02
	Finishing	Cereals & oilseeds	n.r. [3]	n.r.	n.r.
		Grain corn	19,870	79,478	1.94
	Finishing-phy	Cereals & oilseeds	12,914	51,654	1.26
		Grain corn	10,249	40,997	1.00
La Broquerie	Farrow to 5 kg	Hay	37,128	185,639	3.72
		Pasture	n.r.	n.r.	n.r.
	Finishing	Hay	n.r.	n.r.	n.r.
		Pasture	n.r.	n.r.	n.r.
	Finishing-phy	Hay	23,966	95,864	2.34
		Pasture	n.r.	n.r.	n.r.

[1] Total costs: transport and manure application compared with N-based manure management costs (Table 5.6).
[2] Compared to N-based manure management costs: farrow to 5 kg $9,971 and $49,856 for small and large operations respectively and finishing or finishing-phy, $10,249 and $40,997.
[3] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

[15] Total costs comprised manure transport and application at a cost of $0.009/imp gal.

For transport with a truck over the same distance, overall costs of transport plus application were lower than for tractor-drawn tanker since transport cost per gallon was lower (Table 5.11). For farrow to 5 kg, transport and application costs were up to $22,816 for small operations and to $114,078 for the large ones. For finishing, total costs were up to $14,799 for small operation and up to $59,197 for large operations. Finally, for finishing-phy, total costs represented up to $16,737 for small operations and to $66,948 for the large operations. Highest transport costs were once again calculated for pasture since the volume of extra manure for this cropping system is the largest of any cropping system. Once again, these costs translated into significant increases over the baseline management scenario, ranging from 2.0 to 2.3 times N-based manure management costs for farrow to 5 kg, 1.4 times for finishing and from 1.1 to 1.6 times for finishing-phy. Detailed results are presented in table C.5 (Appendix C).

As for transport with a truck for a longer distance (40 km), costs were higher than the previous alternative but lower than with a tank (Table 5.12). For this option, manure management increases ranged from 2.6 to 3.2 times for farrow to 5 kg, 1.8 times for finishing and from 1.0 to 2.1 times for finishing-phy. Detailed results are presented in table C.6 (Appendix C).

Table 5.11 Total manure management costs for strategy 3: transport with truck for 20 km.

Location	Livestock	Crop rotations	Overall costs[1] ($) Small operation	Overall costs[1] ($) Large operation	Increased cost (ratio)[2]
Hanover	Farrow to 5 kg	Cereals & oilseeds	20,289	101,446	2.03
		Grain corn	19,518	97,590	1.96
	Finishing	Cereals & oilseeds	n.r.[3]	n.r.	n.r.
		Grain corn	14,799	59,197	1.44
	Finishing-phy	Cereals & oilseeds	11,509	46,037	1.12
		Grain corn	10,249	40,997	1.00
La Broquerie	Farrow to 5 kg	Hay	22,816	114,078	2.29
		Pasture	n.r.	n.r.	n.r.
	Finishing	Hay	n.r.	n.r.	n.r.
		Pasture	n.r.	n.r.	n.r.
	Finishing-phy	Hay	16,737	66,948	1.63
		Pasture	n.r.	n.r.	n.r.

[1] Total costs: transport and manure application compared with N-based manure management costs (Table 5.6).
[2] Compared to N-based manure management: farrow to 5 kg $9,971 and $49,856 for small and large operations respectively and finishing, $10,249 and $40,997.
[3] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

Table 5.12 Total manure management costs for strategy 3: transport with truck for 40 km.

Location	Livestock	Crop rotations	Overall costs[1] ($)		Increased cost (ratio)[2]
			Small operation	Large operation	
Hanover	Farrow to 5 kg	Cereals & oilseeds	27,659	138,296	2.77
		Grain corn	26,337	131,685	2.64
	Finishing	Cereals & oilseeds	n.r. [3]	n.r.	n.r.
		Grain corn	18,049	72,198	1.76
	Finishing-phy	Cereals & oilseeds	12,409	49,638	1.21
		Grain corn	10,249	40,997	1.00
La Broquerie	Farrow to 5 kg	Hay	31,990	159,950	3.21
		Pasture	n.r.	n.r.	n.r.
	Finishing	Hay	n.r.	n.r.	n.r.
		Pasture	n.r.	n.r.	n.r.
	Finishing-phy	Hay	21,371	85,484	2.09
		Pasture	n.r.	n.r.	n.r.

[1] Total costs: transport and manure application compared with N-based manure management costs (Table 5.6).
[2] Compared to N-based manure management: farrow to 5 kg $9,971 and $49,856 for small and large operations respectively and finishing, $10,249 and $40,997.
[3] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

5.4 Strategy 4: current land base sufficient for N-based annual manure application no additional spreading land available, manure treatment required

This strategy illustrated the case where the land base is insufficient for P-based manure application and no additional spreading land is available. Therefore, one of the options for the pig producer is to treat the manure in order to modify the nutrient content of the resulting product to better suit the manure management of the operation. As mentioned in section 4.4, many manure treatment technologies are available and efficient. To represent different possibilities, two treatment systems were chosen for this assessment: solid-liquid separation with polymers and aerobic treatment. The manure solid-liquid system selected for this assessment was Filtramat® and Biofertile® for the aerobic treatment. For the simulations of this strategy, many assumptions were made because of the lack of local data and information.

For both systems, the solid, nutrient-rich fraction resulting from the treatment was assumed to be marketed and sold by the company developing and promoting the systems, providing no additional revenue or cost to the pig producer. Manure treatment costs were $0.0085/imp gal for solid-liquid separation, $0.036/imp gal (small pig operations) and $0.027/imp gal (large operations) for aerobic manure treatment (Tables 4.7 and 4.8). As for the liquid fraction from the solid-liquid system, it was assumed to be used to fertilize the land on an N-basis and the fraction from the aerobic treatment, applied for irrigation purposes, once again with no additional benefit to the pig producer. These manure treatment costs were considered as additional costs to the management of the pig operations. As expected, treatment costs for the solid-liquid separation are overall lower than for the aerobic treatment (Table 5.13). Total costs for the solid-liquid separation treatment ranged from $12,187 to $47,087 for farrow to 5 kg and from $12,527 to $38,719 for both finishing operations. As for aerobic manure treatment, total costs ranged from $39,885 to $149,569 for farrow to 5 kg and from $40,997 to $122,990 for finishing operations. For the small livestock operations, costs associated with the solid-liquid separation were 3.3 times less expensive than for aerobic treatment and for the large operations, they were 3.2 times less costly.

Table 5.13 Manure treatment costs for all hog operations and treatment systems.

Livestock	Number of pig places	Manure (imp gal/year)	Total costs[1] ($/year)	
			Solid-liquid separation	Aerobic manure treatment
Farrow to 5 kg	600	1,107,921	12,187	39,885
	3,000	5,539,605	47,087	149,569
Finishing[2]	2,000	1,138,800	12,527	40,997
	8,000	4,555,200	38,719	122,990

[1] Included financial and operation costs (energy, maintenance and operation).
[2] For both finishing operations (without and with phytase).

5.5 Strategy 5: no winter application, construction of sufficient manure storage facility

The selected impact of the SMAs of the new proposed environmental regulations was the prohibition of winter manure application in certain areas. In order to comply with this, some producers will have to build appropriate manure storage facilities. As mentioned in section 4.5, most of the large pig operations already have sufficient storage capacity, as required by current regulations. Therefore, this strategy was most directed to assess the cost for the small pig operations to conform. A minimum of 400 days of storage was established for this strategy. Table 5.14 presents the volume and costs for all livestock operation considered. Building costs (capital costs) for an earthen manure storage facilities building were $60,708 for small farrow to 5 kg and $62,400 both small finishing operations. Annual costs of sufficient storage capacity were amortized over a 10 year-period with an interest rate of 7.5%[16]. For small farrow to 5 kg operation, these annual costs represented $8,884 and $9,091 for both small finishing operations.

[16] Corresponds to the same period used to amortize the capital cost of building a pig barn (Scott Dick, Elite Swine inc., personal communication).

Table 5.14 Earthen manure storage facility construction costs for all hog operations.

Livestock	Pig place	Manure storage capacity[1] (imp gal)	Total building costs ($)	Annual costs[2] ($)
Farrow to 5 kg	600	1,214,160	60,708	8,884
	3,000	6,070,800	121,416	17,689
Finishing[3]	2,000	1,248,000	62,400	9,091
	8,000	4,992,000	99,840	14,545

[1] Calculated for a minimum of 400 days of storage and including associated equipment to operate the storage.
[2] Annual costs calculated with an amortization over a 10 year-period with an interest rate of 7.5%.
[3] For both finishing operations (without and with phytase).

6. IMPACTS ON RELATED ENTERPRISES

Implementation of the new proposed environmental regulations will also have an impact on related enterprises such as cropping and beef operations. In an attempt to demonstrate the magnitude of this impact, this chapter presents the simulation results of a multi-year manure management strategy involving the purchase and application of commercial fertilizer as an alternative to application of manure onto land owned by the pig producer. This strategy was basically the same as strategy 2 discussed in chapter 5 but this time we made the assumption that the producer owned the land needed to apply the manure on a P-basis. However, any additional land required to apply manure on a P-basis was assumed to be owned by neighbours. Therefore, the producer would need to supplement his or her own crops with commercial nitrogen fertilizer in the case of insufficient fertilization by manure application. These simulations illustrated the situation when the producer owning the land would have to give away manure to his neighbours and fertilize his or her crops in order to comply with the new regulations. This chapter first presents the nutrient balance used to determine if additional nutrients are needed and the selected commercial fertilizers. A description and economic assessment of the main costs of the new environmental regulations on cropping and beef enterprises is then offered.

6.1 Nutrient management

6.1.1 Nutrient balance

As mentioned, the hypothesis for this assessment implied that if necessary, commercial fertilizer was applied to supplement the underapplication of N under a P-based regulatory system. Nutrient balance determined if commercial fertilizers were needed: a negative balance implied that commercial fertilizer was needed to correct the under application. For all cropping systems where a two times crop P_2O_5 removal system of manure management was practiced, there was an under-application of N: the only exception was the cropping system where grain corn was fertilized with finishing-phy manure (Figure 6.1). Pasture was the cropping system with the highest N fertilizer requirements (deficit between 94.4 and 97.2 lb N/ac for all operations) and cereals and oilseeds with the lowest (deficit between 50 and 72 lb N/ac). Detailed results are presented in Table C.7 (Appendix C).

6.1.2 Commercial fertilizers

For this commercial fertilizer utilization assessment, only the costs of N supplementation were considered. Anhydrous ammonia was chosen as the N supplement for cereals, oilseeds and grain corn and urea for grasses (hay and pasture) (Table 6.1). As for commercial fertilizer application costs, the application method was fall banding for anhydrous ammonia and spring broadcast for urea.

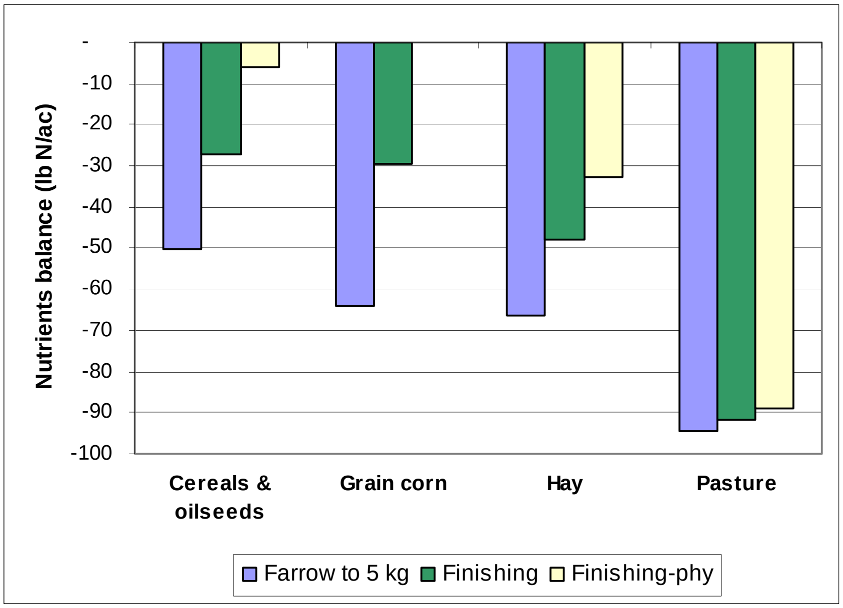

Figure 6.1 **Nutrient balance (lb N/ac) for nutrient management simulations of up to two times crop P_2O_5 removal.**

Table 6.1 **Commercial nitrogen fertilizer prices and application costs.**

Nitrogen fertilizer	Fertilizer price[1] ($/lb N)	Application costs[2] ($/ac)
Anhydrous ammonia (82-0-0)	$0.36	$8.00
Urea (46-0-0)	$0.43	$4.80

[1] John Heard (MAFRI), personal communication.
[2] Fall banding for anhydrous ammonia and spring broadcast for urea.

6.2 Economic costs for cropping enterprises

As expected, the nutrient management simulations with the highest deficit showed the highest requirements for commercial nitrogen fertilizer to supplement cropping systems on an annual basis for the multi-year P-based manure strategy. Commercial fertilizer requirements were assessed with MARC2005. For cereals and oilseeds cropping rotations, fertilizer applications rates were 138 lb N/ac, for grain corn, 191 lb N/ac and for hay and pasture, 260 lb N/ac. Detailed results are presented in Table C.8 in Appendix C.

Overall, the total nutrient management cost of the multi-year P-based strategy (commercial fertilizer and manure application costs) showed increases compared to the N-based annual manure application. For annual crops (cereals and oilseeds and grain corn), fertilizer costs for small pig operations averaged $5,531 for farrow to 5 kg, $10,539 for finishing and $7,572 for finishing-phy (Table 6.2). As for large pig operations, fertilizer costs averaged $27,584 for farrow to 5 kg, $42,149 for finishing and $30,249 for finishing-phy. For this multi-year P-based manure strategy, total costs of nutrient management with considering the purchase and utilization of commercial fertilizers and manure application represented average increases of 1.7 times the costs of N-based manure application for farrow to 5 kg, 2.2 for finishing and 1.9 for finishing-phy.

Table 6.2 Annual costs of commercial fertilizers to supplement cropping systems on an annual basis for the multi-year P-based manure strategy[17] and cost increases.

Livestock	Crop rotations	Fertilizer costs[1] ($)		Increased cost (ratio)[2]
		Small operation	Large operation	
Farrow to 5 kg	Cereals & oilseeds	5,637	28,100	1.73
	Grain corn	5,425	27,068	1.71
Finishing	Cereals & oilseeds	10,716	42,940	2.19
	Grain corn	10,363	41,359	2.16
Finishing-phy	Cereals & oilseeds	7,719	30,840	1.86
	Grain corn	7,426	29,657	1.84

[1] Annual fertilizer costs comprised N fertilizer prices and application costs.
[2] Total nutrient management costs of multi-year manure strategy (fertilizer and manure) compared to N-based total nutrient management costs (manure only).

6.3 Economic costs for beef enterprises

Cost impacts of the new environmental regulations on the beef enterprises are quite similar to those for cropping enterprises. In the case of a multi-year manure application, beef producers with financial interests in the land, will have to apply commercial fertilizers to their grass the years when manure application is not possible. For hay, commercial N fertilizers costs were, for small and large operations: for farrow to 5 kg, $10,534 and $52,670; for finishing, $18,161 and $72,476; and for finishing-phy, $15,250 and $60,949, respectively (Table 6.3). Total nutrient management costs represented increases of 2.24 times the N-based nutrient management costs for farrow to 5 kg, 2.93 times for finishing and 2.63 for finishing-phy. As for pasture, even if the manure management strategies used in this study were regarded as neither economically or technical feasible, use of commercial N fertilizers costs were assessed. These costs represented increases of 2.1 times N-based nutrient management for farrow to 5 kg, 3.1 times for finishing and 3.0 times for finishing-phy.

[17] Intermittent application of manure at one times P_2O_5 removal over several years.

Table 6.3 Annual costs of commercial fertilizers to supplement cropping systems for beef enterprises on an annual basis for the multi-year P-based manure strategy and cost increases.

Livestock	Crop rotations	Fertilizer costs[1] ($)		Increased cost (ratio)[2]
		Small operation	Large operation	
Farrow to 5 kg	Hay	10,534	52,670	2.24
	Pasture	8,927	44,510	2.12
Finishing	Hay	18,161	72,476	2.93
	Pasture	19,327	77,308	3.06
Finishing-phy	Hay	15,250	60,949	2.63
	Pasture	18,283	73,139	2.96

[1] Annual fertilizer costs comprised fertilizer purchase and application costs.
[2] Total nutrient management costs of multi-year strategy (fertilizer and manure) compared to N-based total nutrient management costs (manure only).

7. IMPACT OF ADDED COSTS ON PROFITABILITY OF PIG PRODUCTION

In chapter 5, the impact cost assessments of five different strategies was presented. In order to make a more comprehensive comparison between the different strategies, financial figures were calculated on a marketed-pig basis. This chapter presents manure management costs per marketed pig for each strategy of this study. Comparison of these costs with an averaged annual return over operating, labour and depreciation is also examined.

7.1 Manure management costs per marketed pig

The first step to evaluate the cost per marketed pig was to calculate the total number of pigs per operation per year. For farrow to 5 kg, we used 22.14 pigs/sow/year with a mortality rate of 10% and for finishing, a number of 3 cycles per year with mortality rate of 2%[18].

For the first strategy (baseline), manure management costs per marketed pig were $0.83 for farrow to 5 kg and $1.74 for both finishing operations: they were the lowest compared to all other strategies (Tables 7.1, 7.2 and 7.3). For two times crop P_2O_5 removal (strategy 2), costs per marketed pig were $1.83 for finishing operations and ranged from $0.91 to $0.93 for farrow to 5 kg and from $1.74 to $1.77 for finishing-phy. Compared to the baseline, these costs represented increases of about 1.2 times for all farrow to 5 kg and finishing and about 1.1 times for finishing-phy. As for multi-year P-based manure application (strategy 2), cost per marketed pig ranged from $0.97 to $0.99 for farrow to 5 kg, from $2.00 to $2.03 for finishing and from $1.94 to $2.00 for finishing-phy. Compared to the baseline (N-based application), these costs represented increases of 1.9 times for farrow to 5 kg, 2.4 times for finishing and 2.1 for finishing-phy (Table 7.4).

For strategy 3, the manure management costs per marketed pig for transport with tank for 20 km, varied between $2.52 and $3.11 for farrow to 5 kg and between $1.74 and $4.08 for finishing-phy (Table 7.2). For hauling by tanker for finishing operations, cost per marketed pig for grain corn was $3.38. For transport with truck over the same distance, costs ranged from $1.63 to $1.91 for farrow to 5 kg and from $1.74 to $2.85 for finishing-phy. As for finishing, cost per marketed pig was $2.52. Finally, for manure transport with truck for 40 km, costs per marketed pig varied between $2.20 and $2.68 for farrow to 5 kg and between $1.74 and $3.63 for finishing-phy. For finishing, this cost was $3.07. Overall, these costs represented average increases varying between 2.1 times (with truck for 20 km) and 3.3 times (with tank for 20 km) for farrow to 5 kg, between 1.4 times (with truck for 20 km) and 1.9 times (with tank for 20 km) for finishing and between 1.2 times (with truck for 20 km) and 1.5 times (with tank for 20 km) for finishing-phy (Table 7.4).

[18] Dr Ian Seddon (MAFRI), personal communication.

Table 7.1 Total cost per marketed pig for strategies 1 and 2 for all pig operations.

Livestock	Crop rotations	Cost per marketed pig ($) Strategy 1 N-based	Strategy 2 2X crop P_2O_5 removal	Strategy 2 multi-year
Farrow to 5 kg	Cereals & oilseeds	0.83	0.91	0.97
	Grain corn	0.83	0.93	0.97
Finishing	Cereals & oilseeds	1.74	n.r.[1]	2.00
	Grain corn	1.74	1.83	2.00
Finishing-phy	Cereals & oilseeds	1.74	1.77	1.94
	Grain corn	1.74	1.74	1.94
Farrow to 5 kg	Hay	0.83	0.93	0.99
	Pasture	0.83	n.r.	n.r.
Finishing	Hay	1.74	n.r.	2.03
	Pasture	1.74	n.r.	n.r.
Finishing-phy	Hay	1.74	1.87	2.00
	Pasture	1.74	n.r.	n.r.

[1] Manure application rate not practical (n.r.) and, therefore not considered for the economic and technical simulation.

Table 7.2 Total cost per marketed pig for strategy 3 for all pig operations.

Livestock	Crop rotations	Cost per marketed pig ($) Strategy 3[1] Tank 20km	Strategy 3[1] Truck 20km	Strategy 3[1] Truck 40km
Farrow to 5 kg	Cereals & oilseeds	2.66	1.70	2.31
	Grain corn	2.52	1.63	2.20
Finishing	Cereals & oilseeds	n.r.[2]	n.r.	n.r.
	Grain corn	3.38	2.52	3.07
Finishing-phy	Cereals & oilseeds	2.20	1.96	2.11
	Grain corn	1.74	1.74	1.74
Farrow to 5 kg	Hay	3.11	1.91	2.68
	Pasture	n.r.	n.r.	n.r.
Finishing	Hay	n.r.	n.r.	n.r.
	Pasture	n.r.	n.r.	n.r.
Finishing-phy	Hay	4.08	2.85	3.63
	Pasture	n.r.	n.r.	n.r.

[1] Costs for this strategy comprised transport costs and manure application of all manure.
[2] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

Table 7.3 Incremental cost per marketed pig for strategies 4 and 5 for all pig operations.

Livestock	Size of the operation	Cost per marketed pig ($) Strategy 4 Solid-liquid treatment	Strategy 4 Aerobic treatment	Strategy 5[2] Storage facility
Farrow to 5 kg	Small	1.02	3.34	0.74
	Large	0.79	2.50	0.30
Finishing [1]	Small	2.13	6.97	1.55
	Large	1.65	5.23	0.62

[1] For both finishing operations (without and with phytase).
[2] Annual costs assessed with an amortization over a 10 year-period with an interest rate of 7.5%.

Table 7.4 Increased cost per marketed pig: ratios of costs for strategies 2 and 3 compared to strategy 1.

Livestock	Crop rotations	Increased manure management cost per marketed pig (ratio)				
		Strategy 2 2X crop	Strategy 2 multi-year[1]	Strategy 3[1] Tank 20km	Strategy 3[1] Truck 20km	Strategy 3[1] Truck 40km
Farrow to 5 kg	Cereals & oilseeds	1.09	1.17	3.19	2.03	2.77
	Grain corn	1.11	1.17	3.02	1.96	2.64
Finishing	Cereals & oilseeds	n.r.[2]	1.15	n.r.	n.r.	n.r.
	Grain corn	1.05	1.15	1.94	1.44	1.76
Finishing-phy	Cereals & oilseeds	1.01	1.11	1.26	1.12	1.21
	Grain corn	1.00	1.11	1.00	1.00	1.00
Farrow to 5 kg	Hay	1.12	1.18	3.72	2.29	3.21
	Pasture	n.r.	n.r.	n.r.	n.r.	n.r.
Finishing	Hay	n.r.	1.17	n.r.	n.r.	n.r.
	Pasture	n.r.	n.r.	n.r.	n.r.	n.r.
Finishing-phy	Hay	n.r.	1.15	n.r.	n.r.	n.r.
	Pasture	n.r.	n.r.	n.r.	n.r.	n.r.

[1] Manure application of manure at one times crop P_2O_5 removal.
[2] Costs for this strategy comprised transport costs and manure application of all manure.
[3] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

As for strategy 4, manure management costs per marketed pig were highest for the aerobic treatment (Table 7.3). For the solid-liquid treatment, incremental costs per marketed pig averaged \$0.90 for farrow to 5 kg and \$1.89 for both finishing operations. As for the aerobic manure treatment system, averaged incremental costs to manure management per marketed pig were \$2.92 for farrow to 5 kg and \$6.10 for both finishing operations. The total costs associated with manure treatment (baseline plus strategy) represented average increases of 2.1 times for solid-liquid treatment and 4.5 times for aerobic treatment compared to the N-based manure management options (Table 7.5). As for the building of manure storage facilities, incremental costs were \$0.74 and \$0.30 per marketed pig for small and large farrow to 5 kg operations, and \$1.55 and \$0.62 for finishing small and large operations (Table 7.3). These costs represented increases of 89% compared to the baseline scenario (strategy 1) for small pig operations and 35% for large operations.

Table 7.5 Increased cost per marketed pig: ratios for strategies 4 and 5 compared to strategy 1.

Size of the operation[1]	Increased cost per marketed pig (ratio)		
	Strategy 4 Solid-liquid treatment	Strategy 4 Aerobic treatment	Strategy 5[2] Storage facility
Small	2.22	5.00	1.89
Large	1.94	4.00	1.35

[1] For both finishing operations (without and with phytase).
[2] Annual costs assessed with an amortization over a 10 year-period with an interest rate of 7.5%.

7.1.1 Impacts on related enterprises

As mentioned, purchase and application of commercial N fertilizers onto land where manure application was restricted to P removal by crops was one way to assess the impacts of the new regulations on cropping enterprises. Average additional fertilizer cost per marketed pig with the strategy of multi-year P-based application when the land is owned was $1.58 for farrow to 5 kg, $4.24 for finishing and $3.68 for finishing-phy (Table 7.6). Overall, these costs represented averaged increases of 1.9 times N-based manure management costs for farrow to 5 kg, 2.4 times for finishing and 2.1 for finishing-phy.

Table 7.6 Cost per marketed pig and increases for simulations of manure management strategy 2 involving commercial fertilizers (multi-year P-based manure application).

Livestock	Crop rotations	Cost per marketed pig[1] ($)	Increase cost per marketed pig (ratio)[2]
Farrow to 5 kg	Cereals & oilseeds	1.44	1.73
	Grain corn	1.43	1.71
Finishing	Cereals & oilseeds	3.82	2.19
	Grain corn	3.76	2.16
Finishing-phy	Cereals & oilseeds	3.25	1.86
	Grain corn	3.20	1.84
Farrow to 5 kg	Hay	1.87	2.24
	Pasture	1.73	2.08
Finishing	Hay	5.12	2.94
	Pasture	5.34	3.06
Finishing-phy	Hay	4.60	2.64
	Pasture	5.16	2.96

[1] Total costs comprised fertilizer purchase and application costs and also manure application costs.
[2] Costs for multi-year P-based strategy relative to N-based strategy, after adding costs of fertilizer for owned cropland.

7.2 Comparison with annual returns

Annual returns over operating, labour and depreciation for each type of pig operation were compared in order to have a realistic assessment of the impact of these strategies on the industry. Long-term average returns for farrow to 5 kg operations has been $2.08/weanling pig (1998-2005) and for finishing operations, $6.62/finishing pig (1990-2005)[19]. Proportions of long-term net annual return of simulations of all nutrient management strategies are presented in Tables 7.7 and 7.8. Proportion values greater than one suggest that the additional costs associated with the manure management strategies exceed the long-term average net return.

[19] Petra Loro (MAFRI), personal communication.

Table 7.7 Incremental cost[20] per marketed pig as a proportion of long-term average net annual returns for pig operations for manure management strategies 2 and 3.

Livestock	Crop rotations	Proportion of net annual return[1]				
		Strategy 2 2X crop	Strategy 2 multi-year[2]	Strategy 3 Tank 20km	Strategy 3 Truck 20km	Strategy 3 Truck 40km
Farrow to 5 kg	Cereals & oilseeds	0.04	0.07	0.88	0.41	0.71
	Grain corn	0.04	0.07	0.81	0.38	0.66
Finishing	Cereals & oilseeds	n.r.[3]	0.04	n.r.	n.r.	n.r.
	Grain corn	0.01	0.04	0.25	0.12	0.20
Finishing-phy	Cereals & oilseeds	0.004	0.03	0.07	0.03	0.06
	Grain corn	0.00	0.03	0.00	0.00	0.00
Farrow to 5 kg	Hay	0.05	0.07	1.09	0.52	0.89
	Pasture	n.r.	n.r.	n.r.	n.r.	n.r.
Finishing	Hay	n.r.	0.04	n.r.	n.r.	n.r.
	Pasture	n.r.	n.r.	n.r.	n.r.	n.r.
Finishing-phy	Hay	0.02	0.04	0.35	0.17	0.29
	Pasture	n.r.	n.r.	n.r.	n.r.	n.r.

[1] Long-term average returns for farrow to 5 kg operations has been $2.08/weanling pig (1998-2005) and for finishing operations, $6.62/finishing pig (1990-2005)
[2] Manure application of manure at one times crop P_2O_5 removal.
[3] Manure application rate not realistic (n.r.) and, therefore not considered for the economic and technical simulation.

Table 7.8 Incremental cost per marketed pig as a proportion of long-term average net annual returns for pig operations for manure management strategies 4 and 5.

Livestock	Size of the operation	Proportion over net annual return[1]		
		Strategy 4[2] Solid-liquid treatment	Strategy 4[2] Aerobic treatment	Strategy 5 Increased storage
Farrow to 5 kg	Small	0.49	1.60	0.36
	Large	0.38	1.20	0.14
Finishing[1]	Small	0.32	1.05	0.23
	Large	0.25	0.79	0.09

[1] Long-term average returns for farrow to 5 kg operations has been $2.08/weanling pig (1998-2005) and for finishing operations, $6.62/finishing pig (1990-2005).
[2] For both finishing operations (without and with phytase).

For the multi-year P-based manure application strategy (strategy 2), for farrow to 5 kg, average increased of incremental cost per marketed pig as a proportion of net annual return was 0.04 and for finishing and finishing-phy operations, 0.01. As for the manure transport strategy (strategy 3), increased of incremental costs as a proportion of net returns were overall higher. For farrow to 5 kg, they ranged from 0.81 to 1.09 for transport with tank over 20 km (i.e. additional costs exceeded net returns), from 0.38 to 0.52 for transport with truck over 20 km and from 0.66 to 0.89 for transport with truck over 40 km. For finishing, increased costs as a proportion over net returns were overall lower; they varied between 0.12 and 0.25. For finishing-phy, they ranged from 0.03 and 0.35.

[20] Calculated by the difference between the cost per marketed pig for the manure management strategy and the baseline (N-based): $0.83 for farrow to 5 kg and $1.94 for both finishing operations.

As for manure treatment, increased costs as a proportion of annual return for the solid-liquid technology were overall lower than for the aerobic treatment; they averaged 0.43 for farrow to 5 kg and 0.29 for both finishing operations for solid-liquid treatment versus 1.4 and 0.92 for aerobic treatment (Table 7.8). As for building of sufficient manure storage, increased costs as a proportion of annual return were 0.36 for small farrow to 5 kg operations and for both finishing small operations, 0.23.

As for impact on related enterprises, one series of simulations of manure management strategy 2 examined the impact of purchasing synthetic N fertilizers to substitute for the manure N that was exported to another farm. In this case, incremental costs as a proportion over return ranged from 0.29 to 0.50 for farrow to 5 kg, from 0.31 to 0.51 for finishing and from 0.22 to 0.43 for finishing-phy (Table 7.9).

Overall, the negative impact on farrowing operations was greater than on finishing operations. As for the cropping systems, grain corn presented the least increase in land required followed by cereals and oilseeds. Perennial forage was the cropping system with the highest increase in land required. In areas or on farms where there is not sufficient nearby land for manure application a P_2O_5 removal basis, the cost increases are substantial. Also the incorporation of phytase into finishing rations will pay substantial dividends in lowering costs of manure management. Finally, for operations with cropping enterprises, the impact of exporting manure N to other farms and replacing with synthetic fertilizer N is substantial equivalent to a decrease in returns of 22-54%.

Table 7.9 Incremental cost per marketed pig as a proportion of long-term average net annual returns for pig operations where commercial N fertilizer is required to replace manure N that is exported to other farms[21].

Livestock	Crop rotations	Proportion of annual return[1]
Farrow to 5 kg	Cereals & oilseeds	0.29
	Grain corn	0.28
Finishing	Cereals & oilseeds	0.31
	Grain corn	0.31
Finishing-phy	Cereals & oilseeds	0.23
	Grain corn	0.22
Farrow to 5 kg	Hay	0.50
	Pasture	0.43
Finishing	Hay	0.51
	Pasture	0.54
Finishing-phy	Hay	0.43
	Pasture	0.45

[1] Long-term average returns for farrow to 5 kg operations has been $2.08/weanling pig (1998-2005) and for finishing operations, $6.62/finishing pig (1990-2005)

[21] Commercial fertilizer applied onto crops owned by the pig producer to substitute for manure nutrients which are applied onto a neighbour's crop.

8. DISCUSSION AND CONCLUSIONS

As mentioned, the purpose of this study is to provide a cost assessment of the impact of the new proposed environmental regulations on the pig industry in Manitoba. To do so, several BMPs were selected to perform this economic impact assessment: accessibility to sufficient spreading land, appropriate animal diet to reduce P excretion, manure treatment and building of sufficient manure storage.

To illustrate the new regulations, manure application rates were assessed with the help of three different nutrient management options: N-based nutrient recommendations, up to two times crop P_2O_5 removal and up to one times crop P_2O_5 removal. Five nutrient management strategies were defined to offer an overall appreciation of the cost impacts of these new regulations.

The **first manure management strategy** was used to determine the effect of the new P management options on the minimum land requirements assuming there would be no increase in manure application or management costs. Overall, for this strategy and manure P management options, P-based rates of manure application were significantly lower than the N-based rates. Hay and pasture were the two rotations impacted the most: P-based rates of manure application were 94% and 97% lower than those calculated for N-based. These low rates rendered large increase in land requirements for manure application. As expected, simulation results for the most restrictive P management option (up to one times crop P_2O_5 removal) gave the highest increases; these increases were twice as large as those with the less restrictive management option (up to two times crop P_2O_5 removal). However, for the purpose of this study, all manure application rates lower than 3,500 imp gal/ac were regarded as neither practical for the studied regions nor economically feasible. Therefore, for a number of cropping systems, full financial assessments were not completed at these low rates. This was the case for all simulations involving pasture and for the combination of nutrient management options up to two times crop P_2O_5 removal with finishing operations and crops that included cereals and oilseeds and hay.

For both annual and perennial crop systems, the largest increases in land requirements were for farrow to 5 kg operations. As for the cropping system, pasture was the cropping system with the largest increase in additional land to meet the new nutrient application requirement because of the low rates of P removal during grazing. Use of a phytase diet for finishing barns proved to have a considerable benefit on the manure application rates and land needed for application; an average of 24% less land was needed for manure application of finishing-phy, compared to finishing without phytase supplementation. As for costs, because they are dependent on the volume of manure applied, this strategy did not decrease the costs of manure management under the assumption of this particular strategy.

The **second strategy** consisted of periodic applications of manure at a rate equivalent to one times crop removal of P_2O_5 over that multi-year period (up to 5 years), resulting in an increase in land requirement and consequently, a small increase in the costs of applying manure beyond the radius of distance from the manure storage. In some cases, this management practice represents the most realistic way of dealing with low manure application rates that are not practical on an annual basis. Compared to annual applications to meet the crop's N requirements or two times P_2O_5 crop removal, periodic application of manure to meet multiple years of crop P_2O_5 removal were the highest. Average increases in manure management costs for the periodic applications ranged from 1.1 times N-based management (finishing-phy) to 1.2 times (farrow to 5 kg).

The impacts on cropping and beef enterprises were also examined. Overall, these impacts were significant. For the cropping enterprises, the purchase and application of commercial N fertilizer for a multi-year P-based manure application represented average additional costs of $0.75 per marketed pig for farrow to 5 kg operation, $2.49 for finishing, and $1.94 for finishing-phy operations. These costs represented increases of 1.9 times, 2.4 and 2.1 times the baseline costs for farrow to 5 kg operations, finishing and finishing-phy operations, respectively.

Impacts of **strategy 3** on manure management costs were significant. Among the three manure transport options examined, transport with tractor-drawn tank for 20 km was the most expensive. For all cropping systems, average increases were 3.3 times N-based management costs for farrow to 5 kg, 1.9 times for finishing and 1.5 times for finishing-phy. The least expensive manure transport simulations were with truck for 20 km, where average increases were 2.1 times for farrow to 5 kg, 1.4 times for finishing and 1.3 for finishing-phy.

When no additional spreading land is locally available, manure treatment is one of the most probable alternatives. Therefore, **strategy 4** examined two different manure treatment systems: solid-liquid separation and aerobic treatment. Estimated costs for this strategy were considered as extra manure management costs compared to N-based manure management. Solid-liquid manure treatment system was the least expensive: increases of 95% over and above N-based manure management (cost per marketed pig) for large pig operations, and 123% for small operations. Costs per marketed pig for aerobic treatment represented increases of 301% for large operations, and 401% for small operations.

As for the last manure management strategy, cost of building sufficient manure storage facility to comply with prohibition of winter manure application, were substantial for pig operations. Since most of the large pig operations already have sufficient storage capacity, the small operations will be those most affected. Amortized over 10 years, annual costs were $8,884 for farrow to 5 kg operations and $9,091 for finishing operations.

Calculation of incremental cost of compliance per marketed pig allowed a comparison of all strategies on a similar basis (Table 8.1). Overall, annual manure land application (up to two times crop P_2O_5 removal) and multi-year application (up to one times crop P_2O_5 removal) were the least expensive management strategies for complying with the P regulations. Transport management strategies were more costly and aerobic manure treatment was the most expensive of all management strategies. Costs for solid-liquid separation were generally intermediate, between long distance transport and aerobic treatment. However, in one case, solid-liquid separation treatment was less expensive than manure transport: large farrow to 5 kg operations.

To have a better appreciation of the impacts on these manure management strategies on the long-term net average return, Table 8.2 presents the effects of P-based manure management strategies on long-term average net returns. Loss and profitability is calculated by the difference between the incremental cost of the strategy and the average long-term net return for pig operations. For all pig operations, the P-based manure management strategies corresponded to a diminution of the net returns. The strategy for which costs exceeding revenue on average was manure aerobic treatment. As for the other strategies, decreases in profitability per pig were least for the annual application of manure on land at rates up to two times P_2O_5 removal and the multi-year P-based land application: decreases in profitability averaged 5.6% for farrow to 5 kg operations and, 2.4% for finishing operations. More substantial decreases in profitability were assessed for the manure transport strategies: average decreases of 70.6% for the farrow to 5 kg and 14.8% for the finishing operations. Adding solid-liquid separation decreased profitability by 43.4% for farrow to 5 kg and 28.5% for the finishing operations. As mentioned, the losses assessed for the manure aerobic treatment were the most significant: 140.3% for farrow to 5 kg and 92.2% for both finishing operations.

Table 8.1 Incremental cost of P-based manure management strategies for pig operations.

Strategy for compliance	Average incremental cost of compliance ($/marketed pig) [1]					
	Farrow to 5 kg		Finishing		Finishing-phy	
	Small	Large	Small	Large	Small	Large
Annual application on land (2x crop P_2O_5 removal)	0.09	0.09	0.09	0.09	0.05	0.05
Multi-year land application (1x crop P_2O_5 removal)	0.14	0.14	0.27	0.27	0.22	0.22
Transport with tank for 20 km	1.93	1.93	1.64	1.64	0.93	0.93
Transport with truck for 20 km	0.91	0.91	0.77	0.77	0.44	0.44
Transport with truck for 40 km	1.56	1.56	1.33	1.33	0.75	0.75
Solid-liquid separation	1.02	0.79	2.13	1.65	2.13	1.65
Manure aerobic treatment	3.34	2.50	6.97	5.23	6.97	5.23

[1] Average incremental costs over N-based manure management strategy for all cropping systems evaluated; using N-based costs of $0.83/pig for farrow to 5 kg and $1.74/pig for both finishing operations.

Table 8.2 Effects of P-based manure management strategies on long-term average net returns for pig operations.

Strategy for compliance	Net returns ($ / marketed pig)[1]					
	Farrow to 5 kg		Finishing		Finishing-phy	
	Small	Large	Small	Large	Small	Large
Annual application on land (2xP removal)	1.99	1.99	6.53	6.53	6.57	6.57
Multi-year land application (1xP removal)	1.94	1.94	6.35	6.35	6.40	6.40
Transport with truck for 20 km	0.15	0.15	4.98	4.98	5.69	5.69
Transport with truck for 40 km	1.17	1.17	5.84	5.84	6.18	6.18
Transport with tank for 20 km	0.52	0.52	5.29	5.29	5.87	5.87
Solid-liquid separation	1.06	1.29	4.49	4.97	4.49	4.97
Manure aerobic treatment	-1.26	-0.42	-0.35	1.39	-0.35	1.39

[1] Loss and profitability compared to long-term average net annual returns for N-based manure management strategies: $2.08 for farrow to 5 kg and $6.62 for both finishing operations.

As mentioned, the scope of this project was to develop a multidimensional framework to calculate the economic impacts of the new environmental regulations for manure phosphorus proposed by Manitoba Conservation and Manitoba Water Stewardship, on Manitoba's pig industry. Assessment of the numerous strategies for compliance with the new proposed environmental regulations allowed us to develop an idea of the costs related to the implementation of these manure management strategies and the impacts of added costs on profitability. Manure strategies where the current land base was sufficient for P-based annual or multi-year manure application were the least costly. However, in some cases the low manure application rates calculated to comply with these new regulations were not practical for the studied regions and therefore, not economically evaluated (e.g. for pasture systems). Impacts on the two phases of pig production were quite different. Overall, total and incremental costs per marketed pig for all manure management strategies were lower for farrow to 5 kg than for finishing operations. However, comparison with the long-term annual net returns for pig operation, showed that the impact of the added costs were more important in terms of proportion of net returns for farrow to 5 kg since the returns per pig are lower for this type of operation. This initial examination of several representative management strategies allowed a first glance at the impacts of these proposed regulations on several types of pig operations and an overall framework for assessing these impacts at a regional or provincial scale. These costs should be considered before implementing these new recommendations for P management in order to ensure the sustainability for Manitoba's pig industry.

Negative impacts on farrowing operations were larger than on finishing operations. As for the cropping systems, grain corn presented the least increase in land required followed by cereals and oilseeds and hay. Pasture was the cropping system with by far, the most important increase in land required. For the series of simulations where areas or on farms where there is not enough nearby land for manure application a P_2O_5 removal basis, cost increases are substantial. For the finishing operations with phytase in their diet, the costs of manure management were substantially lower. Finally, for operations with cropping enterprises, the impact of exporting manure N to other farms and replacing with synthetic fertilizer N is substantial equivalent to a decrease in returns of 22-54%.

These increased costs could have significant impacts on Manitoba's pork industry. For primary producers, this represents decreased profitability that will reduce further investment in this sector and an increase risk of losses during period of low prices threatening the viability of some existing operations. Beyond the farm gate, these increases in costs could also reduce investment and economic activity in other sub-sectors of the pork industry such as feed suppliers and pork processors.

8.1 Future work

Before the economic impacts of the proposed nutrient management regulations can be determined at a regional or provincial scale, more specific information on the pig industry will be needed, as well as more resources to expand the study. For example, extrapolation of the costs from the farm to the regional and provincial-level requires an accurate prediction of how producers will be affected and how they will respond to these new environmental regulations (Field and Olewiler, 2002). Given that application of manure onto additional nearby land is the lowest cost method of compliance with P regulations (Table 8.1), the availability of suitable, nearby land and the types of cropping systems employed on that land are critical factors for predicting which manure management strategy producers will employ for compliance. Therefore, if the regulation leaves the producers considerable latitude in making their response, it may be hard to predict exactly what they will do and, therefore, what their costs will be (Field and Olewiler, 2002).

Any generalization of the quantitative results to a different region or broader scale should be done with caution. Although the information for scaling up this evaluation does not exist in a useable form (e.g. detailed information on land availability and cropping systems near pig operations), some of this information could be gathered by a survey of individual pig producers. However, the competitive interaction among pig producers for application of manure onto nearby land and the effect of the regulations on cropping systems will also need to be characterized.

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APPENDIX A
CROP PRODUCTION DATA

Table A.1 Crop production statistics for Hanover for the period 2001-2005.

Crop	YEAR	Acres	Yield/acre (Metric)	Yield/acre (Imperial	# Producers	Total ac/crop	Ave Yield/acre (Imperial Units)	Rolling ave (Imperial Units)	Units
ALFALFA	2001	2,430	2.461 t	2.712	21	14,442	2.61	2.88	ton
	2002	2,911	2.704 t	2.98	24				
	2003	3,247	2.220 t	2.446	28				
	2004	2,892	2.666 t	2.938	24				
	2005	2,962	1.774 t	1.955	20				
ALFALFA/GRASS MIX.	2001	1,395	2.120 t	2.336	12	10,164	2.35	2.55	ton
	2002	1,801	2.215 t	2.441	17				
	2003	2,495	1.778 t	1.959	21				
	2004	2,416	2.613 t	2.879	21				
	2005	2,057	1.946 t	2.145	22				
ARGENTINE CANOLA	2001	8,136	0.400 t	17.642	42	53,156	23.99	32.22	bus
	2002	11,348	0.571 t	25.184	55				
	2003	12,076	0.899 t	39.627	56				
	2004	8,146	0.722 t	31.844	43				
	2005	13,450	0.128 t	5.635	51				
BARLEY	2001	5,832	0.690 t	31.704	29	18,273	38.16	48.94	bus
	2002	4,064	0.764 t	35.107	29				
	2003	3,531	1.560 t	71.654	28				
	2004	2,558	0.872 t	40.063	16				
	2005	2,288	0.267 t	12.264	18				
FEED WHEAT	2001	292	0.465 t	17.094	3	636	33.21	33.21	bus
	2004	344	1.342 t	49.324	3				
FLAX	2002	615	0.663 t	26.118	8	1,157	16.68	16.68	bus
	2005	542	0.184 t	7.245	6				
GRAIN CORN	2001	2,837	2.693 t	106.035	18	32,960	73.50	108.55	bus
	2002	8,910	2.772 t	109.118	41				
	2003	10,844	2.807 t	110.497	45				
	2004	6,644	0.105 t	4.119	33				
	2005	3,725	0.959 t	37.75	20				
GRASSES	2001	305	1.109 t	1.222	4	3,187	1.39	1.45	ton
	2002	638	1.346 t	1.483	8				
	2003	923	1.271 t	1.401	11				
	2004	728	1.333 t	1.469	10				
	2005	593	1.226 t	1.351	9				
GREENFEED	2001	470	1.145 t	1.262	6	6,243	1.27	1.56	ton
	2002	910	1.480 t	1.631	13				
	2003	550	1.610 t	1.775	7				
	2004	3,229	0.996 t	1.097	27				
	2005	1,084	0.546 t	0.602	13				
HARD WHITE WHEAT	2005	1,617	0.478 t	17.561	8	1,617	17.56	17.56	bus
OATS	2001	4,175	0.957 t	62.057	23	22,296	74.56	94.32	bus
	2002	6,640	1.292 t	83.767	39				
	2003	4,972	1.616 t	104.762	33				
	2004	3,531	1.456 t	94.423	22				
	2005	2,978	0.428 t	27.773	24				
OIL SUNFLOWERS	2002	355	0.761 t	1678.8	3	355	1,678.80	1,678.80	lbs
RED SPRING WHEAT	2001	15,364	0.546 t	20.056	57	42,268	39.61	46.13	bus
	2002	9,566	0.967 t	35.54	48				
	2003	7,401	1.492 t	54.82	44				
	2004	6,404	1.307 t	48.016	38				
	2005	3,533	0.332 t		24				
SILAGE CORN	2001	875	10.383 t	11.442	11	5,028	8.17	10.14	ton
	2002	1,378	6.939 t	7.647	12				
	2003	939	10.270 t	11.317	13				
	2004	621	5.098 t	5.618	10				
	2005	1,215	4.358 t	4.803	7				
SOYBEANS	2002	1,258	0.999 t	36.689	11	6,766	21.45	21.45	bus
	2003	3,382	0.774 t	28.456	22				
	2004	797	0.039 t	1.432	6				
	2005	1,329	0.523 t	19.215	10				
WHITE PEA BEANS	2001	466	0.316 t	697.4	4	466	697.40	697.40	lbs
WINTER WHEAT	2002	2,262	1.555 t	57.129	5	8,888	65.75	65.75	bus
	2003	2,958	2.032 t	74.663	11				
	2004	3,668	1.782 t	65.46	15				

Table A.2 Crop production statistics for La Broquerie for the period 2001-2005.

Crop	YEAR	Acres	Yield/acre (Metric)	(Imperial	# Producers	Total ac/crop	Ave Yield/acre (Imperial Units)	Rolling ave (Imperial Units)	Units
ALFALFA	2001	423	3.170 t	3.493	4	2,416	2.57	2.91	ton
	2002	577	1.917 t	2.113	5				
	2003	495	1.851 t	2.039	5				
	2004	370	2.611 t	2.877	5				
	2005	551	2.133 t	2.35	5				
ALFALFA/GRASS MIX.	2001	557	2.848 t	3.138	4	5,681	2.27	2.60	ton
	2002	984	2.117 t	2.333	7				
	2003	1,195	2.117 t	2.333	8				
	2004	1,591	1.653 t	1.822	9				
	2005	1,354	1.572 t	1.732	8				
ARGENTINE CANOLA	2001	796	0.354 t	15.587	4	1,621	17.81	17.81	bus
	2003	449	0.755 t	33.276	4				
	2005	376	0.104 t	4.578	4				
BARLEY	2001	321	0.754 t	34.649	4	2,537	33.91	33.91	bus
	2002	1,634	0.359 t	16.477	10				
	2003	582	1.102 t	50.613	8				
GRAIN CORN	2001	678	2.741 t	107.894	5	5,703	65.63	96.92	bus
	2002	1,674	2.371 t	93.337	9				
	2003	1,814	2.274 t	89.532	9				
	2004	801	0.094 t	3.692	6				
	2005	736	0.856 t	33.718	6				
GRASSES	2001	342	0.970 t	1.069	4	3,538	1.39	1.51	ton
	2002	697	1.351 t	1.489	7				
	2003	957	1.414 t	1.558	9				
	2004	836	1.224 t	1.349	8				
	2005	706	1.351 t	1.489	8				
GREENFEED	2001	320	0.561 t	0.618	3	1,493	1.39	1.39	ton
	2002	495	0.865 t	0.954	3				
	2004	678	2.365 t	2.606	6				
OATS	2002	707	0.425 t	27.55	5	1,769	42.50	42.50	bus
	2003	815	0.779 t	50.507	6				
	2005	247	0.762 t	49.434	3				
OIL SUNFLOWERS	2003	240	0.516 t	1137.1	3	240	1,137.10	1,137.10	lbs
RED SPRING WHEAT	2001	281	0.686 t	25.221	4	1,482	21.10	21.10	bus
	2002	715	0.636 t	23.357	5				
	2005	486	0.400 t	14.708	3				
SILAGE CORN	2001	511	12.341 t	13.6	3	1,790	8.05	8.05	ton
	2003	546	8.110 t	8.937	4				
	2004	255	5.639 t	6.214	5				
	2005	478	3.138 t	3.458	4				

Table A.3 Overall crop production statistics for Hanover and La Broquerie for the period 2001-2005.

			Yields		Ave yields + 10%		
		Acres	**Average**	**Rolling Ave**	**Average**	**Rolling Ave**	
HANOVER	**ARGENTINE CANOLA**	**53,156**	**23.99**	**32.22**	**26.4**	**35.4**	**bus**
	RED SPRING WHEAT	**42,268**	**39.61**	**46.13**	**43.6**	**50.7**	**bus**
	GRAIN CORN	**32,960**	**73.50**	**108.55**	**80.9**	**119.4**	**bus**
	OATS	22,296	74.56	94.32	82.0	103.7	bus
	BARLEY	18,273	38.16	48.94	42.0	53.8	bus
	ALFALFA	**14,442**	**2.61**	**2.88**	**2.9**	**3.2**	**ton**
	ALFALFA/GRASS MIX.	10,164	2.35	2.55	2.6	2.8	ton
	WINTER WHEAT	8,888	65.75	65.75	72.3	72.3	bus
	SOYBEANS	6,766	21.45	21.45	23.6	23.6	bus
	GREENFEED	6,243	1.27	1.56	1.4	1.7	ton
	SILAGE CORN	5,028	8.17	10.14	9.0	11.1	ton
	GRASSES	3,187	1.39	1.45	1.5	1.6	ton
	FORAGE ESTABLISHMENT	1,907					bus
	HARD WHITE WHEAT	1,617	17.56	17.56	19.3	19.3	bus
	FLAX	1,157	16.68	16.68	18.3	18.3	bus
	FEED WHEAT	636	33.21	33.21	36.5	36.5	bus
	WHITE PEA BEANS	466	697.40	697.40	767.1	767.1	lbs
	OIL SUNFLOWERS	355	1,678.80	1,678.80	1,846.7	1,846.7	lbs
LA BROQUERIE	**GRAIN CORN**	**5,703**	**65.63**	**96.92**	**72.2**	**106.6**	**bus**
	ALFALFA/GRASS MIX.		2.27	2.60	2.5	2.9	ton
	GRASSES		**1.39**	**1.51**	**1.5**	**1.7**	**ton**
	BARLEY	2,537	33.91	33.91	37.3	37.3	bus
	ALFALFA		**2.57**	**2.91**	**2.8**	**3.2**	**ton**
	SILAGE CORN	1,790	8.05	8.05	8.9	8.9	ton
	OATS	1,769	42.50	42.50	46.7	46.7	bus
	ARGENTINE CANOLA	1,621	17.81	17.81	19.6	19.6	bus
	GREENFEED	1,493	1.39	1.39	1.5	1.5	ton
	RED SPRING WHEAT	1,482	21.10	21.10	23.2	23.2	bus
	FORAGE ESTABLISHMENT						ton
	OIL SUNFLOWERS	240	1,137.10	1,137.10	1,250.8	1,250.8	lbs

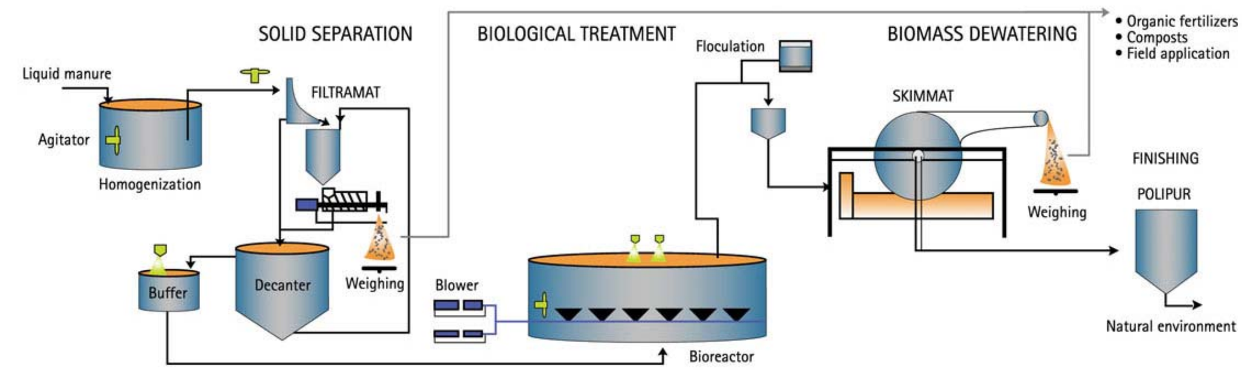
APPENDIX B
MANURE TREATMENT TECHNOLOGIES

BIOFERTILE®

Reference
Envirogain (Quebec city)

Manure treatment type
Aerobic manure treatment

Process - Illustration



Process description
5 steps
1. Homogenization and mechanical separation of manure (Primary treatment)
2. Aerobic treatment by nitrification/denitrification (Secondary treatment)
3. Aerobic treatment of air (odors and GHG control) and advanced liquid treatment
4. Dewatering of the biosolids
5. Electropurification of the final effluent (Tertiary treatment)

Final products
a. Purified water for re-use to flush the barn or irrigation on a small area
b. Value-added biofertilizer (3-6-2) (primary solids and dewatered biosolids)

Performance
Percentage of removal
KTN: 99%
Pt: 99%
BOD_5: >99%
TSS: >99%
E. coli: >99%

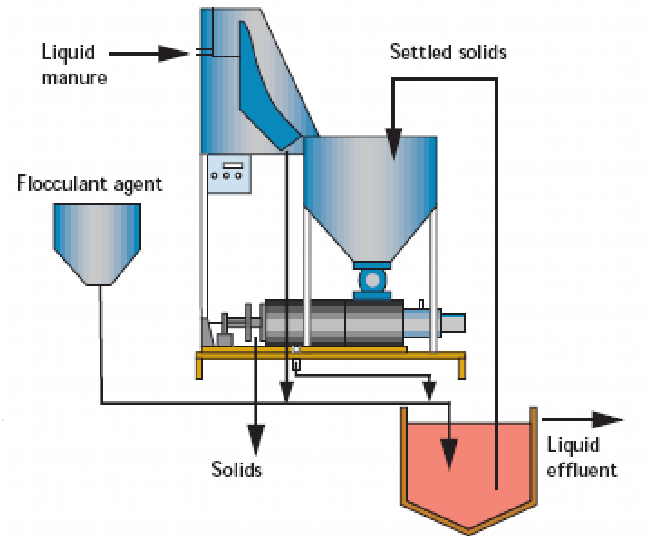
Economics
$8/m^3 of raw manure
$4/m^3 as financial cost and $4/m^3 as operational cost (energy, maintenance and operation)
New generation of Biofertile: lower costs because of end-product sale: $6/m^3

FILTRAMAT®

Reference
Envirogain (Quebec city)

Manure treatment type
Solid-liquid separator

Process - Illustration



Process description
Filtramat is a screw-press separator for liquid pig manure with a feeding tank and a programmable logic control. The separator is available in 3 versions depending of the required level of performance. Capacity of up to 80 m^3/day.

Final products

a. Liquid effluent
b. Solids

Performance
Percentage of removal with flocculant agent
Pt: > 70%
TSS: >60%

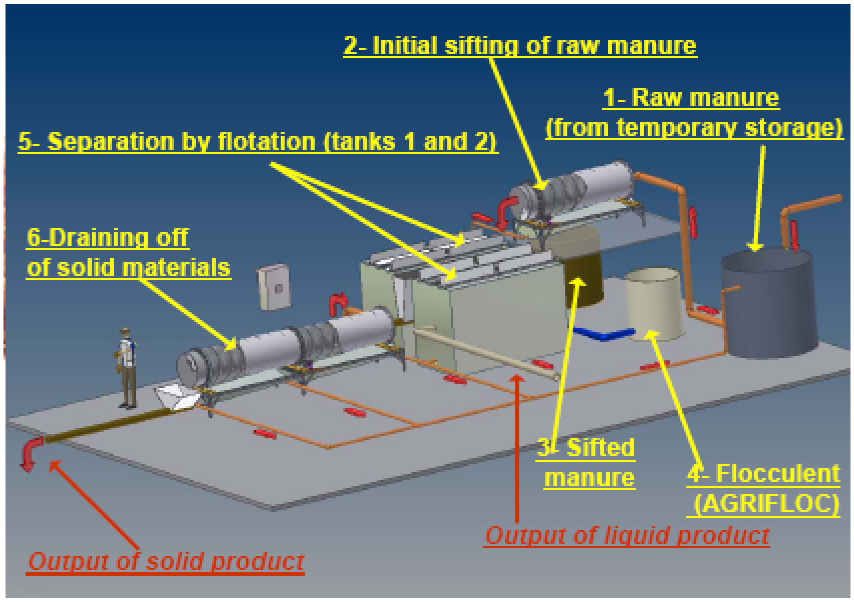
Economics
Investment between 100,000 and $150,000.

LISOX®

Reference
Corporation HET (Quebec city)

Manure treatment type
Solid-liquid separation with polyacrylamide polymers

Process - Illustration



Process description
3 principal steps
1. Rapid decantation
2. Biological passive flotation with simultaneous decantation of the solid (without polymers)
3. Extraction of solids and directed toward the solid reservoir and addition of polymers
4. Dewatering of solids and transport

Final products
Liquid: less than 10% of P in 85% or raw manure volume and nearly 50% of N (mainly ammonia)
Solid: 90% of concentrated P in 15% of the raw manure volume

Performance
Percentage of removal
Pt: between 80 and 95%
Initial manure volume: reduction between 80 and 85%

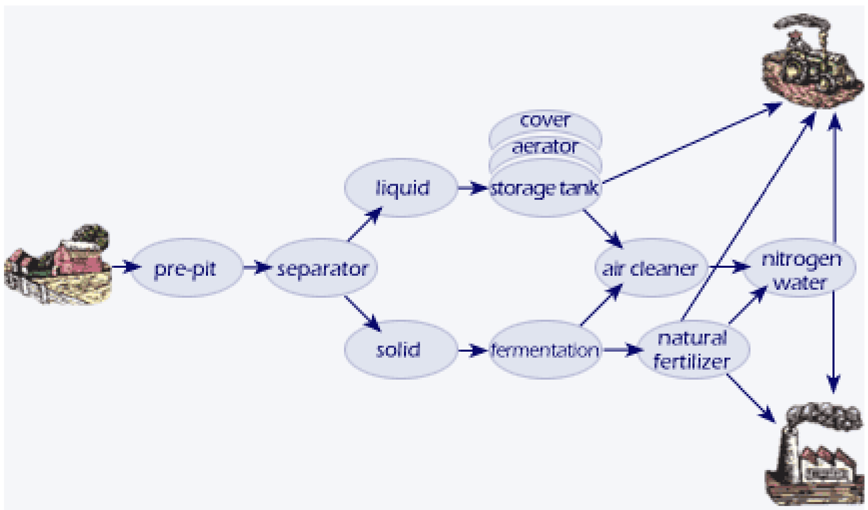
Economics
$6/m^3 for a farm of 2000-head producing 4000 m^3 of manure per year
Full management support (recipient for solid product)

MAXIMIZER®

Reference
Brome Agri-Sales (Quebec)

Manure treatment type
Solid-liquid separation

Process - Illustration
Inclined screen device designed to remove the suspended solids fraction from the waste stream.



http://www.bromeagrisales.ca/

Process description
See illustration.

Final products

a. Liquid fraction (loaded)
b. Solid fraction

Performance

	After separation	
	Liquid fraction	**Solid fraction**
Volume fraction	85%	15%
Total nitrogen	80-90%	10-20%
Total phosphorus	65-75%	25-35%
Potassium	80-90%	10-20%
Dry matter	1.5-2.0%	13-18%

This is purely a mechanical process without any inputs.

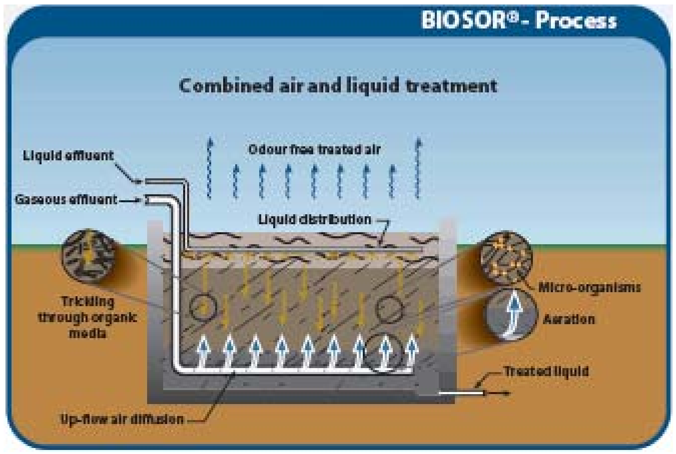
Economics
$1.524/m^3 ($6.93/1,000 imp gal) for investment cost (10 years, $0.52/m^3), man power ($1.00/m^3 manually operated) and electricity ($0.004/m^3). Cost analysis based on 40m^3/day of liquid manure (for 8,000-10,000 finishing pigs)

BIOSOR®

Reference
Biosor Technologies (Montreal city)

Manure treatment type
Aerobic organically-structure biofiltration system.

Process – Illustration



Process description
It consists of passing the liquid and gas effluents through an organic supported bio-filter. The filter media intervenes at two levels, as a natural resin capable of fixing several types of pollutants, or as support for various micro-organisms capable of degrading retained substances.

Final products

Performance
Average reduction
KTN: 93.7%
Pt: 90%
BOD_5: 99.6%
TSS: 99.8%
Odor (NH_3 and H_2S): 95%

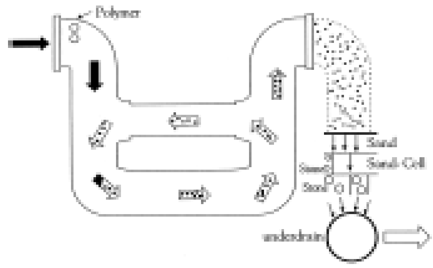
Economics

SOLID-LIQUID SEPARATION WITH PAM

Reference
Vanotti et al. (2005: 2002)

Manure treatment type
Solid-liquid separation with polyacrylamide polymers (PAM)

Process - Illustration



Process description
Prototype unit comprised of:

1. Homogenization tank for the flushed manure
2. In-line PAM injector and mixer to flocculate the manure solids in the flush (348 mg/L)
3. 2 filter beds for dewatering and underdrain system

Final products

a. Liquid (effluent)
b. Manure cake

Performance
Percentage of removal
KTN: 62%
Pt: 76%
Porg: 91%
TSS: >98%

Economics (2002)
$1.37 to $1.27 per finished pig for a 1000-head finishing operation (amount of PAM per day is 2.21 kg).

APPENDIX C
SIMULATION RESULTS

Table C.1 Results of manure application rate simulations.

Variables	Variables/Parameters	Description / units	SCENARIO											
			Farrowing		Finishing		Finishing_P		Farrowing		Finishing		Finishing-P	
Livestock	Size of livestock operation		Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
	Number of Animals	Number	600	3,000	2,000	8,000	2,000	8,000	600	3,000	2,000	8,000	2,000	8,000
	Barns	Number	1	2	1	4			1	2	1	4		
	Total AUs	Number	150	750	286	1144	286	1144	150	750	286	1144	286	1144
	Quantity	Volume (gal/year)	1,107,921	5,539,605	1,138,800	4,555,200	1,138,800	4,555,200	1,107,921	5,539,605	1,138,800	4,555,200	1,138,800	4,555,200
	Nutrient content	Total N (lb/1000 gal)	17.4	17.4	34.0	34.0	34.1	34.1	17.4	17.4	34.0	34.0	34.1	34.1
		Total P (lb/1000 gal)	6.6	6.6	10.0	10.0	6.7	6.7	6.6	6.6	10.0	10.0	6.7	6.7
		Total K (lb/1000 gal)	10.1	10.1	15.3	15.3	14.9	14.9	10.1	10.1	15.3	15.3	14.9	14.9
		NH_4-N (lb/1000 gal)	12.4	12.4	25.9	25.9	24.5	24.5	12.4	12.4	25.9	25.9	24.5	24.5
		DM (%)	3.0	3.0	3.7	3.7	3.4	3.4	3.0	3.0	3.7	3.7	3.4	3.4
	Total Area	Ha or ac	400	800	320	1280	320	1280	400	800	320	1280	320	1280
	Total manured land (1 ac per AU)	Ha or ac	150	750	286	1144	286	1144	150	750	286	1144	286	1144
	Crop Type		Small grains & oilseeds						Grass (hay)					
	Target Yield		? bu/ac						3 ton/ac					
	Nutrient Levels (recommendations)	N	94	94	94	94	94	94	100	100	100	100	100	100
		P_2O_5	32	32	32	32	32	32	30	30	30	30	30	30
		K_2O_5	-	-	-	-	-	-	-	-	-	-	-	-
	Season	Fall, Spring, Summer	Fall	Fall	Fall	Fall	Fall	Fall	Summer	Summer	Summer	Summer	Summer	Summer
	Application Method		Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Spreader/Tanker	Spreader/Tanker	Spreader/Tanker	Spreader/Tanker	Spreader/Tanker	Spreader/Tanker
	Incorporation		Injected	Injected	Injected	Injected	Injected	Injected	Standing/Cover cro	Standing/Cover cro	Standing/Cover cro	Standing/Cover cro	Standing/Cover cro	Standing/Cover cro
	Weather		Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
	Ammonium Loss	%							35	35	35	35	35	35
	Anticipated Start Date													
MARC2005	N-based	Application rate (gal/ac)	8,550	8,550	4,090	4,090	4,270	4,270	11,110	11,110	5,260	5,260	5,560	5,560
		Land required (acres)	129.6	647.9	278.4	1113.7	266.7	1066.8	99.7	498.6	216.5	866.0	204.8	819.3
		Nutrient applied N (lb/ac)	94.0	94.0	94.0	94.0	94.0	94.0	100.0	100.0	100.0	100.0	100.0	100.0
		Nutrient applied P_2O_5 (lb/ac)	68.4	68.4	45.0	45.0	34.2	34.2	88.9	88.9	57.9	57.9	44.5	44.5
		Nutrient balance N (lb/ac)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
		Nutrient balance P_2O_5 (lb/ac)	**36.4**	**36.4**	**13.0**	**13.0**	**2.2**	**2.2**	**58.9**	**58.9**	**27.9**	**27.9**	**14.5**	**14.5**
	2X crop removal - P-based	Application rate (gal/ac)	4,000	4,000	2,910	2,910	4,000	4,000	3,750	3,750	2,730	2,730	3,750	3,750
		Land required (acres)	277.0	1384.9	391.3	1565.4	284.7	1138.8	295.4	1477.2	417.1	1668.6	303.7	1214.7
		Nutrient applied N (lb/ac)	44.0	44.0	66.9	66.9	88.0	88.0	33.8	33.8	51.9	51.9	67.5	67.5
		Nutrient applied P_2O_5 (lb/ac)	32.0	32.0	32.0	32.0	32.0	32.0	30.0	30.0	30.0	30.0	30.0	30.0
		Nutrient balance N (lb/ac)	**-50.0**	**-50.0**	**-27.1**	**-27.1**	**-6.0**	**-6.0**	**-66.2**	**-66.2**	**-48.1**	**-48.1**	**-32.5**	**-32.5**
		Nutrient balance P_2O_5 (lb/ac)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
	1X crop removal - P-based	Application rate (gal/ac)	2,000	2,000	1,450	1,450	2,000	2,000	1,880	1,880	1,360	1,360	1,880	1,880
		Land required (acres)	554.0	2769.8	785.4	3141.5	569.4	2277.6	589.3	2946.6	837.4	3349.4	605.7	2423.0
		Nutrient applied N (lb/ac)	22.0	22.0	33.5	33.5	44.0	44.0	16.9	16.9	25.8	31.3	33.8	33.8
		Nutrient applied P_2O_5 (lb/ac)	16	16	16.0	16.0	16.0	16.0	15.0	15.0	15.0	15.0	15.0	15.0
		Nutrient balance N (lb/ac)	**-72.0**	**-72.0**	**-60.5**	**-60.5**	**-50.0**	**-50.0**	**-83.1**	**-83.1**	**-74.2**	**-68.7**	**-66.2**	**-66.2**
		Nutrient balance P_2O_5 (lb/ac)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table C.1 Results of manure application rate simulations (continued).

			SCENARIO											
Variables	Variables/Parameters	**Description / units**	**Farrowing**		**Finishing**		**Finishing-P**		**Farrowing**		**Finishing**		**Finishing-P**	
Livestock	Size of livestock operation		Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
	Number of Animals	Number	600	3,000	2,000	8,000	2,000	8,000	600	3,000	2,000	8,000	2,000	8,000
	Barns	Number	1	2	1	4			1	2	1	4		
	Total AUs	Number	150	750	286	1144	286	1144	150	750	286	1144	286	1144
	Quantity	Volume (gal/year)	1,107,921	5,539,605	1,138,800	4,555,200	1,138,800	4,555,200	1,107,921	5,539,605	1,138,800	4,555,200	1,138,800	4,555,200
	Nutrient content	Total N (lb/1000 gal)	17.4	17.4	34.0	34.0	34.1	34.1	17.4	17.4	34.0	34.0	34.1	34.1
		Total P (lb/1000 gal)	6.6	6.6	10.0	10.0	6.7	6.7	6.6	6.6	10.0	10.0	6.7	6.7
		Total K (lb/1000 gal)	10.1	10.1	15.3	15.3	14.9	14.9	10.1	10.1	15.3	15.3	14.9	14.9
		NH_4-N (lb/1000 gal)	12.4	12.4	25.9	25.9	24.5	24.5	12.4	12.4	25.9	25.9	24.5	24.5
		DM (%)	3.0	3.0	3.7	3.7	3.4	3.4	3.0	3.0	3.7	3.7	3.4	3.4
	Total Area	Ha or ac	400	800	320	1280	320	1280	400	800	320	1280	320	1280
	Total manured land (1 ac per AU)	Ha or ac	150	750	286	1144	286	1144	150	750	286	1144	286	1144
	Crop Type		**Grass (pasture)**						**Grain corn**					
	Target Yield		3 ton/ac						110 bu/ac					
	Nutrient Levels (recommendations)	N	100	100	100	100	100	100	130	130	130	130	130	130
		P_2O_5	5	5	5	5	5	5	48	48	48	48	48	48
		K_2O_5	-	-	-	-	-	-	-	-	-	-	-	-
	Season	Fall, Spring, Summer	Summer	Summer	Summer	Summer	Summer	Summer	Fall	Fall	Fall	Fall	Fall	Fall
	Application Method		Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose	Flexible Hose
	Incorporation		Standing/Cover cro	nding/Cover c	nding/Cover c	nding/Cover c	nding/Cover c	nding/Cover cr	Injected	Injected	Injected	Injected	Injected	Injected
	Weather		Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
	Ammonium Loss	%	35	35	35	35	35	35						
	Anticipated Start Date													
MARC2005	N-based	Application rate (gal/ac)	11,110	11,110	5,260	5,260	5,560	5,560	11,820	11,820	5,650	5,650	5,910	5,910
		Land required (acres)	99.7	498.6	216.5	866.0	204.8	819.3	93.7	468.7	201.6	806.2	192.7	770.8
		Nutrient applied N (lb/ac)	100.0	100.0	100.0	100.0	100.0	100.0	130.0	130.0	130.0	130.0	130.0	130.0
		Nutrient applied P_2O_5 (lb/ac)	88.9	88.9	57.9	57.9	44.5	44.5	94.6	94.6	62.2	62.2	47.3	47.3
		Nutrient balance N (lb/ac)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
		Nutrient balance P_2O_5 (lb/ac)	**83.9**	**83.9**	**52.9**	**52.9**	**39.5**	**39.5**	**46.6**	**46.6**	**14.2**	**14.2**	**-0.7**	**-0.7**
	2X crop removal - P-based	Application rate (gal/ac)	620	620	450	450	620	620	6,000	6,000	4,360	4,360	5,910	5,910
		Land required (acres)	1787.0	8934.8	2530.7	10122.7	1836.8	7347.1	184.7	923.3	261.2	1044.8	192.7	770.8
		Nutrient applied N (lb/ac)	5.6	5.6	8.5	8.5	11.2	11.2	66.0	66.0	100.3	100.3	132.0	132.0
		Nutrient applied P_2O_5 (lb/ac)	5.0	5.0	5.0	5.0	5.0	5.0	48.0	48.0	48.0	48.0	47.3	47.3
		Nutrient balance N (lb/ac)	**-94.4**	**-94.4**	**-91.5**	**-91.5**	**-88.8**	**-88.8**	**-64.0**	**-64.0**	**-29.7**	**-29.7**	**2.0**	**2.0**
		Nutrient balance P_2O_5 (lb/ac)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-0.7**	**-0.7**
	1X crop removal - P-based	Application rate (gal/ac)	310	310	230	230	310	310	3,000	3,000	2,180	2,180	3,000	3,000
		Land required (acres)	3573.9	17869.7	4951.3	19805.2	3673.5	14694.2	369.3	1846.5	522.4	2089.5	379.6	1518.4
		Nutrient applied N (lb/ac)	2.8	2.8	4.4	4.4	5.6	5.6	33.0	33.0	50.1	50.1	66.0	66.0
		Nutrient applied P_2O_5 (lb/ac)	2.5	2.5	2.5	2.5	2.5	2.5	24.0	24.0	24.0	24.0	24.0	24.0
		Nutrient balance N (lb/ac)	**-97.2**	**-97.2**	**-95.6**	**-95.6**	**-94.4**	**-94.4**	**-97.0**	**-97.0**	**-79.9**	**-79.9**	**-64.0**	**-64.0**
		Nutrient balance P_2O_5 (lb/ac)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table C.2 Results of manure management simulations.

	Crop	Land base[1]	Land base 1 ac/AU	Application rate (gal/ac) N-Based	Application rate (gal/ac) 2X crop P	Application rate (gal/ac) 1X crop P	Land required (acres) N-Based	Land required (acres) 2X crop P	Land required (acres) 1X crop P
Farrowing	Cereals & oilseeds	142	150	8,550	4,000	2,000	130	277	554
	Grain corn	142	150	11,820	6,000	3,000	94	185	369
Small LO	Hay	72	150	11,110	3,750	1,880	100	295	589
	Pasture	72	150	11,110	620	310	100	1,787	3,574
Finishing	Cereals & oilseeds	270	286	4,090	2,910	1,450	278	391	785
	Grain corn	270	286	5,650	4,360	2,180	202	261	522
Small LO	Hay	138	286	5,260	2,730	1,360	217	417	837
	Pasture	138	286	5,260	450	230	217	2,531	4,951
Finishing - P	Cereals & oilseeds	270	286	4,270	4,000	2,000	267	285	569
	Grain corn	270	286	5,910	5,910	3,000	193	193	380
Small LO	Hay	138	286	5,560	3,750	1,880	205	304	606
	Pasture	138	286	5,560	620	310	205	1,837	3,674
Farrowing	Cereals & oilseeds	708	750	8,550	4,000	2,000	648	1,385	2,770
	Grain corn	708	750	11,820	6,000	3,000	469	923	1,847
Large LO	Hay	361	750	11,110	3,750	1,880	499	1,477	2,947
	Pasture	361	750	11,110	620	310	499	8,935	17,870
Finishing	Cereals & oilseeds	1080	1144	4,090	2,910	1,450	1,114	1,565	3,142
	Grain corn	1080	1144	5,650	4,360	2,180	806	1,045	2,090
Large LO	Hay	551	1144	5,260	2,730	1,360	866	1,669	3,349
	Pasture	551	1144	5,260	450	230	866	10,123	19,805
Finishing - P	Cereals & oilseeds	1080	1144	4,270	4,000	2,000	1,067	1,139	2,278
	Grain corn	1080	1144	5,910	5,910	3,000	771	771	1,518
Large LO	Hay	551	1144	5,560	3,750	1,880	819	1,215	2,423
	Pasture	551	1144	5,560	620	310	819	7,347	14,694

[1] According to the Farm Guidelines

Table C.3 Results of simulations for multi-year manure application strategy.

LARGE OPERATIONS

		Manure ($)			
		Cereals & oilseeds	Grain corn	Hay	Pasture
Farrowing	N-based	199,424	199,441	249,275	249,275
	2X crop P	223,262	221,239	285,975	0
	Multi-year	232,661	232,681	295,656	293,591
Finishing	N-based	122,986	122,986	163,986	204,982
	2X crop P	0	129,398	0	0
	Multi-year	141,206	141,206	191,317	241,423
Finishing-P	N-based	81,994	81,998	122,993	204,989
	2X crop P	83,146	81,994	131,892	0
	Multi-year	91,105	91,109	141,215	241,431

		Fertilizers ($)			
		Cereals & oilseeds	Grain corn	Hay	Pasture
Farrowing	N-based	0	0	0	0
	2X crop P	87,944	78,668	148,970	0
	Multi-year	112,398	108,270	263,348	222,551
Finishing	N-based	0	0	0	0
	2X crop P	0	57,322	0	0
	Multi-year	128,819	124,076	289,906	386,541
Finishing-P	N-based	0	0	0	0
	2X crop P	25,153	0	86,550	0
	Multi-year	61,680	59,314	182,848	365,696

		Total costs ($)			
		Cereals & oilseeds	Grain corn	Hay	Pasture
Farrowing	N-based	199,424	199,441	249,275	249,275
	2X crop P	311,206	299,907	472,187	0
	Multi-year	345,059	340,951	559,004	516,142
Finishing	N-based	122,986	122,986	163,986	204,982
	2X crop P	0	186,719	0	0
	Multi-year	270,025	265,282	481,222	627,964
Finishing-P	N-based	81,994	81,998	122,993	204,989
	2X crop P	108,298	81,994	218,442	0
	Multi-year	152,785	150,422	324,063	607,128

		Increase manure			
		Cereals & oilseeds	Grain corn	Hay	Pasture
Farrowing	N-based	1.00	1.00	1.00	1.00
	2X crop P	1.12	1.11	1.15	0.00
	Multi-year	1.17	1.17	1.19	1.18
Finishing	N-based	1.00	1.00	1.00	1.00
	2X crop P	0.00	1.05	0.00	0.00
	Multi-year	1.15	1.15	1.17	1.18
Finishing-P	N-based	1.00	1.00	1.00	1.00
	2X crop P	1.01	1.00	1.07	0.00
	Multi-year	1.11	1.11	1.15	1.18

		Increase total costs			
		Cereals & oilseeds	Grain corn	Hay	Pasture
Farrowing	N-based	1.00	1.00	1.00	1.00
	2X crop P	1.56	1.50	1.89	0.00
	Multi-year	1.73	1.71	2.24	2.07
Finishing	N-based	1.00	1.00	1.00	1.00
	2X crop P	0.00	1.52	0.00	0.00
	Multi-year	2.20	2.16	2.93	3.06
Finishing-P	N-based	1.00	1.00	1.00	1.00
	2X crop P	1.32	1.00	1.78	0.00
	Multi-year	1.86	1.83	2.63	2.96

Table C.3 Results of simulations for multi-year manure application strategy (continued).

SMALL OPERATIONS		Manure ($)			
		Cereals & oilseeds	Grain corn	Hay	Pasture
Farrowing	N-based	39,891	39,871	49,845	49,845
	2X crop P	43,632	44,342	55,720	0
	Multi-year	46,539	46,516	58,977	58,883
Finishing	N-based	30,744	30,754	40,996	51,246
	2X crop P	0	32,279	0	0
	Multi-year	35,298	35,310	47,829	60,356
Finishing-P	N-based	20,499	20,499	30,745	40,993
	2X crop P	20,786	20,520	32,970	0
	Multi-year	22,776	22,777	35,334	60,350
		Fertilizers ($)			
		Cereals & oilseeds	**Grain corn**	**Hay**	**Pasture**
Farrowing	N-based	0	0	0	0
	2X crop P	21,986	15,717	29,788	0
	Multi-year	22,549	21,700	52,670	44,635
Finishing	N-based	0	0	0	0
	2X crop P	0	14,445	0	0
	Multi-year	32,147	31,088	72,644	96,635
Finishing-P	N-based	0	0	0	0
	2X crop P	6,144	0	21,664	0
	Multi-year	15,437	14,852	45,751	91,413
		Total costs ($)			
		Cereals & oilseeds	**Grain corn**	**Hay**	**Pasture**
Farrowing	N-based	39,891	39,871	49,845	49,845
	2X crop P	65,618	60,059	92,955	0
	Multi-year	69,088	68,217	111,646	103,518
Finishing	N-based	30,744	30,754	40,996	51,246
	2X crop P	0	46,724	0	0
	Multi-year	67,445	66,398	120,473	156,991
Finishing-P	N-based	20,499	20,499	30,745	40,993
	2X crop P	26,931	20,520	54,634	0
	Multi-year	38,214	37,629	81,085	151,763
		Increase manure			
		Cereals & oilseeds	**Grain corn**	**Hay**	**Pasture**
Farrowing	N-based	1.00	1.00	1.00	1.00
	2X crop P	1.09	1.11	1.12	0.00
	Multi-year	1.17	1.17	1.18	1.18
Finishing	N-based	1.00	1.00	1.00	1.00
	2X crop P	0.00	1.05	0.00	0.00
	Multi-year	1.15	1.15	1.17	1.18
Finishing-P	N-based	1.00	1.00	1.00	1.00
	2X crop P	1.01	1.00	1.07	0.00
	Multi-year	1.11	1.11	1.15	1.18
		Increase total costs			
		Cereals & oilseeds	**Grain corn**	**Hay**	**Pasture**
Farrowing	N-based	-	-	-	-
	2X crop P	1.64	1.51	1.86	0.00
	Multi-year	1.73	1.71	2.24	2.08
Finishing	N-based	-	-	-	-
	2X crop P	0.00	1.52	0.00	0.00
	Multi-year	2.19	2.16	2.94	3.06
Finishing-P	N-based	-	-	-	-
	2X crop P	1.31	1.00	1.78	0.00
	Multi-year	1.86	1.84	2.64	3.70

Table C.4 Results of simulations for total manure management costs for strategy 3: transport with tractor-drawn tank for 20 km.

		Transport with Tanker (13 miles, 20 km)					
		Transport ($)		Overall costs ($)[1,2]		Costs increase[3]	
	Crop	2X crop P	1X crop P	2X crop P	1X crop P	2X crop P	1X crop P
Farrowing	Cereals & oilseeds	21,815	31,404	31,786	41,375	3.19	4.15
	Grain corn	20,184	30,589	30,156	40,560	3.02	4.07
Small LO	Hay	27,157	34,056	37,128	44,028	3.72	4.42
	Pasture	38,705	39,849	48,677	49,821	4.88	5.00
Finishing	Cereals & oilseeds	12,156	27,198	22,406	37,447	2.19	3.65
	Grain corn	9,620	25,878	19,870	36,127	1.94	3.52
Small LO	Hay	20,267	31,241	30,516	41,490	2.98	4.05
	Pasture	38,531	40,293	48,780	50,542	4.76	4.93
Finishing-P	Cereals & oilseeds	2,664	22,400	12,914	32,649	1.26	3.19
	Grain corn	0	20,747	10,249	30,996	1.00	3.02
Small LO	Hay	13,717	27,888	23,966	38,138	2.34	3.72
	Pasture	37,437	39,786	47,686	50,036	4.65	4.88
Farrowing	Cereals & oilseeds	109,075	157,020	158,932	206,877	3.19	4.15
	Grain corn	100,922	152,944	150,778	202,800	3.02	4.07
Large LO	Hay	135,783	170,282	185,639	220,138	3.72	4.42
	Pasture	193,527	199,246	243,384	249,103	4.88	5.00
Finishing	Cereals & oilseeds	48,626	108,790	89,623	149,787	2.19	3.65
	Grain corn	38,481	103,512	79,478	144,509	1.94	3.52
Large LO	Hay	81,067	124,965	122,064	165,962	2.98	4.05
	Pasture	154,123	161,173	195,120	202,169	4.76	4.93
Finishing-P	Cereals & oilseeds	10,657	89,600	51,654	130,597	1.26	3.19
	Grain corn	0	82,988	40,997	123,985	1.00	3.02
Large LO	Hay	54,867	111,553	95,864	152,550	2.34	3.72
	Pasture	149,748	159,145	190,745	200,142	4.65	4.88

[1] Annual manure application at the cost of $0.009/imp gal.

[2] All costs: manure application plus extra costs of transport.

[3] Compared to cost of manure applicationfor N-based at the cost of $0.009/imp gal.

Table C.5 Results of simulations for total manure management costs for strategy 3: transport with truck for 20 km.

		Transport with Truck (13 miles, 20 km)					
		Transport ($)		Overall costs ($)[1,2]		Costs increase[3]	
	Crop	2X crop P	1X crop P	2X crop P	1X crop P	2X crop P	1X crop P
Farrowing	Cereals & oilseeds	10,318	14,853	20,289	24,825	2.03	2.49
	Grain corn	9,547	14,468	19,518	24,439	1.96	2.45
Small LO	Hay	12,844	16,108	22,816	26,079	2.29	2.62
	Pasture	18,307	18,848	28,278	28,819	2.84	2.89
Finishing	Cereals & oilseeds	5,750	12,864	15,999	23,113	1.56	2.26
	Grain corn	4,550	12,240	14,799	22,489	1.44	2.19
Small LO	Hay	9,586	14,776	19,835	25,025	1.94	2.44
	Pasture	18,224	19,058	28,473	29,307	2.78	2.86
Finishing-P	Cereals & oilseeds	1,260	10,595	11,509	20,844	1.12	2.03
	Grain corn	0	9,813	10,249	20,062	1.00	1.96
Small LO	Hay	6,488	13,190	16,737	23,440	1.63	2.29
	Pasture	17,707	18,818	27,956	29,067	2.73	2.84
Farrowing	Cereals & oilseeds	51,590	74,266	101,446	124,123	2.03	2.49
	Grain corn	47,733	72,338	97,590	122,195	1.96	2.45
Large LO	Hay	64,222	80,539	114,078	130,395	2.29	2.62
	Pasture	91,533	94,238	141,390	144,095	2.84	2.89
Finishing	Cereals & oilseeds	22,999	51,455	63,996	92,452	1.56	2.26
	Grain corn	18,201	48,958	59,197	89,955	1.44	2.19
Large LO	Hay	38,342	59,105	79,339	100,102	1.94	2.44
	Pasture	72,896	76,230	113,893	117,227	2.78	2.86
Finishing-P	Cereals & oilseeds	5,041	42,378	46,037	83,375	1.12	2.03
	Grain corn	0	39,251	40,997	80,248	1.00	1.96
Large LO	Hay	25,951	52,762	66,948	93,758	1.63	2.29
	Pasture	70,827	75,271	111,824	116,268	2.73	2.84

[1] Annual manure application at the cost of $0.009/imp gal.

[2] All costs: manure application plus extra costs of transport.

[3] Compared to cost of manure applicationfor N-based at the cost of $0.009/imp gal.

Table C.6 Results of simulations for total manure management costs for strategy 3: transport with truck for 40 km.

		Transport with Truck (25 miles, 40 km)					
		Transport ($)		Overall costs ($)[1,2]		Costs increase[3]	
	Crop	2X crop P	1X crop P	2X crop P	1X crop P	2X crop P	1X crop P
Farrowing	Cereals & oilseeds	17,688	25,463	27,659	35,434	2.77	3.55
	Grain corn	16,366	24,802	26,337	34,773	2.64	3.49
Small LO	Hay	22,019	27,613	31,990	37,585	3.21	3.77
	Pasture	31,383	32,310	41,354	42,281	4.15	4.24
Finishing	Cereals & oilseeds	9,857	22,052	20,106	32,301	1.96	3.15
	Grain corn	7,800	20,982	18,049	31,231	1.76	3.05
Small LO	Hay	16,432	25,331	26,682	35,580	2.60	3.47
	Pasture	31,241	32,670	41,490	42,919	4.05	4.19
Finishing-P	Cereals & oilseeds	2,160	18,162	12,409	28,411	1.21	2.77
	Grain corn	0	16,822	10,249	27,071	1.00	2.64
Small LO	Hay	11,122	22,612	21,371	32,861	2.09	3.21
	Pasture	30,354	32,259	40,604	42,508	3.96	4.15
Farrowing	Cereals & oilseeds	88,439	127,314	138,296	177,170	2.77	3.55
	Grain corn	81,829	124,008	131,685	173,865	2.64	3.49
Large LO	Hay	110,094	138,066	159,950	187,923	3.21	3.77
	Pasture	156,914	161,551	206,770	211,407	4.15	4.24
Finishing	Cereals & oilseeds	39,426	88,208	80,423	129,205	1.96	3.15
	Grain corn	31,201	83,929	72,198	124,925	1.76	3.05
Large LO	Hay	65,730	101,323	106,727	142,320	2.60	3.47
	Pasture	124,965	130,681	165,962	171,677	4.05	4.19
Finishing-P	Cereals & oilseeds	8,641	72,649	49,638	113,645	1.21	2.77
	Grain corn	0	67,287	40,997	108,284	1.00	2.64
Large LO	Hay	44,487	90,449	85,484	131,445	2.09	3.21
	Pasture	121,417	129,037	162,414	170,033	3.96	4.15

[1] Annual manure application at the cost of $0.009/imp gal.

[2] All costs: manure application plus extra costs of transport.

[3] Compared to cost of manure applicationfor N-based at the cost of $0.009/imp gal.

Table C.7 Nutrient balance (lb N/ac) for N-based and up to two times crop P_2O_5 removal simulations for all cropping systems.

		Final nutrients balance (lb/ac)					
		N-based	2X crop P	1X crop P	Land required		
	Crop	P	N	N	N-based	2X crop P	1X crop P
Farrowing	Cereals & oilseeds	36.4	-50.0	-72.0	130	277	554
	Grain corn	46.6	-64.0	-97.0	94	185	369
Small LO	Hay	58.9	-66.2	-83.1	100	295	589
	Pasture	83.9	-94.4	-97.2	100	1787	3574
Finishing	Cereals & oilseeds	13.0	-27.1	-60.5	278	391	785
	Grain corn	14.2	-29.7	-79.9	202	261	522
Small LO	Hay	27.9	-48.1	-74.2	217	417	837
	Pasture	52.9	-91.5	-95.6	217	2531	4951
Finishing-P	Cereals & oilseeds	2.2	-6.0	-50.0	267	285	569
	Grain corn	-0.7	2.0	-64.0	193	193	380
Small LO	Hay	14.5	-32.5	-66.2	205	304	606
	Pasture	39.5	-88.8	-94.4	205	1837	3674
Farrowing	Cereals & oilseeds	36.4	-50.0	-72.0	648	1385	2770
	Grain corn	46.6	-64.0	-97.0	469	923	1847
Large LO	Hay	58.9	-66.2	-83.1	499	1477	2947
	Pasture	83.9	-94.4	-97.2	499	8935	17870
Finishing	Cereals & oilseeds	13.0	-27.1	-60.5	1114	1565	3142
	Grain corn	14.2	-29.7	-79.9	806	1045	2090
Large LO	Hay	27.9	-48.1	-74.2	866	1669	3349
	Pasture	52.9	-91.5	-95.6	866	10123	19805
Finishing-P	Cereals & oilseeds	2.2	-6.0	-50.0	1067	1139	2278
	Grain corn	-0.7	2.0	-64.0	771	771	1518
Large LO	Hay	14.5	-32.5	-66.2	819	1215	2423
	Pasture	39.5	-88.8	-94.4	819	7347	14694

Table C.8 Commercial fertilizers needed to supplement all cropping systems for simulations of up to two times crop P_2O_5 removal simulations.

	Crop	Fertilizer (lb N/ac)			Fertilizer qty needed (lbs)		
		N-based	2X crop P	1X crop P	N-based	2X crop P	1X crop P
Farrowing	Cereals & oilseeds	0	73	106	0	20,220	58,720
	Grain corn	0	94	143	0	17,357	52,811
Small LO	Hay	0	173	218	0	51,112	128,472
	Pasture	0	245	255	0	437,807	911,354
Finishing	Cereals & oilseeds	0	40	88	0	15,654	69,113
	Grain corn	0	44	117	0	11,492	61,119
Small LO	Hay	0	130	195	0	54,229	163,284
	Pasture	0	240	252	0	607,360	1,247,729
Finishing-P	Cereals & oilseeds	0	9	73	0	2,562	41,566
	Grain corn	0	0	94	0	0	35,682
Small LO	Hay	0	85	173	0	25,813	104,794
	Pasture	0	232	250	0	426,132	918,387
Farrowing	Cereals & oilseeds	0	73	106	0	101,098	293,599
	Grain corn	0	94	143	0	86,787	264,055
Large LO	Hay	0	173	218	0	255,560	642,358
	Pasture	0	245	255	0	2,189,037	4,556,772
Finishing	Cereals & oilseeds	0	40	88	0	62,614	276,454
	Grain corn	0	44	117	0	45,970	244,476
Large LO	Hay	0	130	195	0	216,914	653,135
	Pasture	0	240	252	0	2,429,440	4,990,915
Finishing-P	Cereals & oilseeds	0	9	73	0	10,249	166,265
	Grain corn	0	0	94	0	0	142,730
Large LO	Hay	0	85	173	0	103,251	419,175
	Pasture	0	232	250	0	1,704,526	3,673,548