A Regional Dynamic Assessment of Emerging Manure Management in MB

Collin Gyles

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Derek Brewin, advisor

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Abstract

This thesis uses a cost minimization simulation to identify manure phosphorus demand at the municipal level Manitoba. The initial conditions are based on 2006 Census of Agriculture livestock and land use. The model includes probabilistic phosphorus distributions. After the manure demand has been determined the livestock quantities which would produce the manure necessary to meet the demand are also calculated. The results of the simulation indicate that, dependent upon the price of mineral fertilizer and the manure acceptance rate, the phosphorus contained in manure can be effectively utilized as a resource by crop producers in Manitoba.

Contents

List of Tables

List of Figures

Chapter 1: Introduction

Livestock production in Manitoba, hog production in particular, is a large part of the agricultural economy; in 2007 the cash receipts from hog production totaled almost $440 MM (Manitoba Agriculture, Food and Rural Initiatives, 2007). The Southeast section of the province, specifically the rural municipalities of Hanover and La Broquerie, are home to a little over a third the province's total hog production (Statistics Canada, 2006). The cost savings associated with the economies of scale and agglomeration achieved as a result of this concentration might benefit both food consumers and agricultural producers; however, the complications arising from excess manure accumulation in such a concentrated area can have negative consequences. Excess phosphorus runoff, which is often blamed on hog production, is a problem in Manitoba because in many of the province's large fresh water lakes, notably Lake Winnipeg, algae growth due to eutrophication has had a negative impact on water quality and the related tourism and fishing industries. Phosphorus is the limiting nutrient in algae growth and the excess accumulation of phosphorus in fresh water has been identified as major cause of this harmful blue-green algae growth (Flaten, Whittenberg, & Zhang, 2007).

Despite the fact that it can cause environmental harm, hog manure has great potential value as a fertilizer for agricultural crops; the estimated 346,000 tonnes of pig manure produced in Manitoba contains nutrients, such as nitrogen and phosphorus, with an approximate value of between $30 MM to $40 MM (Flaten, Whittenberg, & Zhang, 2007). Unfortunately the majority of this manure is applied to a very small percentage of available farmland in a very concentrated area in the Southeastern part of the province, close to the areas of pig production and not fully utilized as a resource. Due to its relatively small contribution to farm returns in comparison to the value of hog production, manure sales do not generally play a significant role in a profit maximizing hog producers' production decisions (Roka & Hoag, 1996). Consequently hog producers have an economic incentive to dispose of this manure "waste" in the most cost effective manner possible. Normally this is done by applying it to the farmland that is closest to the manure storage facility. In the absence of regulation, the natural outcome of this behavior will be an over-application of nutrients. A nutrient over-application, which occurs when nutrients are applied to crops at rates that are higher than the rate at which the crop will remove them, results in an accumulation of excess nutrients in the soil. These excess nutrients become a problem when, through various processes, they leach out of the soil and collect in surface water. Since most of the environmental problems associated with nutrient runoff are a result of excess phosphorus accumulation the focus of this research will be on phosphorus and how better management of this nutrient in Manitoba soils and manure can lead to economic efficiencies in the province's crop and animal production industries.

Previous research indicates that more phosphorus is removed from Manitoba soils via crop removal then is contributed through manure and mineral fertilizer applications (Flaten & Rawluk, 2007); this implies that there is a problem not with the quantity of phosphorus generated by manure but in how it is distributed. Previous research has examined the economic impact on phosphorus and nitrogen limited application regulations with respect to the hog industry (Salvano et. al., 2006; Mann & Grant, 2006). Newly enacted provincial legislation, specifically the The Environment Amendment Act

(Permanent Ban on Building or Expanding Hog Facilities) recently passed by the Manitoba Legislative Assembly, will indefinitely ban the construction of new hog barns in certain regions of the province. This new legislation has been perceived as unfair by many producers who feel that the province still has ample capacity for hog production (McLean, 2008). A solution that could balance the concerns of hog producers and crop producers with environmental concerns would be to more fully utilize manure as a fertilizer under the proposed soil nutrient level based regulations (Salvano et. al., 2006). This solution would limit the accumulation of environmentally harmful phosphorus while allowing for expansion of the economically important hog industry and providing a valuable input to the crop production sector in Manitoba.

With the recent dramatic increase in the price of mineral phosphorus fertilizer (see Table 1) the value of manure, a close substitute, should correspondingly increase. The phosphorous content of hog manure is a valuable and underutilized source of plant nutrition for Manitoba crop producers; however, earlier research has found that, for the most part pig, manure is expensive to transport and handle and entails a substantial cost to hog producers for the necessary treatment and land application under environmental regulations (Salvano et. al., 2006). Nevertheless, the estimated $18 MM to $28 MM cost of manure management to the hog industry (Mann & Grant, 2006) is still less than the value nutrients contained in the manure ($30 MM to $40 MM; Brewin, Honey, & Young, 2007), this implies that there is an opportunity for both the crop producers and animal producers to benefit by utilizing manure as fertilizer.

Table 1: Manitoba Producer Phosphorus Fertilizer Price Survey Results 1999-2008

Year	Dry 12-52-0 ($/tonne)	Liquid 10-34-0 ($/tonne)
1999	$399.24	$364.72
2005	$402.65	$366.94
2006	$502.64	$414.59
2007	$616.63	$470.56
2008	$1,210.72	$824.50

Source: (Keystone Agricultural Producers, 2008)

In light of the recent increase in the cost mineral phosphorus fertilizer the benefit of manure fertilization to crop producers who are willing to apply manure to their fields has also increased and should be further explored. To date economic analysis of the proposed soil test phosphorus threshold regulations has been largely limited to the impact and costs that they will impose on the hog sector, while ignoring the impact and potential benefits to the crop production sector.

Using a cost minimization simulation this thesis will identify manure demand for all of the Rural Municipalities (R.M.) in Manitoba for which sufficient data are available. The initial conditions are based on 2006 Census of Agriculture livestock and land use. The model will include probabilistic phosphorus distributions. After the manure demand has been determined the livestock quantities which would produce the manure necessary to meet the demand will also be calculated.

The chapters of this thesis are described as follows. Chapter Two will consist of a review of the relevant literature with respect to livestock waste and its management. Chapter Three will present the economic theory relevant to this examination. Chapter

Four will describe the simulation model used in this thesis. Chapter Five will describe the data used in the simulation model. Chapter Six will explain the procedures used in calculating the simulation model. Chapter Seven will present the results obtained from the simulation model. Chapter Eight will discuss the implications and conclusions of the results from the simulation model.

Chapter 2: Review of Literature

The literature addressing the economic implications of livestock waste is vast. This chapter will provide an overview of some of the previous research relevant to the economics of: manure transportation and utilization, hog production, phosphorus runoff pollution, and how they might relate to Manitoba.

In general manure runoff is considered to be a non-point pollution externality problem, to ameliorate the sometimes opposing concerns of agricultural production and environmental sustainability, regulations must be put in place to control runoff. How these regulations will impact on agricultural production is the topic of a large volume of research. The frameworks developed to analyze the economic implications of manure are for the most part developed in an ad hoc basis. Manure can be viewed as either a waste or a resource. The focus of a large amount of previous research has been on making this determination. The factors that influence this determination include the quantity of manure nutrients produced in a given geographic area; the costs involved in the transportation and processing of manure; and the area of farmland available to apply manure to. An important component of this research is to determine an animal capacity for which manure can still be viewed as a resource.

A theoretical framework for analyzing the economics of manure in a spatial context was presented by Innes (2000). This research developed a regional model to analyze the potential impact of a number of environmental problems associated with large scale animal production in areas with limited land. Among the possible environmental problems examined by Innes was the impact of manure spreading and subsequent nutrient runoff problems. Innes made the assertion that nutrient runoff was dependant on the total application of nutrients from manure and mineral fertilizers. In the absence of manure, crop producers will apply mineral nutrients until some optimal point is reached, when manure is added it becomes a benefit equivalent to its nutrient content which can be used towards reaching this optimal point. An important point raised in Innes's theoretical analysis was that as the number of animals increases, the marginal value of manure decreases, leading to an increase in the potential for runoff. The idea that the number of animals can influence the value of manure is important in that it implies that an optimal number of animals does exist. Another important point which can be derived from Innes's research is that all sources of nutrient runoff need to be considered in an analysis not just livestock manure.

In addition to the theoretical research by Innes (2000) substantial empirical research has been published. In most cases the crop base, soil variables, and regulations differ substantively from region to region meaning that many of the models developed to analyze the economics of manure cannot be fully transferred to another region. A discussion of some of the empirical research done in other jurisdictions and how they might apply to Manitoba is provided below.

Johnsen (1993) conducted farm level simulations on the economic implications of phosphorus runoff in Norway. Among the phosphorus runoff reducing methods examined by Johnsen was planned fertilization (i.e. matching manure fertilization to crop nutrient needs); in this simulation it was determined that planned fertilization paid off from both farm-economic and socio-economic perspectives. The implication is that manure can be utilized as resource which benefits producers if it is used in accordance with a plan that takes into account crop needs. This possibility has not yet been fully explored in Manitoba.

Keplinger & Hauck (2006) used a cost minimization model of manure utilization to examine the economic implications of using livestock waste as a replacement for fertilizer. They found that as manure production increases, manure value decreases and the potential for excess phosphorus application increases which leads to the potential for an increase in phosphorus runoff. Keplinger & Hauck also found that increasing the proportion of land using manure increases the value of the manure and reduces the potential for excess phosphorus application. The findings of Keplinger and Hauck illustrate the importance that manure acceptance rates and livestock concentration can have in determining if manure is a resources or a waste.

Feinerman, Bosch, & Pease (2004) conducted an empirical analysis of economic welfare implications due to manure regulations in a number of Virginia counties. Notable about the analytical framework used in this analysis is that it allowed for a simultaneous use of commercial and different types of manure fertilization strategies including both poultry litter, which has relatively low transportation costs, and dairy slurry, which has higher transportation costs. High nutrient content and low transportation cost manure such as chicken litter is not produced in large quantities in Manitoba; however, dairy slurry, which is a low density and high transportation cost manure, has characteristics similar to hog manure and as such is a more appropriate comparison to Manitoba's hog manure problem. Feinerman, Bosch, & Pease (2004) found that dairy slurry had a relatively high cost in relation to its nutrient content and as such had a slightly negative demand. This negative demand implies that the manure would not be applied under normal circumstances. The different crop base in Virginia and recent increases in the cost of fertilizer do not preclude the possibility for low density nutrient manure to be applied as fertilizer in an economically efficient way in Manitoba.

Lazarus & Koehler (2002) presented an empirical farm level study on the economics of applying swine manure in Minnesota. This analysis examined three manure application rates which included: an over application of manure, a phosphorus based application, and a nitrogen based application. They found that that a fertilization strategy using a combination of hog manure and mineral fertilizer to meet the crop's nutrient was lowest cost fertilization strategy when using phosphorus based application rates. By demonstrating that phosphorus based hog manure applications can be a profitable fertilization strategy for farmers, Lazarus & Koehler's research suggests that an economically rational farmer utilizing manure and mineral fertilizer would choose to apply manure at rates based on it phosphorus content. It is possible that such conclusions could hold in Manitoba as well. Another important question that Lazarus & Koehler attempted to address was how far manure could be transported while remaining profitable. In this evaluation they found that with differing technology it is possible to transport hog manure distances in excess of six miles while still realizing a fertilizer cost saving and a return to the initial investment on manure hauling equipment. The fact that under phosphorus based regulatory systems manure was able to be transported and applied to crops profitably in Minnesota suggests the importance analyzing manure management in Manitoba.

A further study that attempted to quantify a possible economic benefit of manure fertilization was the work of Roka & Hoag (1996) who examined the economics of manure from the perspective of hog producers in North Carolina. Using the premise that finishing weight and manure are both a product of animal production, an optimal management choice that maximized the value of both products should exist. In their analysis Roka & Hoag found that the costs of handling manure were greater than its value as a fertilizer and the value of pork dominated the producers marketing decisions. In their conclusion Roka & Hoag noted that manure value can be positive or negative depending on the cost of the nutrients they are replacing, and that manure management policies should be flexible in order to allow producers to maximize the value of their manure resources. The research proposed here will attempt to determine livestock quantities under which manure can be utilized with a positive value in Manitoba.

Building on the work of Roka & Hoag (1996), Fleming, Babcock, & Wang (1998) analyzed Iowa swine production operations and found that manure applications based on phosphorus can better match crop nutrient needs thus leading to higher profits in the long run for manure providers. Also of note in the Fleming, Babcock, & Wang study was the approach used to calculate the distance manure must be hauled before it can be applied to crops. Since the number of possible routes a truckload of manure can take from a storage facility to a field it is very difficult to estimate. This research put forth the proposition that most important factor in determining the distance manure must be hauled is the area that must be searched to find available land. The required search area can be determined as a function of the minimum area required in which the manure can be spread according to regulation and the nutrient needs of available crops. Since not all land in the minimum required area will allow manure application, the search area is a subset of the total land available based on an acceptance rate. Once the search area is established the average distance manure might be transported in a given region can be calculated, this approach to calculating transportation costs was modified and used in a regional model of the United States (Kaplan, Johansson, & Peters, 2004), and could also be used to calculate manure transportation costs at the regional level in Manitoba.

A large part of the success or failure in using manure as a fertilizer is in getting crop producers to accept it as a substitute for fertilizer. Thus an acceptance rate was assumed in many of the above models. For the most part very little is known about farmer's willingness to pay for and attitudes towards manure; however, some research has been done on producers in Oklahoma (Norwood, Luter, & Massey, 2005) and Colorado (Hoag, Lacy, & Davis, 2004). Hoag, Lacy, & Davis (2004) surveyed producers in Colorado and noted that pressures such as owning cattle and preferences (i.e. attitude towards manure) can influence a producer's willingness to apply manure; however, they concluded that "willingness to apply is not predictable from current knowledge". Norwood, Luter, & Massey (2005) surveyed producers in Oklahoma and found that the majority of crop producers would pay up to the equivalent nutrient value of commercial fertilizer for manure, but 25% would require a payment to apply it to their field.

Janzen et. al. (1999) used Alberta as an example to model conditions under which manure can be used as a resource rather than a waste. This analysis was different from traditional economic models in that the steady state ecological balance model used in the analysis was more restrictive than most types of economic models. It required nutrients to be utilized only to the lowest limiting factor. With these tight ecological restrictions

Janzen et. al. still showed that effective manure utilization had the potential increase the profitability of agricultural production.

Substantial research on the economics of hog manure in Manitoba has been conducted. Salvano et. al. (2006) and Mann & Grant (2006) completed comprehensive reports on the costs and implications of phosphorus constraints on manure application; however, both reports focused largely on the cost to hog producers of complying with new phosphorus based regulations and paid little attention to the potential value of manure if it is utilized beyond hog production operations. In a report to the Clean Environment Commission, Flaten, Whittenberg, & Zhang (2007) provided an overview of the current knowledge with respect to hog production and the associated environmental problems in Manitoba and in their conclusion noted that flexibility is important in creating win/win solutions if they are possible. Using manure to fertilize crops at agronomic rates has the potential to be a win/win solution for helping to resolve Manitoba's phosphorus runoff problems. If phosphorus from manure is applied to crops, at levels which crops can utilize it, it does not leach out of the soil and damage the environment while at the same time providing crop producers with a source of plant nutrition.

Much of the early research on livestock manure management treated manure as a factor of production (Schute, 1977). Over time as animal producers have become more specialized and larger they came to view manure as a waste that they could not efficiently apply to the limited crop land they controlled and as such the manure management became a cost to be managed rather than a resource. This behavior becomes problematic when livestock producers over-apply manure to dispose of this "waste" in a cost minimizing manner. As a result of manure over-application and the related nutrient runoff, phosphorus especially, environmental damage to the environment has occurred. As such, regulations must be put in place to limit the damage. Complying with the regulations entails a cost to the producer. When the nutrient benefit of manure is accounted for, these costs can be reduced or turned into a net-benefit for surrounding crop producers. The conditions under which manure can be utilized as a resource are dependent on a number of factors which can differ greatly from region to region meaning results from one area are rarely fully transferable to another area.

The cost of complying with Manitoba's proposed phosphorus based regulations has been studied and estimated. What is not known is if manure can be utilized as a resource under these regulations and if such utilization were possible what spatial distribution and hog capacity would allow for it. The objective of the research proposed here is to determine the livestock quantities (using hogs as an example) under which manure can be used as resource and the subsequent savings using this manure would provide to crop producers.

Chapter 3: Theory

The phosphorus contained in hog manure can be a resource when it is used as a substitute to mineral fertilizer to meet crop's phosphorus requirements. However, hog manure becomes a waste when it is produced in quantities that exceed the capacity of the surrounding crop production operations to utilize it and may become a pollutant. In order to create a framework capable of analyzing the economic implications of manure utilization it is necessary to determine: regional nutrient demands at the municipality level; the costs of meeting the nutrient demand using a combination of mineral fertilizer and manure; and the proportion of crop producers who are willing to accept manure as a substitute for fertilizer. This simulation framework developed below incorporates these factors.

The behavioral model used in this simulation will be a cost minimization model similar to the model used by Keplinger & Hauck (2006) in their economic analysis of manure utilization. A cost minimization model, rather than a profit maximizing model, is appropriate to determine the economic implications of manure application in Manitoba because the object of study is to determine the implications of crop producers' choices between mineral phosphorus and hog manure to fertilize crops. Provincial manure application guidelines are based on agronomic concerns not profit maximization concerns. The addition of crop yields, commodity prices, and other factors necessary to construct a profit maximization model would add significant complexity to the study thus in the interest of parsimony a cost minimization model is sufficient. Furthermore, the marginal damage function for phosphorus pollution is not known making a cost minimization model at least as appropriate as an incomplete profit maximization model.

A requirement of this model is that each region is treated as a separate cost minimizing entity. A R.M. creates a workable management zone and is often used in a regulatory context. The region in the simulation model will consist of the 79 Manitoba R.M.'s and the four census agricultural regions (CAR) for which the required data are available. Each R.M. produces livestock and grain in significant quantities, the municipalities included in the model are specified in Table 4 of Chapter 6.

The sources of phosphorus in the model can take either the form of manure or mineral fertilizer. These two sources of phosphorus can be used to meet the phosphorus nutrient demand for crops in each municipality at a minimum price. The phosphorus nutrient demand can be approximated as a function of planted crop acreage, estimated soil test phosphorus levels, and the corresponding provincial fertilizer application guidelines. The provincial fertilizer guidelines (Manitoba Agriculture, Food and Rural Initiatives, 2008) represent common Manitoba agronomic management practices and are a reasonable assumption of the levels Manitoba crop producers choose to apply nutrients to their crops.

Once a given municipality's nutrient demand is determined the objective function of the simulation will minimize the total cost of meeting this nutrient demand by utilizing the lowest cost combination of the available sources of phosphorus consisting of either manure or mineral fertilizer subject to regulatory and environmental constraints. The price of mineral phosphorus fertilizer is exogenous to the model and is based on the retail price of mono-ammonium phosphate (MAP), a common source of mineral phosphorus fertilizer in Manitoba. The price of manure, which from the perspective hog producers generating it is a byproduct of animal production and not part of their management decisions, is the hog producer' cost of disposal, which in this model this will be the cost of treating, transporting, and applying manure to surrounding fields which require it for crop production. This cost consists of a manure volume related cost of treating, loading, and applying manure and a transportation cost related to how far manure must be hauled before it is applied to a field.

A major component in the cost of manure utilization is the cost of transportation which is proportional to the distance manure must be hauled before it is applied to a field. The distance manure must be hauled can be estimated in a manner similar to the method used by Kaplan, Johansson, & Peters (2004) and Fleming, Babcock, & Wang (1998). The theory behind this method is that the distance that manure must be hauled can be determined based on the area of land that must be searched before land suitable for application can be found. The exact locations of the field the manure will be applied to; the location of the hog production facility that produced the manure; and the route that the manure will take between these two points are all unknown. However, it is possible to make some generalizations about what is known which can allow for a reasonable estimate of an average transportation distance. The planted crop acreage of each RM is known. Using the estimated soil phosphorus distributions created to estimate the municipalities nutrient demand, it is also possible to estimate the area of land which manure cannot be applied to due to environmental constraints. When a manure acceptance rate, which is determined exogenously to the model, is taken into account it is possible to determine the total number of acres in a given municipality which manure cannot be applied to due to the crop producer's choice. The total number of acres in a municipality is also known, as such the maximum distance manure could be transported, specifically across all of the land which it cannot be applied to, can be determined. The minimum manure transportation distance occurs when manure is applied to the field directly beside the animal production facility or a distance of zero. With the minimum and maximum manure transportation distance known the median distance is also known. For large distances, such as a municipality, the distribution of distance travelled will approach a normal distribution and as the distribution approaches normal the median approaches the mean (Fleming, Babcock, & Wang, 1998). This median manure transportation distance serves as a reasonable assumption of the distance manure must be hauled before it can be applied in a given region (see Equation 7 for the exact calculation). Since not all RMs are the same size it is necessary to adjust these differences. This adjustment will be made by indexing all RMs to the average RM size.

The minimum cost quantity of manure phosphorus computed in the model gives the amount of manure phosphorus that a given region can produce and utilize in a manner in which environmental quality can be preserved. If manure phosphorus is produced in quantities that the surrounding crop production operations can use at rates that their crops require the phosphorus, then the manure is more likely to be used by the crop as opposed to being over applied and increasing the phosphorus load on Manitoba's freshwater lakes. Thus the manure becomes a resource rather than a waste. This quantity of manure can be used to calculate a number of hogs which can be supported in an economically and ecologically balanced manner in a given municipality. The simulation model is presented formally in the next chapter below.

Chapter 4: Simulation Model

The simulation model can be described by the following seven equations. A full description of the equations and variables used in the model will be provided in this chapter.

1. Min $C_i = \sum_i \theta Q_{m,i} P_{m,i} + (1-\theta) Q_{p,i} P_f$

   $Q_{m,i}$

Subject to:

2. $P_{m,i} \leq P_f$
3. $Q_{m,i} + Q_{p,i} = \sum_c \sum_j A_{c,j,i} R_{c,j}$
4. $Q_{p,i} = (1-\theta) Q_{m,i} + \sum_c \sum_{j=180}^{\infty} A_{c,j,i} R_{c,j} + \delta\{\sum_c \sum_{j=120}^{179} A_{c,j,i} R_{c,j} - \sum_c \sum_{j=120}^{179} A_{c,j,i} X_{c,i}\}$;

   $\delta = 1\ if \sum_c \sum_{j=120}^{179} A_{c,j,i} R_{c,j} - \sum_c \sum_{j=120}^{179} A_{c,j,i} X_{c,i} \geq 0;$

   $\delta = 0\ if \sum_c \sum_{j=120}^{179} A_{c,j,i} R_{c,j} - \sum_c \sum_{j=120}^{179} A_{c,j,i} X_{c,i}\} < 0$
5. $P_{m,i} = LC + TC(r_i) - N_m - K_m$
6. $P_f = RP_f - N_f$
7. $r_i = \frac{\sqrt{[\{(1-\theta)A_i + \sum_{j=120}^{179} A_{j,i} + \sum_{j=180}^{\infty} A_{j,i}\}/640]\varphi}}{4}$

C_i is the total cost of meeting the phosphorus demand in RM *i*

θ is the proportion of crop producers willing to apply hog manure

$Q_{m,i}$ is the quantity of manure phosphorus demanded in RM *i* in pounds

$P_{m,i}$ is the price per pound of phosphorus of hog manure in RM i dollars

P_f is the exogenous mineral phosphorus fertilizer price in dollars per pound of phosphorus based on the price of MAP

$Q_{p,i}$ is the quantity of mineral phosphorus fertilizer demanded in RM i in pounds based on MAP

$A_{c,j,i}$ is the number of acres of crop c, with soil phosphorus level j in RM i

$R_{c,j}$ is the recommended phosphorus rate for crop c grown in soil with soil test phosphorus level j

$X_{c,i}$ is the phosphorus removal rate of crop c in RM i in pounds

δ is a binary switch that is one if the crop phosphorus removal is less than the applied phosphorus on regulated soils

r_i is the median distance that hog manure must be hauled in RM i

LC is the loading and application cost per unit of phosphorus for hog manure

TC is the cost of transporting one unit of hog manure phosphorus per mile

N_m is the value of the nitrogen in manure per pound of phosphorus

K_m is the value of the potassium in manure per pound of phosphorus

φ is the index adjustment to account for size differences in RMs

RP_f is the retail price of mono-ammonium phosphate per pound of phosphorus

N_f is the value of the nitrogen contained in mono-ammonium phosphate per pound of phosphorus

Equation 1 is the constrained cost minimization objective function of the model. This equation is solved by choosing a quantity of manure which minimizes the total cost of meeting the crop production phosphorus demand for each municipality in the model. The constraints placed on the model (Equations 2 to 4) reflect regulatory and economic realities of crop production and manure utilization in Manitoba.

Equation 2 specifies that the price of manure in a given RM is less than the price fertilizer of mineral fertilizer. This constraint is included because previous research indicates that while many crop producers would be willing to pay up to the equivalent nutrient value for manure, no research has shown that they would be willing to pay a premium (Norwood, Luter, & Massey, 2005; Hoag, Lacy, & Davis, 2004). As such Equation 2 precludes this possibility and ensures that manure will be used only if it costs less then or the same as mineral sources of nutrition.

The second constraint (Equation 3) specifies that the quantity of manure and phosphorus fertilizer used in a given RM is equal to the nutritional requirements of the plants grown in the municipality. This is an environmental constraint which limits the potential for phosphorus runoff as the total quantity of phosphorus utilized in the RM is equivalent to the phosphorus required for cropping operations in that RM. This equation ensures that the quantity of manure utilized in a RM is equal to the crop demands of the region.

The final constraint (Equation 4) represents compliance with the provincial manure application regulations. Under the provincial regulations manure cannot be applied to land with soil test phosphorus levels above 180 ppm, as such Equation 4 specifies that the crops grown on this land and with any phosphorus demand are fertilized only with mineral phosphorus. Provincial regulations further restrict manure application on crops grown on land with soil test phosphorus levels between 120 to 180 ppm and 60 to 120 ppm. Cropland in this range can only receive manure at the crop removal rate or twice the crop removal rate respectively. Equation 4 specifies that phosphorus demand in excess of crop removal rates (if it exists) on land with soil test phosphorus between 120 and 180 ppm is met with mineral fertilizer only. The twice crop removal application rate is greater than the crop demand in all municipalities and can be ignored for the purpose of this analysis because nutrients are not applied at rates in excess of provincial nutrient application recommendations in the model (see Equation 3).

The price or cost of manure is formally defined in equation 5 as the volume related loading and application costs of manure added to the transportation cost which is dependent on the distance the manure must be hauled (r_i). MAP is the most commonly used source of mineral phosphorus fertilizer in Manitoba and serves as the best comparison to manure phosphorus. Since manure and mono-ammonium phosphate both contain nutrients such as nitrogen (MAP and manure) and potassium (manure) in addition to phosphorus the value of these other nutrients must be taken into account when comparing the price of manure to the price of mineral fertilizer. These additional nutrient credits are reflected in variables N_f,N_m, and K_m in Equations 5 and 6. The values used in the nutrient credits are based on the retail prices of the most common mineral fertilizer sources for their respective nutrients, in this case urea (46-0-0) for nitrogen and potash (0-0-60) for potassium.

The distance the manure must be hauled is shown in Equation 7 and is represented as the median (mean as the area becomes large) of the minimum distance (0 miles) and the maximum across all land that is unavailable as a result of crop producer preference or regulations. For the estimation of a maximum manure hauling distance the area of land excluded because of regulations will include soils with soil phosphorus in the 120 to 180 ppm range (this land would be fertilized to capacity with manure) as well the crop production land with soil test phosphorus over 180 ppm which is excluded explicitly from manure application by the regulations. The area of land excluded due to regulations can be added to the area of land that manure cannot be applied to because of crop producer choice (θ). The total area in acres of excluded land can be divided by 640 to be converted to square miles. The root of which is the median distance between the maximum and minimum distance a livestock producer might have to haul manure.

This simulation model will generate a reasonable estimate of the quantity of manure that can be utilized in an environmental and economical sustainable manner in each RM. If the crop phosphorus demand, of which the manure demand is a function, in a given RM can support the level of hog manure phosphorus generated in the RM, the manure can be utilized as a resource in an ecologically sustainable manner. If the hog manure phosphorus generated in a given municipality can be utilized at cost equal to or less than the cost of mineral fertilizer, then the manure can be utilized as a resource in an economically efficient manner. However, if the hog manure phosphorus generated is in excess of local crop needs and/or the cost of utilizing manure is greater than the cost of using mineral fertilizer, the manure becomes a waste and should be treated and managed as such. The optimal manure capacity, in which manure is a resource, computed in this simulation can be used to further determine the number of hogs which would generate this quantity of manure. A municipality that has a quantity of hogs that would generate manure phosphorus in excess of the optimal quantity would require a reduction in the herd size to utilize the manure as a resource efficiently. RMs with a current quantity of hogs generating manure phosphorus at levels below the optimal manure capacity have an unutilized capacity and room to expand hog herd size in a sustainable manner.

Chapter 5: Data

The data required to estimate the model as specified above are for the most part readily available. A description of the available data is discussed in this chapter.

Information on the crops grown in each municipality, their phosphorus removal rates, and phosphorus fertilization requirements are all available from various provincial and federal sources. Much of the information used to estimate nutrient (phosphorus) flows in agricultural systems at the municipal level for a different study can also be used in the economic aspects of this research. The phosphorus balances for the municipalities included in this research are shown in Table 4 in following chapter. The procedure used to estimate these balances are also described in detail in Chapter 6.

The Statistics Canada 2006 Census of Agriculture (Statistics Canada, 2006) provides a comprehensive static view of agriculture in Canada and the data are available aggregated by municipality. The data was collected by Stats Canada in May 2006 with respondents asked to provide information about their operation current as of May 16th and for the year 2005. Respondents provided the numbers of all farm animals on their farms, this information is aggregated at the RM level and is an accurate representation of the stock of animals on Manitoba farms at the municipal level which were used to estimate yearly supply. The 2006 Agriculture Census also surveyed agricultural crop producers and reported the land area of each crop in each municipality. It should be noted that the RM of Winnipeg has crop land and livestock assigned to it that likely actually exist in other municipalities this error is likely small and should not substantively impact on the results of the simulation model. Privacy concerns prevented the release of census of agricultural data for RMs in the census agricultural regions (CAR) three, four, five, and six located in northwestern Manitoba. These areas will be represented in this research as CAR 3, CAR 4, CAR 5, and CAR 6 all of which consist of multiple municipalities. CAR 3 includes the RMs of Langford, Odanah, Saskatchewan, Blanshard, Hamiota, Miniota, Archie, Ellice, Birtle, Shoal Lake, Strathclair, Harrison, Minto, Rosedale, Clanwilliam, and Park (South). The RMs of Rossburn, Silver Creek, Russell, Shellmouth-Boulton, Hillsburg, Shell River, and Park (North) are contained in CAR 4. CAR 5 includes the RMs of Mountain (South), Minitonas, Swan River, and Mountain (North). Lastly, CAR 6 includes the RMs of Alonsa, McCreary, Ste. Rose, Ochre River, Dauphin, Gilbert Plains, Grandview, Ethelbert, Mossey River, and Lawrence. For the purpose of this research CARs three to six will be referred to as municipalities even though they consist of multiple RMs.

Data on the retail price of fertilizer is available from survey work done by the Keystone Agricultural Producers (KAP) (Keystone Agricultural Producers, 2008). The KAP survey samples Manitoba producers on the price they paid for fertilizer and best represents the retail cost of fertilizer as paid by producers in the province. The KAP fertilizer prices should serve as the initial estimates for the cost of mineral fertilizer in this simulation model. The cost of mineral fertilizer has been volatile recently, as such it is necessary to simulate the model at a number of different mineral fertilizer price levels to gauge the sensitivity of the results to fluctuations in the price of fertilizer. Information on the approximate cost of handling and utilizing liquid hog manure can be obtained from Salvano et.al. (2006).

Unfortunately detailed information on the soil test phosphorus levels necessary to estimate a phosphorus demand does not exist in a useable or consistent forum. As a result it is necessary to estimate a distribution of soil phosphorus which can then be applied to a region the size of a municipality. To accomplish this estimation, municipal nutrient budgets repeated over time can be used to determine an average soil phosphorus concentration which a distribution can be built around. Further details on how this process could be accomplished are provided in the procedure section.

Information on the proportion of Manitoba crop producers willing to apply manure is also not available. As has been previously mentioned this information is not possible to predict with current knowledge (Hoag, Lacy, & Davis, 2004); however, survey data has found that most crop producers sampled would pay a positive price close to the savings in commercial fertilizer, but approximately 25% of crop producers would require a payment before accepting manure (Norwood, Luter, & Massey, 2005), this necessitates the use of a wide range of acceptance rates in the simulation to check the sensitivity of our results to acceptance rates.

Chapter 6: Procedure

Once the necessary data has been assembled the method used to calculate the simulation is straightforward. The method used to determine each RMs phosphorus budget is described in section 6.1 and the procedure used in calculating the remainder of the simulation model is detailed in section 6.2

6.1 Municipal Phosphorus Budget Procedure

The nutrient budgets used to determine soil phosphorus levels in this research were developed by Matthew Wiens as a first step to this project. In order to create a phosphorus balance for a municipality it is necessary to determining the phosphorus inputs and phosphorus removals for a given RM. The Wiens approach is similar to the approach used by Nicolas et. al. (2002). The all-encompassing approach used by Nicolas et. al. (2002) is complex and can be simplified to the major components by focusing only on soil inputs and outputs. The potential phosphorus inputs identified by Nicolas et. al. (2002) are animal manure, fertilizer, seed, atmospheric deposition, and municipal waste. The potential phosphorus outputs included nutrient runoff, plant products, organic matter runoff, and wind erosion

Manure phosphorus inputs can be estimated using Statistics Canada's 2006 Census of Agriculture values for livestock quantities in a municipality. The amount of phosphorus produced annually from livestock in a municipality can be determined by multiplying the number of animals in each livestock category by a coefficient for annual phosphorus excretion, these coefficients were determined in consolation with Manitoba Conservation (Trudelle, 2008; Centre de Référence en Agriculture et Agroalimentaire du Québec, 2003). The total phosphorus additions from manure for each RM were calculated by multiplying total livestock populations in each municipality by the total phosphorus excretion over the year for that specific animal type. The livestock manure phosphorus values used in the nutrient budget calculation are shown in Table 2.

Table 2: Annual Livestock Phosphate Excretions used in Nutrient Budget Calculation

Animal	Kg P_20_5/Animal
Cattle and Calves	
Calves Under 1 Year	14
Steers 1 Year and Over	16.5
Heifers for Slaughter	16.5
Heifers for Beef Herd Replacement	16.5
Heifers for Dairy Herd Replacement	27.4
Beef Cows	32
Dairy Cows	52
Bulls 1 Year and Over	27.4
Hogs	
Boars	16.7
Sows and Gilts for Breeding	16.7
Nursing and Weaner pigs	0.167
Grower and Finisher pigs	2.05
Sheep and Lambs	
Rams	6.04
Ewes	6.22
Lambs	0.74
Poultry	
Broilers, Roasters and Cornish Hens	0.0402
Pullets Under 19 Weeks	0.068
Laying Hens 19 Weeks and Over	0.367
Turkeys	0.161
Other poultry	0.07
Other livestock	
Horses and Ponies	14
Goats	3
Wild Boars	16.7
Deer	17
Elk	6.22
Bison	14

The amount of fertilizer phosphorus used in a municipality was estimated by using the Canadian Fertilizer Institute (2007) values for the amount of phosphate sold annually for agricultural purposes in Manitoba. The proportion of the total phosphorus sold provincially that is sold in each municipality can be determined by using Census of Agriculture (2006) values to calculate the proportion of total provincial dollars spent on fertilizer that are spent in a municipality, and then multiplying the total amount of phosphate sold in Manitoba by the fraction of provincial fertilizer dollars spent in a municipality.

Phosphorus is added to the soil in the form of seed when a field is seeded. The total amount of seed-phosphorus added to soil in a municipality can be estimated by determining average seeding rates for each crop and multiplying that rate by the Census of Agriculture (2006) values for crop acres for each crop type. After the total amount of each type of seed is calculated the amount of phosphorus can be calculated by multiplying the amount of seed by the amount of phosphorus contained in each type of seed. Concentrations of phosphorus in seed are derived from the Canadian Fertilizer Institute (2007) values for phosphorus removal in crops.

Phosphorus that is added to soil from dust that settles out of the atmosphere or is washed out of the atmosphere in precipitation is called atmospheric deposition, Nicolas et. al. (2002) used a value of 1.1 kg P/ha/year; however, the quantity of phosphorus that ends up on agricultural land as a result of atmospheric deposition is assumed to be insignificant and as such is not included in the nutrient budget calculations. Some municipalities may have a measureable amount of phosphorus added to agricultural land in the form of municipal bio-solids or irrigation of municipal waste-water. Whether values for the amount of land-applied bio-solids can be acquired is not certain. The amount of phosphorus added to agricultural soils in the form of municipal wastes is too small to be of concern for the purposes of our municipal soil phosphorus balance and is ignored for in the calculation of municipal phosphorus budgets below.

Phosphorus is removed from the soil in the form of plants and plant products such as grain and forage. The total phosphorus removal in plant products can be estimated by using Census of Agriculture (2006) data for acres planted to each crop and then multiplying this area by the long-term average yield of each crop type. The long-term average yields (2001-2007) for each crop for each municipality is available from the Manitoba Agricultural Services Corporation (2007). When the yield and acreage data is combined with the Canadian Fertilizer Institute (2001) values for crop removal an estimate of the phosphorus removed by crops can be calculated. Table 3 shows the average phosphate crop removal rates for the crops used in the nutrient budgets, the values used in each particular RM are based on the yield of the municipality's crops. The phosphate pasture removal rate was estimated at 10 tons per acre after consultation with a Manitoba agronomy expert (Entz, 2008).

An unknown amount of phosphorus removal is also occurring in the form of cereal and flax straw; however, this amount that is not eventually returned to the land and is assumed to be very small for most municipalities in Manitoba. As such cereal and flax straw phosphorus removal will not be included in the nutrient balance calculation.

Table 3: Crop P_2O_5 Removal Rates used in Nutrient Budget Calculations

Crop	Average P2O5 Removal (lbs/Ac)
Alfalfa	13.4
Spring Wheat	28.5
Winter Wheat	25.5
Barley	33.5
Oats	25.5
Rye	24.5
Corn	43.5
Canola	36.5
Flax	15.5
Sunflower	16
Peas	34.5
Lentils	18.5
Fababeans	61
Potatoes	36.5

Source: Canadian Fertilizer Institute, 2001

The value used by Nicolas et. al. (2002) for the amount of soil phosphorus lost in run-off was 0.3 kg/ha/yr from perennial crops, and 0.5 kg/ha/yr from annually cropped land. This value was determined to be insignificant and as a result was not included in the calculation. Organic matter that is removed from the soil during run-off will also remove phosphorus from the soil system. Nicolas et. al. (2002) used 0.3 kg/ha/yr and 0.5 kg/ha/yr as the amount of actual phosphorus from organic matter removed from perennial and annual crop land, respectively. This value was also determined to be insignificant and as a result was not included in the calculation. Nicolas et. al. (2002) found no literature values for the amount of phosphorus lost from soil in the form of dust. This value was also determined to be insignificant and as a result was not included in the calculation.

The phosphorus soil balances calculated as described in this section are shown below in Table 4.

Table 4: Phosphorus Surplus or Deficit by Municipality

RM	Phosphorus Surplus or Deficit (lbs per acre)	RM	Phosphorus Surplus or Deficit (lbs per acre)
Albert	-0.81	Pipestone	-1.54
Alexander	-3.79	Portage la Prairie	-0.69
Argyle	-2.35	Reynolds	-0.70
Armstrong	-12.17	Rhineland	3.72
Aurthur	-5.91	Ritchot	2.22
Bifrost	-3.89	Riverside	1.72
Brenda	-2.65	Roblin	-0.11
Brokenhead	-0.43	Rockwood	-2.78
Cameron	-2.81	Roland	3.77
Cartier	9.64	Rosser	-3.14
Coldwell	-12.01	Sifton	-6.23
Daly	-0.57	Siglunes	-8.58
De Salaberry	3.09	South Cypress	0.46
Dufferin	4.11	South Norfolk	7.46
Edward	-7.07	Springfield	0.30
Elton	0.59	St. Andrews	-3.60
Eriksdale	-9.94	St. Clements	-0.47
Fisher	-6.12	St. Francois Xavier	1.37
Franklin	-2.79	St. Laurent	-10.14
Gimli	-3.32	Stanley	-0.66
Glenella	-2.58	Ste. Anne	16.67
Glenwood	-0.82	Strathcona	1.48
Grahamdale	-7.73	Stuartburn	-9.88
Grey	3.43	Tache	9.90
Hanover	31.74	Thompson	1.79
Headingley	4.30	Turtle Mountain	0.89
La Broquerie	89.99	Victoria	-3.71
Lac du Bonnet	-6.85	Wallace	-2.20
Lakeview	-8.81	West St. Paul	0.22
Lansdowne	-1.83	Westbourne	1.52
Lorne	4.30	Whitehead	-3.52
Louise	-2.17	Whitemouth	9.99
Macdonald	4.32	Whitewater	0.02
Montcalm	2.91	Winchester	-1.47

RM	Phosphorus Surplus or Deficit (lbs per acre)	RM	Phosphorus Surplus or Deficit (lbs per acre)
Morris	5.65	Winnipeg	10.67
Morton	-6.52	Woodlands	-5.80
North Cypress	3.32	Woodworth	-6.57
North Norfolk	3.77	CAR 3	-8.25
Oakland	-2.30	CAR 4	-10.25
Pemina	0.45	CAR 5	-7.22
Piney	1.82	CAR 6	-10.58

6.2 Simulation Model Procedure

Computing the simulation model is accomplished in the ten steps discussed in further detail in this section.

i.) The regional nutrient balances calculated in the preceding section can be used to build a soil level phosphorus probability distribution for each RM. Accounting for all relevant phosphorus inputs into agricultural soils within a municipality, and all phosphorus outputs from a municipality's soils makes it possible to create a phosphorus budget for a municipality. When these phosphorus budgets are extrapolated over a period of time historically consistent with the expansion of the Manitoba hog industry years, in this case 5 years, and if it is further assumed that soils in each municipality were constantly mined (phosphorus deficit) or enhanced (phosphorus surplus) over this period of time then this value obtained can serve as an approximation of the mean for the level of soil phosphorus in the municipality. The municipal average phosphorus addition or deficit can be converted to soil test phosphorus using MAFRI (2008) values. The variance calculated between the municipalities can then be used to create a probability distribution for the soil phosphorus level in each RM, which for the purpose of this research is assumed to be a truncated normal (never below zero). Since phosphorus is relatively stable in the soil these distributions serve as a reasonable proxy for the unavailable soil test data. This assumption is consistent with the widely held belief in Manitoba that soil phosphorus levels while not well known, but are believed to be low in phosphorus (Johnston & Roberts, 2001). Figure 1 shows the estimated soil phosphorus probability distribution of a high soil phosphorus area like the RM of La Broquerie, the shape of this probability distribution curve resembles a traditional bell-curve of a normal distribution. Figure 2 shows a more typical probability distribution (the RM of Wallace). Since soil phosphorus levels can not fall below zero, and most RMs with a history soil phosphorus deficits (such as the RM of Wallace) or small surpluses, soil test phosphorus level distribution is heavily concentrated around zero. The cropland in each RM can be assumed to be distributed across the municipality with the portion of land falling within a given soil phosphorus level specified by the probability distribution function created for the RM. For example slightly more than 50% of the crop land in the RM of Wallace has soil phosphorus contributions in the 0 to 5 pounds per acre range.

The specific maximum soil phosphorus capacity is not well known. The point at which soil becomes saturated and excess phosphorus is either runoff or leaches out of the soil depends on numerous factors which are difficult to model. Soil testing laboratories generally do not receive samples with soil phosphorus levels in excess of 3000 ppm (Patrick, 2009) and field research indicates that soil samples above 200 ppm are exceedingly rare (Dyck, 2009). As such, the maximum soil test phosphorus level assumption of 2500 ppm used in this research, which the soil phosphorus levels calculated from nutrient budgets do not approach, is reasonable. Nutrient application guidelines and manure application restrictions are capped at 20 ppm and 180 ppm respectively which implies that a theoretical soil phosphorus maximum above these values will have no impact on the nutrient demands calculated in this research.

Figure 1: Estimated Soil Phosphorus Additions Probability Distribution for the RM of La Broquerie

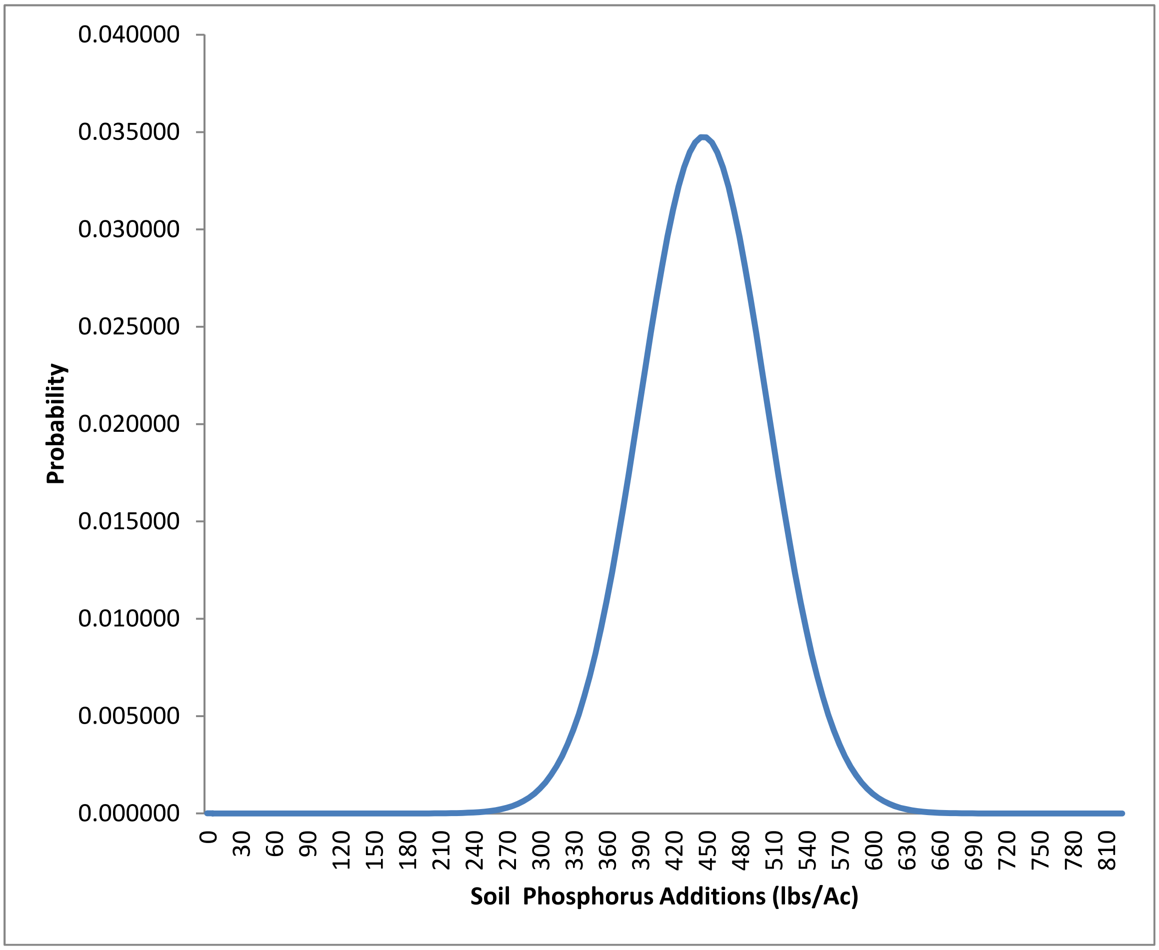
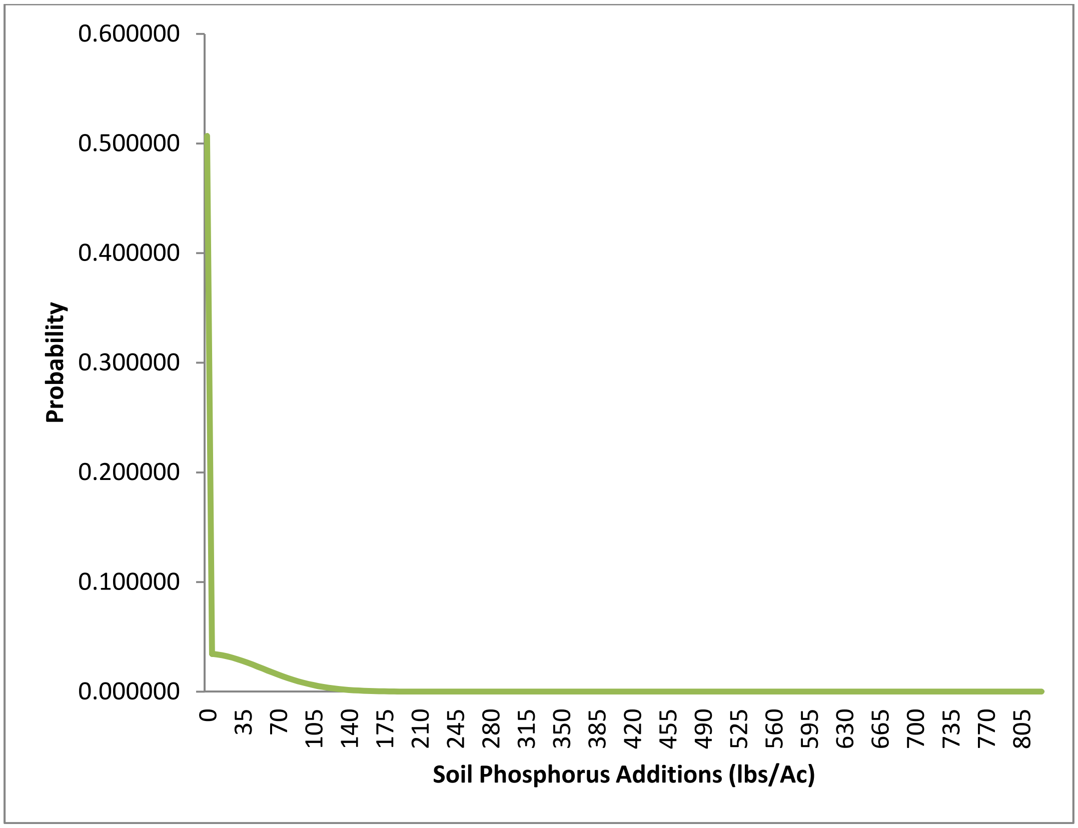


Figure 2: Estimated Soil Phosphorus Additions Probability Distribution for the RM of Wallace



ii.) Once the soil phosphorus distributions for each RM have been estimated they can be applied to the known planted acreage of each crop and the corresponding provincial phosphorus application rate. For the purpose of consistency when more than one phosphorus application rate is specified for a particular crop the lowest rate is used. The quantity of phosphorus specified by this calculation is the total quantity of phosphorus demanded in the given municipality

iii.) After calculating the total phosphorus demand for each municipality it is necessary to determine the quantity of phosphorus which cannot be sourced from manure (or alternatively the quantity of phosphorus which must be sourced from mineral phosphate) there are three reasons that manure would not be utilized on a given acre of cropland in this model: environmental restrictions, the effective price of manure being greater than the price of the mineral fertilizer equivalent, and non-acceptance by the crop producer. To determine the quantity of manure phosphorus which must be excluded due to environmental regulations requires knowledge of the phosphorus crop removal rates in each RM as well as soil phosphorus levels. Since the crop removal rates have already been calculated as part of the nutrient budgets they are known. The same soil phosphorus distribution used to calculate the phosphorus demand can be used to calculate the portion of cropland that will fall into one of three categories: land on which manure can be applied at up to a maximum of the nitrogen removal rate (for the purpose of this analysis land in this category will be able to receive manure at rates consistent with the provincial fertilizer recommendations); land which manure can only be applied to at a rate of up to a maximum of the crop's phosphorus removal rate (manure can be applied to this land at up to the phosphorus removal rate of the crops grown in the land), any further phosphorus requirements if they exist may only be met with mineral fertilizer; and land which manure cannot be applied to, land falling into this category planted with crops which require phosphorus fertilization, for example potatoes or other crops with high phosphorus demand, can only be fertilized by mineral phosphorus. After the proportion of a municipality's cropland which falls under the previously mentioned environmental restrictions has been determined the corresponding phosphorus demands for the crops grown on the regulated cropland should be excluded from the potential manure demand of the municipality. It should be noted that in some cases it is possible for the recommend phosphorus application rate to be higher than the crop removal rate for a given piece of land.

iv) The second type of land that manure cannot be applied to as fertilizer is land which the owner does not accept manure as a substitute for mineral fertilizer. The process for determining this quantity of farmland is simple since it is a function of the exogenously set acceptance rate (the proportion of farmland not accepting manure is equal to $1 - \theta$). This land is excluded from the land available for manure and the phosphorus requirements of the crops grown on this land are removed from the potential manure phosphorus demand. The quantity of manure excluded due to the crop producers' unwillingness to apply it can be combined with the quantity of manure that cannot be applied because of environmental regulations. The remainder is the total amount of manure sourced phosphorus that can be applied in the municipality. If the effective price of manure in a given RM is greater than the price of the equivalent quantity of mineral fertilizer, then no manure is used as fertilizer in that municipality.

v.) After determining the total area of land which manure can and cannot be applied to and the corresponding quantities of both mineral and manure sourced phosphorus which could be used in a municipality it is possible to estimate the distance that manure must be transported from the animal production operation to the cropland which it is to be applied. This process is carried out by taking the area of cropland precluded from manure application (as determined in steps iii and iv) this area converted to miles which serves as the maximum distance that manure would be transported. Once the maximum distance is calculated it can be combined with the minimum (zero) to determine the median transportation distance. The median transportation distance then serves as an estimate of the mean transportation distance that manure will be hauled before it is applied in a given municipality. This distance is then indexed to the mean RM area to adjust for size differences between municipalities to get an adjusted manure transportation distance.

vi.) Computing the manure transportation distance is the last step necessary to compute the cost of hauling and handling manure for application as a fertilizer substitute. Manure has two main cost components: the cost of loading and applying it to a field, which is based on the volume of the manure; and the cost of transporting it to the field for application, which is based on the distance the manure must be transported. The cost estimates derived by Salvano et. al. (2006) for both application and tranportation can be adapted for use in this research by converting them to costs per pound of phosphorus in the manure. Hog manure has different nutrient characteristics depending upon the growth stage of the animals (weinling, finsishing, and etc.) producing it. Using an average weighted by the number of hogs at various growth stages over a period of one year it is posible to determine an average nutreint concetration for Manitoba Hog manure. This research will use a weighted average for the nutreint concetration of manure consisitng of 23.4 lbs nitrogen, 7.8 lbs phosphorus, and 12.0 lbs of potassium per 1,000 imerial gallons manure (Salvano et. al. 2006). When the tranportation costs are multipled by the manure tranportation distance and then added to the loading and handleing costs the result is the total cost it would take to use manure to meet one pound of a crop's phosphorus demand in a given municpality.

vii.) As mentioned previously both manure and MAP fertilizer contain nutrients in addition to phosphorus, in order to compare the cost of mineral phosphorus fertilizer to the cost of manure phosphorus an adjustment is necessary. This adjustment is accomplished by deducting the equivalent value of the other nutrients from the price of the mineral fertilizer and the total cost of the phosphorus. The value of the additional nutrients can be taken from the retail price of urea (46-0-0) for nitrogen and potash (0-0-60) for potassium. After the price of mineral fertilizer and manure have been adjusted to account for the additional nutrients the adjusted prices can be used to compare the two sources of phosphorus.

viii.) In this simulation manure will only be utilized as a fertilizer replacement if it is economically rational to do so. It is thus economically rational to use manure when the price of manure sourced phosphorous is less than or equal to the price of mineral fertilizer phosphorus. The price of manure is different in each municipality; however, the price for mineral fertilizer is exogenous to the model and will be the same in all municipalities. This price discrepancy allows for the possibility of manure being an economically rational choice in some municipalities and being a non-economical waste in others. The nature of the simulation is such that if it is economical to do so manure will be utilized on all land available to it in the specified RM, if manure is not economically rational to use then none will be utilized. This step of the calculation will compare the price of mineral fertilizer phosphorus to the price of manure phosphorus and utilizes the amount of available manure when it is economical to do so. The quantity of manure utilized in this step represents the optimal manure capacity of the RM.

ix.) Once the quantity of manure that can be utilized in a given municipality is known the value of the potential fertilizer savings due to manure utilization can be calculated as well. The potential fertilizer savings from using manure are can be calculated by multiplying the quantity of manure phosphorous used by the retail price of mineral phosphorus fertilizer, this is the value of the fertilizer that does not need to be purchased by crop producers; however since the manure is not costless the costs of using the manure must be subtracted from this saving. The end result is the net welfare benefit of manure utilization.

x.) The optimal additional manure quantity computed in step eight can be used further to determine the number hogs which would produce this quantity of manure. This quantity of hogs would serve as an optimal hog capacity for the RM. Since it is not possible to predict the exact expansion or reduction path that the Manitoba hog industry would follow to get to this optimum hog capacity, it is can be assumed that the overall structure of the hog industry will not change and thus any expansion or contraction of the industry can be represented as a proportion of the current industry.

The data once assembled will be calculated as described in the ten steps above. Outputs of the model computed for each municipality will include manure transportation distance, net manure benefit, the effective cost of manure phosphorus, the quantity of manure phosphorus demanded, and the potential expansion or necessary reduction in hogs that would be required to support this demand. The results are presented in the following chapter.

Chapter 7: Results

The simulation model developed in this thesis determines a manure demand and the corresponding quantity of hogs for each selected municipality. The reported results include the average manure transportation distance, effective manure cost, manure phosphorus demand, and the hog capacity for each of the 82 specified municipalities and the province as whole. The average manure transportation distance is the solved value of Equation 7 which represents the average distance that manure has to be hauled before land suitable for application is found. The effective manure cost is the cost of transporting and applying manure per unit of phosphorus, a negative price implies that the value of the additional (non-phosphorus) nutrients contained in manure is greater than the costs of utilizing the manure. The manure phosphorus demand is the quantity of manure phosphorus which can be utilized in a specified municipality subject to the constraints of the model it is the $Q_{m,i}$ which solves Equation 1. The final output of simulation model reported in the results is the change in hog capacity of each RM. This number represents the change in number of hogs (per year) that is necessary to meet the manure demand of a given RM.

Assumptions about grower acceptance of manure and the retail price of mineral fertilizer, which is often volatile, have the potential to significantly impact the outcome of the model. As a result it is necessary to conduct a sensitivity analysis to properly gauge the impact of these variables on the model. The range of acceptance rates and fertilizer prices used in the simulation and the results of the model will be described in this chapter.

The base level of manure acceptance will be set as at 50% which serves as a natural starting point and is consistent with previous research which indicated that the majority of crop producers surveyed would be willing to pay for and thus accept manure. To gauge the impact on the model if higher proportion of growers would be willing to apply manure to their crops, the simulation will also be run using a manure acceptance rate of 75%. The acceptance rate is capped at 75% because previous research indicated that 25% of growers in other jurisdictions would require payment prior to utilization manure (Norwood, Luter, & Massey, 2005). To account for low crop producer acceptance of manure the model will also be run with a manure acceptance rate of 25%.

The price of mineral fertilizer, a close substitute to manure, is an important and volatile factor in determining a municipalities' manure nutrient demand. The base level of mineral fertilizer price will be based on 2008 prices the most current year for which retail price information is available. To allow for the very realistic possibility of substantial movements in the price of mineral fertilizer the model will also be run with fertilizer price increases and decreases of 25% and 50%.

In the interest of brevity, the results of the baseline simulation with 50% manure acceptance and 2008 (current) mineral fertilizer prices are presented in this chapter in Table 5. The remaining scenarios are presented in Appendix 1 as Tables A1 to A14. Table 5 shows the results of the baseline scenario with a manure acceptance rate of 50% and current fertilizer prices. The rest of price spectrum at the 50% manure acceptance level is shown in tables A6 to A9. Tables A1 to A5 show the simulation results at the 25% manure acutance rate across different mineral fertilizer price levels. The final set of simulation results are shown in tables A10 to A14 which show the results at the highest level of manure acceptance 75% at various fertilizer price levels.

Table 5: Simulation Results with a 50% Manure Acceptance Rate and Current Mineral Fertilizer Prices

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	5.65	-0.83	1,482,225	2,734,584	424,217
Alexander	14.35	-0.21	229,291	278,182	69,294
Argyle	5.71	-0.83	1,427,399	2,626,741	391,957
Armstrong	8.02	-0.66	837,661	1,400,756	227,475
Aurthur	5.18	-0.87	1,734,100	3,258,605	569,291
Bifrost	4.74	-0.90	2,085,660	3,984,532	610,215
Brenda	5.12	-0.87	1,688,163	3,179,641	488,604
Brokenhead	6.01	-0.81	1,310,215	2,382,442	357,403
Cameron	5.91	-0.81	1,322,863	2,415,215	400,288
Cartier	5.57	-0.84	793,612	1,468,372	-260,736
Coldwell	9.06	-0.59	704,102	1,124,666	231,328
Daly	6.28	-0.79	1,131,866	2,035,944	336,289
De Salaberry	5.70	-0.83	1,213,426	2,233,855	15,940
Dufferin	4.60	-0.91	1,752,855	3,367,531	407,711
Edward	5.95	-0.81	1,339,657	2,441,662	423,121
Elton	4.34	-0.93	2,306,288	4,473,905	682,102
Eriksdale	10.20	-0.51	599,118	907,320	177,360
Fisher	5.04	-0.88	1,953,705	3,691,045	451,598
Franklin	5.47	-0.85	1,494,269	2,776,382	447,354
Gimli	11.64	-0.40	358,375	505,200	115,967
Glenella	8.13	-0.65	808,137	1,345,324	191,663
Glenwood	6.51	-0.77	1,071,465	1,909,278	325,438
Grahamdale	10.09	-0.51	478,520	728,364	142,498
Grey	4.86	-0.89	1,649,925	3,138,254	470,441
Hanover	5.97	-0.81	529,673	964,843	-174,081
Headingley	13.38	-0.28	196,236	251,776	39,154
La Broquerie	19.60	0.17	0	0	-90,341
Lac du Bonnet	9.71	-0.54	519,924	805,805	146,541
Lakeview	10.38	-0.49	470,231	706,070	154,492
Lansdowne	6.45	-0.77	1,148,657	2,052,047	343,966
Lorne	4.57	-0.91	1,749,743	3,364,857	327,095
Louise	4.69	-0.90	1,969,967	3,771,376	557,651

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Macdonald	3.77	-0.97	2,327,777	4,611,863	371,364
Montcalm	5.82	-0.82	1,058,091	1,938,793	284,326
Morris	3.90	-0.96	1,974,101	3,892,128	240,355
Morton	5.31	-0.86	1,549,426	2,896,998	434,726
North Cypress	5.01	-0.88	1,847,847	3,495,086	509,694
North Norfolk	4.82	-0.89	1,775,773	3,383,373	476,488
Oakland	6.60	-0.76	1,080,665	1,918,874	320,206
Pemina	4.55	-0.91	2,013,337	3,874,137	436,324
Piney	11.69	-0.40	302,560	425,430	33,887
Pipestone	5.18	-0.87	1,674,992	3,147,099	519,677
Portage la Prairie	3.51	-0.99	3,453,619	6,908,653	781,575
Reynolds	14.95	-0.17	186,547	218,201	11,248
Rhineland	4.17	-0.94	1,973,858	3,852,667	359,222
Ritchot	7.95	-0.67	609,142	1,022,014	124,967
Riverside	6.84	-0.75	880,312	1,547,714	145,932
Roblin	5.79	-0.82	1,366,895	2,507,974	341,915
Rockwood	5.08	-0.87	1,821,517	3,435,764	393,086
Roland	5.76	-0.82	1,016,320	1,866,763	306,030
Rosser	6.36	-0.78	1,107,605	1,986,008	338,350
Sifton	7.86	-0.67	872,411	1,469,138	277,417
Siglunes	8.49	-0.63	863,966	1,415,800	283,851
South Cypress	6.88	-0.74	991,460	1,740,478	231,728
South Norfolk	5.62	-0.83	995,974	1,839,233	23,249
Springfield	5.36	-0.85	1,532,552	2,859,848	424,697
St. Andrews	5.82	-0.82	1,316,812	2,413,192	375,712
St. Clements	6.67	-0.76	971,651	1,720,476	239,872
St. Francois Xavier	10.12	-0.51	397,467	604,206	119,952
St. Laurent	14.45	-0.20	280,828	338,535	92,264
Stanley	4.60	-0.91	2,179,694	4,186,383	626,961
Ste. Anne	8.53	-0.63	298,712	488,552	-98,140
Strathcona	8.41	-0.63	639,446	1,051,482	192,145
Stuartburn	9.24	-0.58	573,693	908,909	153,571
Tache	6.58	-0.77	605,920	1,076,740	16,385
Thompson	6.59	-0.76	913,324	1,622,480	181,880
Turtle Mountain	4.84	-0.89	1,773,454	3,375,563	296,123
Victoria	7.47	-0.70	828,358	1,418,660	239,192
Wallace	4.87	-0.89	1,991,432	3,785,678	552,169
West St. Paul	18.34	0.08	131,095	121,042	43,070

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Westbourne	4.38	-0.92	2,274,996	4,406,880	587,743
Whitehead	6.40	-0.78	1,142,898	2,045,625	362,035
Whitemouth	9.86	-0.53	312,871	481,417	-102,792
Whitewater	6.04	-0.80	1,180,056	2,143,207	315,654
Winchester	5.41	-0.85	1,555,872	2,897,202	510,767
Winnipeg	10.92	-0.46	210,466	307,697	50,107
Woodlands	5.38	-0.85	1,763,113	3,286,699	467,751
Woodworth	5.87	-0.82	1,386,359	2,535,065	412,007
CAR 3	1.78	-1.11	14,366,600	30,540,723	4,262,371
CAR 4	2.73	-1.04	6,402,816	13,170,811	2,103,284
CAR 5	2.75	-1.04	5,758,001	11,834,156	1,827,760
CAR 6	2.00	-1.09	12,073,743	25,471,745	3,902,691

Average Manure Transportation Distance (miles)	6.95
Average Effective Manure Cost ($)	-0.74
Total Manure Phosphorus Demand (lbs P)	130,963,756
Total Net Manure Benefit ($)	250,811,733
Total Hog Capacity (animals per year)	34,402,143

The absolute hog capacity is the total number of animals per year that a RM can support based on the phosphorus demand of its crops. This capacity was estimated for the baseline scenario (50% manure acceptance and current fertilizer prices. The results are shown in Table 6.

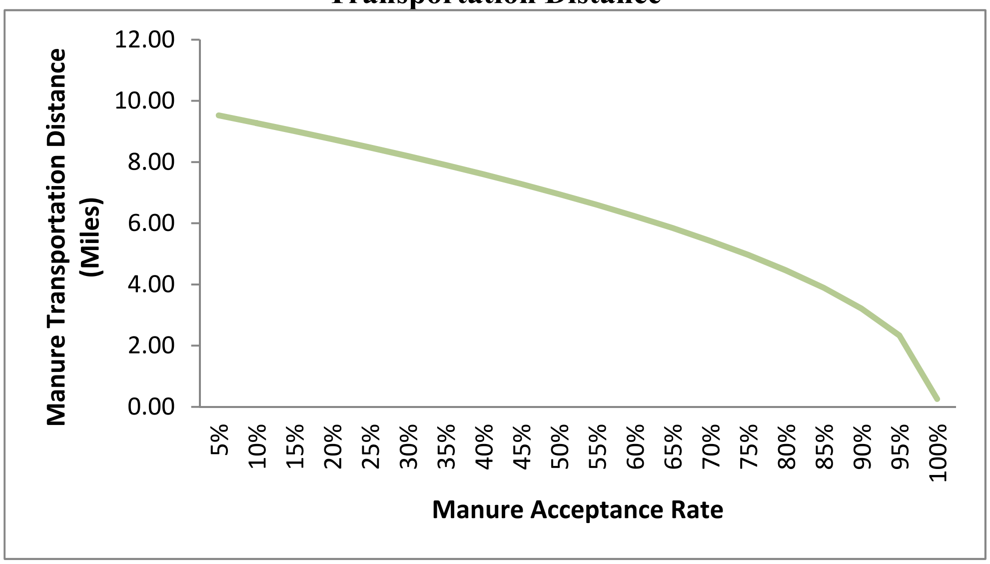
Table 6: Absolute Hog Capacities in Baseline Scenario by Rural Municipality

RM	Absolute Hog Capacity (Animals/Year)	RM	Absolute Hog Capacity (Animals/Year)
Albert	507,969	Pipestone	544,171
Alexander	72,243	Portage la Prairie	1,128,440
Argyle	458,118	Reynolds	72,801
Armstrong	275,525	Rhineland	611,265
Aurthur	569,532	Ritchot	180,446
Bifrost	671,751	Riverside	283,472
Brenda	564,393	Roblin	429,385
Brokenhead	382,552	Rockwood	599,655

RM	Absolute Hog Capacity (Animals/Year)	RM	Absolute Hog Capacity (Animals/Year)
Cameron	482,201	Roland	325,351
Cartier	87,115	Rosser	362,477
Coldwell	231,328	Sifton	295,068
Daly	373,210	Siglunes	283,851
De Salaberry	432,305	South Cypress	355,029
Dufferin	537,551	South Norfolk	372,022
Edward	424,549	Springfield	519,641
Elton	746,067	St. Andrews	429,492
Eriksdale	213,119	St. Clements	276,686
Fisher	669,165	St. Francois Xavier	140,289
Franklin	507,097	St. Laurent	92,264
Gimli	130,860	Stanley	685,685
Glenella	256,465	Ste. Anne	152,214
Glenwood	345,259	Strathcona	208,801
Grahamdale	157,811	Stuartburn	258,868
Grey	535,566	Tache	202,514
Hanover	1,502,198	Thompson	296,054
Headingley	53,459	Turtle Mountain	592,267
La Broquerie	1,827,576	Victoria	272,350
Lac du Bonnet	192,084	Wallace	672,551
Lakeview	154,492	West St. Paul	43,070
Lansdowne	373,402	Westbourne	771,732
Lorne	573,239	Whitehead	376,283
Louise	631,982	Whitemouth	0
Macdonald	819,162	Whitewater	362,165
Montcalm	334,015	Winchester	511,520
Morris	793,336	Winnipeg	60,113
Morton	516,188	Woodlands	563,923
North Cypress	593,346	Woodworth	474,725
North Norfolk	612,875	CAR 3	4,740,305
Oakland	342,526	CAR 4	2,103,311
Pemina	684,534	CAR 5	1,882,965
Piney	83,132	CAR 6	3,941,085

The results of the simulation show some interesting trends. Figures 3 to 5 show the impact of the manure acceptance rate on the average manure transportation distance, manure phosphorus demand, and hog capacity respectively. As can be expected, the transport distance decreases as the more land becomes available for manure application which occurs as the acceptance rate increases, this relationship is shown in Figure 3. The average manure transportation distance is not affected by changes in the price of mineral fertilizer. At full (100%) manure acceptance the average distance that manure must be hauled before suitable land can be found drops to less than one mile.

Figure 3: Impact of Changes in Manure Acceptance Rate on the Average Manure Transportation Distance



Also consistent with theory is the finding that the demand for manure increases as the acceptance rate increases. Figure 4 shows the impact that changes in the acceptance rate have on the demand for manure phosphorus. As the price of mineral fertilizer, a substitute for manure, increases the demand for manure increases as well.

Figure 5 shows the results of changes in the manure acceptance rate on the total hog capacity of the province. At current prices the total animal capacity of the province becomes positive at 19% manure acceptance. This implies that once this level of acceptance is obtained, the industry can expand in a manner in which the manure generated by additional hogs will be in demand by the surrounding crop land. At a 50%

decrease in the price of mineral fertilizer the same point is reached at 27% acceptance, further increases in mineral fertilizer prices beyond the current price levels do not change the total hog capacity of the province. However, it should be noted that in these scenarios while the province as a whole would not require a reduction in the total number of hogs to efficiently utilize manure phosphorus as fertilizer. Most of the hog production would have to switch from municipalities currently producing substantial quantities of hogs to municipalities not currently producing hogs in significant numbers for the manure phosphorus to be efficiently utilized.

Figure 4: Impact of Changes in the Manure Acceptance Rate on the Total Provincial Demand for Manure Phosphorus

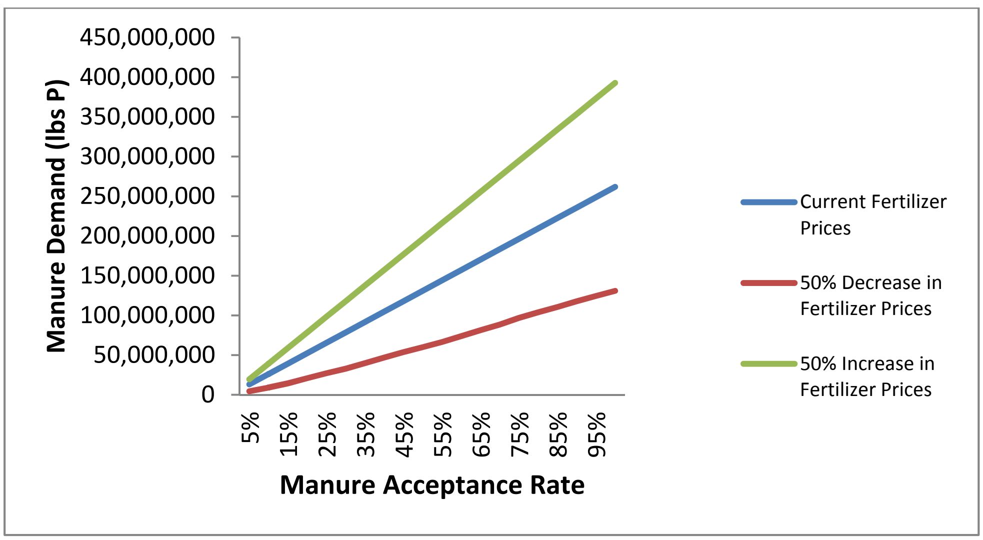
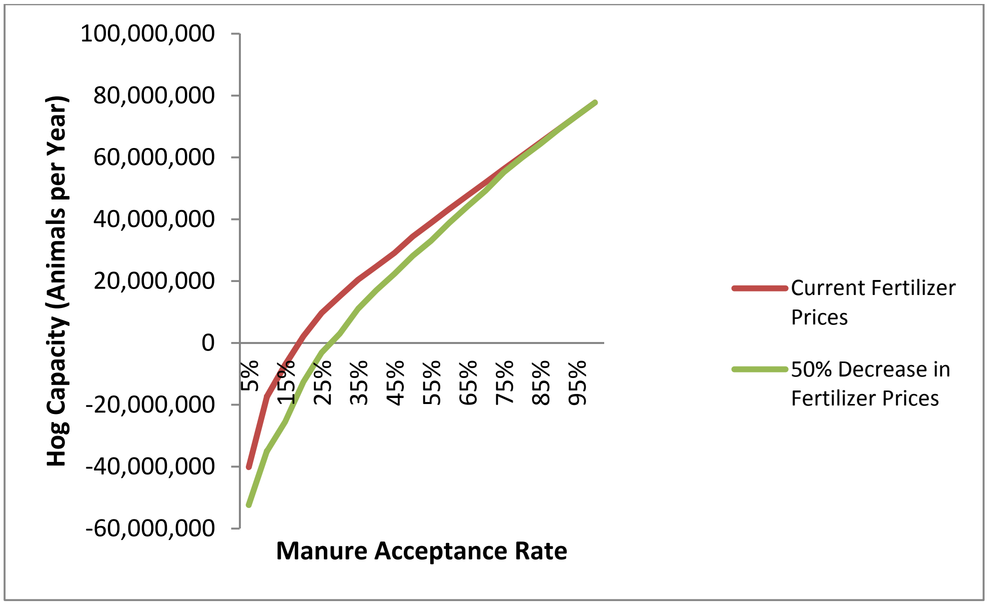
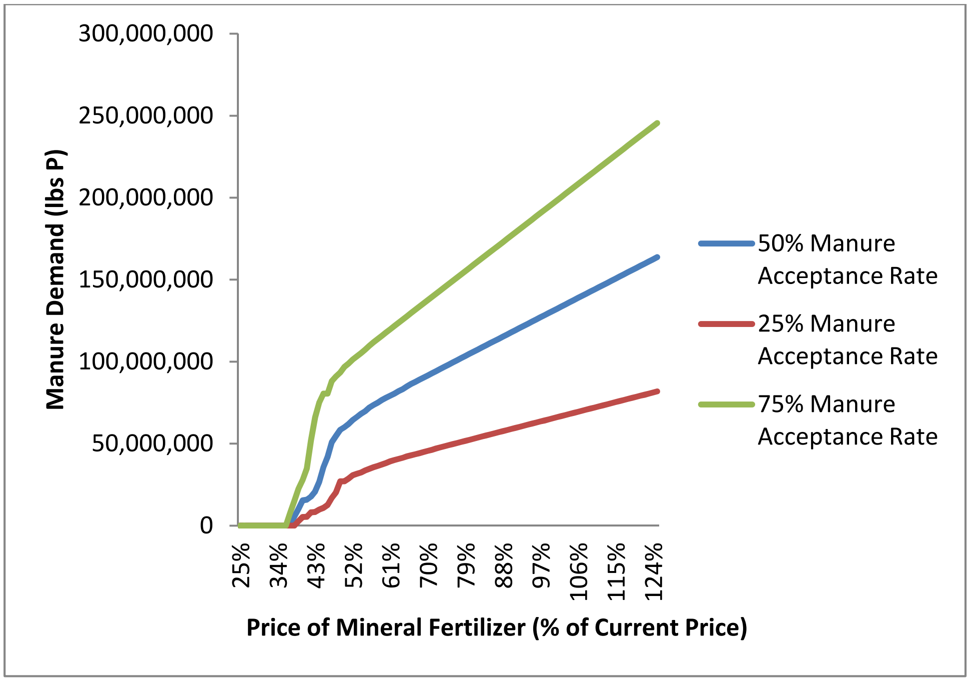


Figure 5: Impact of Changes in Manure Acceptance Rates on the Total Provincial Change in Hog Capacity



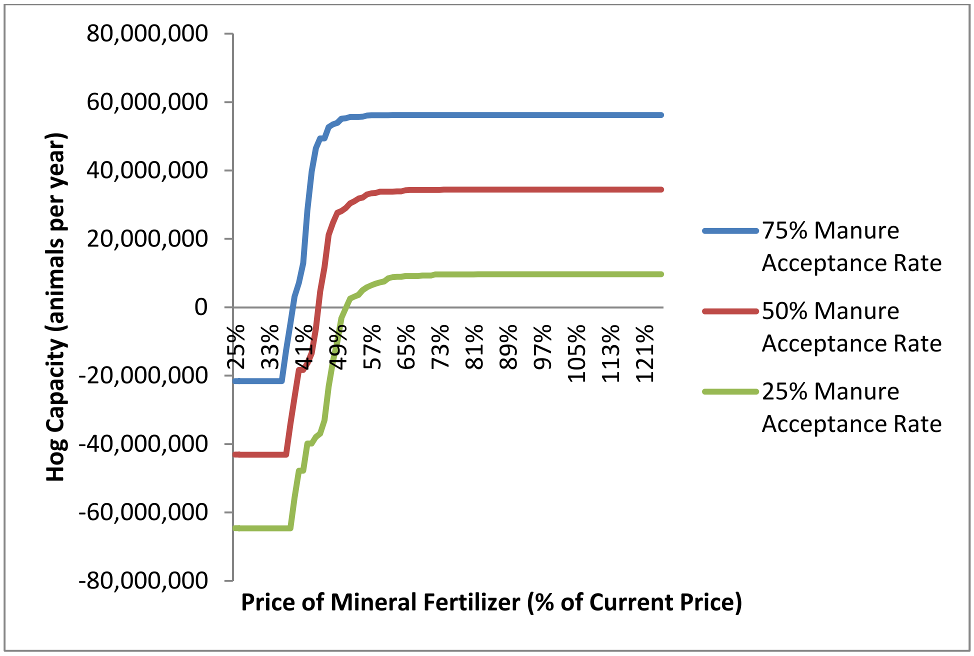
Figures 6 and 7 show the impact of changes in the price of mineral fertilizer on the total manure phosphorus demand and total hog capacity of the province. As can be seen in Figure 6, manure phosphorus demand increases as the price of fertilizer increases. Manure demand starts when fertilizer prices are between 36% and 38% of their current levels. This implies that manure phosphorus starts to become a cost effective alternative to mineral fertilizer in some parts of Manitoba at fertilizer prices significantly lower than current prices. At higher manure acceptance levels more land is available demand grows faster.

Figure 6: Impact of Changes in the Price of Mineral Fertilizer on the Total Manure Phosphorus Demand



Changes in the price of fertilizer show interesting results on the total hog capacity of the province. Hog capacity increases with price as soon as manure demand is greater than zero. The increase in hog capacity is quite steep and continues to move with the price of fertilizer until the land base is saturated and a plateau is reached. At higher levels of manure acceptance more land is available and the plateau occurs at a higher total hog capacity.

Figure 7: Impact of Changes in the Price of Mineral Fertilizer on the Total Change in Provincial Hog Capacity



In the baseline scenario of 50% manure acceptance and current fertilizer prices Manitoba has room to expand the total hog capacity by slightly more than 34 million animals per year; however, the RMs of Cartier, Hanover, La Broquerie, Ste. Anne, and Whitemouth would all still require a reduction in the number of animals to bring manure phosphorus output in line with the demands of their crop base. Since these municipalities make up a significant proportion of the province's current hog production a reduction in these RMs would represent a significant change to current structure of the hog industry in Manitoba.

The extreme scenarios simulated in this research and are represented in Table A1 and Table A14. With manure acceptance rate of 25% and fertilizer prices 50% lower than the current levels the values shown in Table A1 represent a situation in which manure is least likely to be utilized as a resource. As shown in Table A1 with low fertilizer prices and low crop producer acceptance of manure a reduction livestock quantities would be necessary in 42 of the 82 municipalities studied. The most optimistic scenario for manure utilization in Manitoba is shown in Table A14, with high manure acceptance and high mineral fertilizer prices. In this optimistic scenario Manitoba can expand the quantity of hogs by almost 55 million animals per year; however, even under the most favorable conditions the RMs Hanover, La Broquerie, and Ste. Anne would still require a reduction in hogs before manure phosphate could be utilized as a resource.

Two further extreme scenarios which are not likely to occur across the entire province but which could be realistic in individual municipalities are presented in Tables A15 and A16. The results of a scenario with an extremely low manure acceptance rate of 5% and a large drop in the price of fertilizer are presented in Table A15. The simulation results with complete (100%) manure acceptance and very high fertilizer prices are shown in Table A16. Notable results from these two extreme scenarios include the fact that under the least favorable conditions for manure utilization only 8 of 82 municipalities have the capacity to expand hog operations. Under the most favorable conditions with a 50% increase in the price of mineral fertilizer and 100% acceptance of manure the RM of Hanover would have capacity for all but 30 of the animals currently in production there, while the RM of La Broquerie would still require a significant reduction in the number of hogs produced in a year. In the extreme positive scenario all of the other municipalities have room to significantly increase the number of hogs they produce.

Chapter 8: Conclusion

The simulation model presented in this thesis calculated the quantity of manure phosphorus that Manitoba municipalities could use in relation to the crops that they produce and the required shifting of current production to optimize manure supply. Using probabilistic soil phosphorus distributions based on 5 years of agricultural production at 2006 levels current soil phosphorus levels were estimated. This quantity of phosphorus stocks and an ongoing sustainable hog population was estimated. By utilizing hog manure as a commercial fertilizer substitute it is possible to identify areas of the province in which hog manure phosphorus can serve as a resource to surrounding crop producers and the optimal number of hogs required to meet this phosphorus demand.

The results shown in the previous chapter illustrate that under certain conditions hog manure phosphorus can be used as a resource by the surrounding crops in most municipalities. High fertilizer prices and a high manure acceptance rate are the most favorable set of circumstances that lead to higher quantities of manure utilization which allows for a sustainable increase in the province's hog capacity. However, even under the most favorable conditions some municipalities (Hanover, La Broquerie, and Ste. Anne) do not have sufficient phosphorus crop demand to utilize the existing sources of manure phosphors in an economically efficient manner. The fact that with high manure acceptance and fertilizer prices some municipalities in the southeast cannot utilize the manure phosphorus they produce as fertilizer indicates that a reduction in the herd or a focus on treating manure as a waste is necessary in these municipalities. All of the other municipalities examined have the capacity to increase the quantity of hogs (or other livestock) produced to meet their crop production phosphorus demand in the best case scenario (high manure acceptance and high fertilizer prices). In the baseline scenario (50% manure acceptance, current fertilizer prices) the province has room for a significant number of additional hogs in the majority of municipalities; however, five municipalities (Cartier, Hanover, La Broquerie, Ste. Anne, and Whitemouth) produce manure phosphorus in excess of their crop requirements. As such a targeted herd reduction or more aggressive manure phosphorus abatement will be more efficient in reducing phosphorus runoff than utilizing manure phosphorus as a fertilizer substitute in these municipalities under the currently available technology.

When considering the results of this thesis it is important to keep in mind some of the limitations of this study. Data aggregation by Statistics Canada required that in some cases provincial average values had to be used rather than the unavailable specific values in the computation of the nutrient budgets. Since the budgets serve as an estimation of unknown soil samples the use of these average values will not likely significantly impact the results of simulation.

The fact that phosphorus nutrient budgets are used to proxy for unknown soil phosphorus levels also limits the research in this thesis. The nutrient budgets are a good approximation phosphorus additions and removals within a geographic area; however, the nutrient budgets do not account for potential phosphorus soil runoff and other soil process. The process in which phosphorus either runs off of or leaches out of phosphorus saturated soil is not well understood and complex. Not accounting for runoff and other soil processes can potentially result in an overestimation of soil phosphorus levels and a corresponding underestimation of crop phosphorus demand. Most regions examined in this study are still deficient and the provincial fertilizer recommendations and manure regulations are in force at relatively low soil phosphorus levels. As a result the use of nutrient balances as opposed to unavailable soil test data will likely have minimal impact on the results presented in this research. Further experimentation is also required to confirm assumptions used in this paper regarding nutrient composition in manure. The nutrient budgets were based on the best available data but livestock diets and local conditions could mean assumptions used in the budgets were considerably different then actual Manitoba levels.

The estimation of average transportation distance was limited in that only crop land was included in the calculation, which means that urban and forest lands were not taken into consideration. Urban areas are small in comparison to cropland in the majority of rural RMs. As such, this omission is likely negligible. Forested area is found mostly in CAR 3, CAR 4, CAR 5, and CAR 6 which also had the lowest average transportation distance this was likely a result of not including forested areas in the initial calculation. However, the average transportation distance in these regions could double without meaningful impact on the simulation results.

A further limitation of the research presented in this thesis is the lack of knowledge about Manitoba crop producers' attitudes and use of manure as a substitute for mineral fertilizer. As the results of the simulation show, changes in the manure acceptance rate have a substantial impact on the costs of manure utilization and provincial hog capacity. Attempts to model the manure acceptance rate have proved to be difficult in other jurisdictions; future research should attempt to determine current crop producer attitudes in this province as well as factors that might influence them. Encouraging more crop producers to utilize manure as fertilizer will increase the number of hogs that can be sustainably raised in Manitoba and any further benefits arising from a strong livestock industry.

The results presented in this thesis reflect the current available manure application technologies (injection and broadcast). Increased use of more advanced application technologies such as pelletization, ultra violate bailing, or other technologies which are not feasible under the current manure volumes and level of technological advancement would decrease the cost of using manure and possibly increase manure acceptance by crop producers which would further increase the hog capacity of the province. These technological advances while not currently feasible would likely become more common with further technological advances and an increasing quantity of hogs.

A final limitation of the model was the assumption that livestock farming would remain profitable at any level needed for phosphorus supplies. While previous studies suggest hog farming was profitable, especially if nutrient were valueable and earned further profits, large increases in livestock in Manitoba could lead to higher grain demand that drove prices and limited expansion.

The simulation results presented in this thesis indicate that room for expansion of the hog industry exists based on crop phosphorus demand for the province as a whole as well as the majority of RMs under most circumstances. Areas including the Interlake, Red River Valley, and Southeast, which are currently under a restriction on the construction of new hog production facilities (Legislative Assembly of Manitoba, 2008), all have the potential to utilize the phosphorus contained in manure to meet local crop demands.

Table 7 shows the estimated hog expansion capacity of municipalities affected by bill 17 at current mineral fertilizer prices and acceptance manure rates of 25%, 50%, and 75%.

Table 7: Simulated Hog Capacity in Municipalities Under Moratorium due to Bill 17

	Hog Capacity (Animals/Year)		
RM/ Acceptance Rate	25%	50%	75%
Armstrong	89,871	227,475	365,080
Bifrost	267,599	610,215	952,830
Coldwell	115,664	231,328	346,993
De Salaberry	-597,996	15,940	215,272
Eriksdale	78,941	177,360	275,778
Fisher	130,659	451,598	772,538
Gimli	57,096	115,967	174,839
Grahamdale	63,891	142,498	221,106
Hanover	-261,106	-174,081	-87,056
La Broquerie	-90,341	-90,341	-90,341
Rockwood	93,862	393,086	692,310
Rosser	156,402	338,350	520,299
Siglunes	141,925	283,851	425,777
Springfield	172,941	424,697	676,452
St. Andrews	159,396	375,712	592,027
St. Clements	80,257	239,872	399,487
St. Laurent	46,132	92,264	138,397
Ste. Anne	-147,210	-98,140	-49,070
Tache	-298,607	16,385	115,920
Woodlands	178,120	467,751	757,381

The Southeast is typically considered to be over capacity with respect to hog production. In the baseline scenario the RMs of De Salaberry and Tache both have capacity for minor expansion and if the level of manure acceptance is increased in these RMs they would have capacity to sustainability produce a larger quantity of hogs. However, even under the most favorable circumstances the RMs of Hanover and La Broquerie, also in the Southeast, would require a reduction in the number of hogs under production in order for their crop bases to support the manure phosphorus produced by hogs.

The Red River Valley is another area of the province currently under a moratorium on the construction of new hog production operations. With the exception of the RM of Cartier all municipalities in the Red River Valley have room for significant expansion in the quantity of hogs under production based on their phosphorus demand in the baseline scenario. The crop base in this region has a high phosphorus demand and as a result the crops grown in this area would be able to utilize substantial quantities of hog manure phosphorus. The major exception in the Red River Valley region is the RM of Cartier which currently has a large number of hogs and poultry under production and would require a reduction in production to balance its crop phosphorus demand. The RM of Cartier does not have capacity for an increase in its quantity of hogs under production in the baseline scenario; however, if manure acceptance increases to 75% Cartier would have room for an increased number of hogs.

The provincial government has also mandated that no new hog production facilities can be constructed in the Interlake region of the province. The crop phosphorus demand is not as high in this area as it is in the Red River Valley; however, there is still room for a significant increase in the number of hogs under production in the Interlake based on the phosphorus demand of the crops grown there. In the baseline scenario numerous RMs in the Interlake have room for very large increases in the number of hogs they can produce on the basis of their phosphorus demand. While other reasons for curtailing the expansion of the hog industry in the Interlake may exist, the crop base of this region is capable of utilizing the manure phosphorus of a much greater quantity of animals than is currently under production.

When considering the results of this simulation model the spatial aspect of the results are important. As has been discussed above, provincial regulations pertaining to where a new hog barn can be built are currently based on regional characteristics. Excess phosphorus is generally considered to be the pollutant causing the most damage to Manitoba's freshwater ecosystems. If hog manure phosphorus can be managed in a manner which allows the phosphorus contained in the manure can be matched to the crop demands, environmental damage would be reduced. Overall with a manure acceptance level of 50% and 2008 mineral fertilizer prices the crop phosphorus demand of the province as a whole can support a 30 million hogs per year increase. The spatial aspect becomes important due to the fact that areas with the most hog expansion potential are not the areas where current province's hog production takes place but some of the regions under a hog expansion moratorium can still benefit from manure phosphorus.

The phosphorus contained in manure can be a valuable resource to crop producers in Manitoba if it is managed properly and a potential pollutant if it is not. Based on their crop demand most municipalities have the potential to use all of the manure phosphorus they produce as fertilizer and have room to expand from their current livestock herds. Using manure as a substitute for mineral fertilizer represents a triple win for agriculture in Manitoba. Livestock producers win in that they can expand the industry in municipalities with capacity to utilize the phosphorus they produce. Crop producers win by gaining access to a less expensive product to meet their crops nutrient demands. Lastly, the environment wins because the phosphorus in manure is taken up by crops and is therefore less likely to end up feeding algae blooms in Lake Winnipeg and other freshwater ecosystems.

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Appendix 1: Simulation Results

Table A1: Simulation Results with a 25% Manure Acceptance Rate and a 50% Decrease in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	6.92	0.45	370,555	30,351	180,728
Alexander	17.57	1.21	0	0	-112,999
Argyle	6.99	0.46	356,850	25,129	157,475
Armstrong	9.83	0.66	0	0	-412,814
Aurthur	6.34	0.41	433,525	71,841	284,427
Bifrost	5.81	0.37	521,415	126,394	267,599
Brenda	6.27	0.41	422,041	74,444	211,286
Brokenhead	7.36	0.48	327,553	5,520	142,171
Cameron	7.24	0.48	330,715	11,559	182,978
Cartier	6.83	0.45	198,403	18,847	-391,104
Coldwell	11.09	0.75	0	0	-346,994
Daly	7.69	0.51	0	0	-557,802
De Salaberry	6.98	0.46	303,357	21,897	-597,996
Dufferin	5.63	0.36	438,214	117,742	119,767
Edward	7.29	0.48	334,914	9,124	203,053
Elton	5.31	0.34	576,572	181,329	303,243
Eriksdale	12.49	0.85	0	0	-295,256
Fisher	6.17	0.40	488,426	93,048	130,659
Franklin	6.69	0.44	373,567	42,586	201,887
Gimli	14.26	0.98	0	0	-176,613
Glenella	9.95	0.67	0	0	-398,264
Glenwood	7.98	0.53	0	0	-528,035
Grahamdale	12.36	0.84	0	0	-235,823
Grey	5.95	0.38	412,481	91,519	199,405
Hanover	7.17	0.47	132,395	5,984	-261,106
Headingley	16.39	1.13	0	0	-96,708
La Broquerie	21.17	1.47	0	0	-90,341
Lac du Bonnet	11.89	0.81	0	0	-256,228
Lakeview	12.71	0.87	0	0	-231,737
Lansdowne	7.90	0.52	0	0	-566,076
Lorne	5.60	0.36	437,436	119,557	39,662
Louise	5.74	0.37	492,492	124,202	234,041
Macdonald	4.62	0.29	581,944	241,976	-1,147,165
Montcalm	7.13	0.47	264,523	13,523	110,512
Morris	4.78	0.30	493,525	193,565	-972,868
Morton	6.50	0.42	387,357	55,262	180,199

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	6.13	0.40	461,962	90,478	206,144
North Norfolk	5.90	0.38	443,943	102,020	184,778
Oakland	8.08	0.54	0	0	-532,569
Pemina	5.58	0.36	503,334	139,019	105,589
Piney	14.32	0.98	0	0	-149,108
Pipestone	6.34	0.41	418,747	69,127	244,523
Portage la Prairie	4.29	0.26	863,405	399,566	214,243
Reynolds	18.30	1.27	0	0	-91,934
Rhineland	5.11	0.32	493,464	169,667	34,972
Ritchot	9.73	0.65	0	0	-300,195
Riverside	8.38	0.56	0	0	-433,832
Roblin	7.09	0.46	341,724	19,517	117,372
Rockwood	6.22	0.40	455,379	83,357	93,862
Roland	7.05	0.46	254,080	15,752	139,077
Rosser	7.79	0.51	0	0	-545,845
Sifton	9.63	0.65	0	0	-429,940
Siglunes	10.39	0.70	0	0	-425,778
South Cypress	8.42	0.56	0	0	-488,607
South Norfolk	6.89	0.45	248,994	21,467	-490,832
Springfield	6.56	0.43	383,138	51,231	172,941
St. Andrews	7.12	0.47	329,203	17,032	159,396
St. Clements	8.17	0.54	0	0	-478,845
St. Francois Xavier	12.39	0.84	0	0	-195,878
St. Laurent	17.70	1.22	0	0	-138,398
Stanley	5.64	0.36	544,924	145,689	268,898
Ste. Anne	10.44	0.70	0	0	-147,210
Strathcona	10.30	0.69	0	0	-315,132
Stuartburn	11.31	0.77	0	0	-282,727
Tache	8.06	0.53	0	0	-298,607
Thompson	8.07	0.53	0	0	-450,100
Turtle Mountain	5.93	0.38	443,364	99,808	4,794
Victoria	9.15	0.61	0	0	-408,228
Wallace	5.97	0.38	497,857	109,149	225,032
West St. Paul	22.46	1.56	0	0	-64,606
Westbourne	5.36	0.34	568,749	174,998	214,025
Whitehead	7.84	0.52	0	0	-563,239
Whitemouth	12.08	0.82	0	0	-154,188
Whitewater	7.40	0.49	295,014	3,404	121,804

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	6.63	0.43	388,968	48,237	255,180
Winnipeg	13.37	0.91	0	0	-103,721
Woodlands	6.59	0.43	440,778	56,861	178,120
Woodworth	7.19	0.47	346,589	14,515	184,267
CAR 3	2.18	0.11	3,591,650	2,765,417	1,902,342
CAR 4	3.34	0.20	1,600,704	962,794	1,051,481
CAR 5	3.37	0.20	1,439,500	859,556	881,882
CAR 6	2.45	0.13	3,018,435	2,204,782	1,919,314

Average Manure Transportation Distance (miles)	8.48
Average Effective Manure Cost ($)	0.56
Total Manure Phosphorus Demand (lbs P)	27,052,164
Total Net Manure Benefit ($)	10,298,842
Total Hog Capacity (animals per year)	-3,136,320

Table A2: Simulation Results with a 25% Manure Acceptance Rate and a 25% Decrease in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	6.92	-0.14	555,833	664,672	180,728
Alexander	17.57	0.62	85,984	14,124	31,628
Argyle	6.99	-0.14	535,275	635,988	157,475
Armstrong	9.83	0.06	314,122	287,045	89,871
Aurthur	6.34	-0.19	650,287	813,953	284,427
Bifrost	5.81	-0.22	782,122	1,018,957	267,599
Brenda	6.27	-0.19	633,061	796,898	211,286
Brokenhead	7.36	-0.11	491,330	566,229	142,171
Cameron	7.24	-0.12	496,073	577,680	182,978
Cartier	6.83	-0.15	297,604	358,476	-391,104
Coldwell	11.09	0.15	264,038	208,975	115,664
Daly	7.69	-0.09	424,450	475,561	150,355
De Salaberry	6.98	-0.14	455,035	541,186	-597,996
Dufferin	5.63	-0.24	657,321	867,881	119,767
Edward	7.29	-0.12	502,371	582,433	203,053
Elton	5.31	-0.26	864,858	1,168,312	303,243
Eriksdale	12.49	0.25	224,668	147,410	78,941
Fisher	6.17	-0.20	732,638	929,140	130,659
Franklin	6.69	-0.16	560,351	682,062	201,887
Gimli	14.26	0.38	134,391	65,193	57,096
Glenella	9.95	0.07	303,051	273,216	58,908
Glenwood	7.98	-0.07	401,799	439,149	149,426
Grahamdale	12.36	0.24	179,445	119,991	63,891
Grey	5.95	-0.21	618,722	797,609	199,405
Hanover	7.17	-0.13	198,593	232,619	-261,106
Headingley	16.39	0.53	73,588	20,477	6,918
La Broquerie	21.17	0.88	0	0	-90,341
Lac du Bonnet	11.89	0.21	194,971	139,204	61,132
Lakeview	12.71	0.27	176,337	111,987	77,246
Lansdowne	7.90	-0.07	430,746	473,982	155,274
Lorne	5.60	-0.24	656,154	868,364	39,662
Louise	5.74	-0.23	738,737	967,254	234,041
Macdonald	4.62	-0.31	872,916	1,238,154	-1,147,165
Montcalm	7.13	-0.13	396,784	466,336	110,512
Morris	4.78	-0.30	740,288	1,038,387	-972,868
Morton	6.50	-0.17	581,035	718,343	180,199

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	6.13	-0.20	692,943	881,269	206,144
North Norfolk	5.90	-0.22	665,915	861,967	184,778
Oakland	8.08	-0.06	405,249	438,756	142,683
Pemina	5.58	-0.24	755,001	1,000,632	105,589
Piney	14.32	0.38	113,459	54,373	-149,108
Pipestone	6.34	-0.19	628,121	785,943	244,523
Portage la Prairie	4.29	-0.33	1,295,107	1,877,552	214,243
Reynolds	18.30	0.67	69,955	6,517	-91,934
Rhineland	5.11	-0.27	740,197	1,014,385	34,972
Ritchot	9.73	0.06	228,428	210,816	24,902
Riverside	8.38	-0.04	330,117	347,979	1,321
Roblin	7.09	-0.13	512,586	604,483	117,372
Rockwood	6.22	-0.19	683,069	862,880	93,862
Roland	7.05	-0.13	381,120	450,688	139,077
Rosser	7.79	-0.08	415,352	461,512	156,402
Sifton	9.63	0.05	327,153	305,243	134,104
Siglunes	10.39	0.10	323,986	278,335	141,925
South Cypress	8.42	-0.04	371,797	390,292	68,859
South Norfolk	6.89	-0.15	373,490	447,697	-490,832
Springfield	6.56	-0.17	574,707	707,091	172,941
St. Andrews	7.12	-0.13	493,804	580,565	159,396
St. Clements	8.17	-0.06	364,369	391,540	80,257
St. Francois Xavier	12.39	0.25	149,050	99,186	54,659
St. Laurent	17.70	0.63	105,310	15,968	46,132
Stanley	5.64	-0.24	817,385	1,078,495	268,898
Ste. Anne	10.44	0.11	112,017	95,714	-147,210
Strathcona	10.30	0.10	239,791	208,212	87,101
Stuartburn	11.31	0.17	215,134	165,706	59,329
Tache	8.06	-0.06	227,220	246,535	-298,607
Thompson	8.07	-0.06	342,496	371,271	31,847
Turtle Mountain	5.93	-0.22	665,045	858,762	4,794
Victoria	9.15	0.01	310,634	304,348	103,116
Wallace	5.97	-0.21	746,786	961,386	225,032
West St. Paul	22.46	0.97	0	0	-64,606
Westbourne	5.36	-0.26	853,124	1,148,588	214,025
Whitehead	7.84	-0.08	428,586	473,972	174,289
Whitemouth	12.08	0.22	117,327	81,641	-154,188
Whitewater	7.40	-0.11	442,521	508,412	121,804

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	6.63	-0.17	583,451	714,076	255,180
Winnipeg	13.37	0.32	78,925	45,033	15,534
Woodlands	6.59	-0.17	661,168	811,390	178,120
Woodworth	7.19	-0.12	519,884	607,810	184,267
CAR 3	2.18	-0.48	5,387,475	8,913,641	1,902,342
CAR 4	3.34	-0.40	2,401,056	3,702,896	1,051,481
CAR 5	3.37	-0.40	2,159,251	3,323,708	881,882
CAR 6	2.45	-0.46	4,527,653	7,371,771	1,919,314

Average Manure Transportation Distance (miles)	8.48
Average Effective Manure Cost ($)	-0.03
Total Manure Phosphorus Demand (lbs P)	49,062,192
Total Net Manure Benefit ($)	64,376,283
Total Hog Capacity (animals per year)	9,590,875

Table A3: Simulation Results with a 25% Manure Acceptance Rate and the Current Price of Mineral Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	6.92	-0.74	741,111	1,298,993	180,728
Alexander	17.57	0.02	114,645	112,249	31,628
Argyle	6.99	-0.74	713,699	1,246,847	157,475
Armstrong	9.83	-0.53	418,829	645,523	89,871
Aurthur	6.34	-0.78	867,049	1,556,065	284,427
Bifrost	5.81	-0.82	1,042,830	1,911,520	267,599
Brenda	6.27	-0.79	844,081	1,519,351	211,286
Brokenhead	7.36	-0.71	655,107	1,126,938	142,171
Cameron	7.24	-0.72	661,430	1,143,802	182,978
Cartier	6.83	-0.75	396,806	698,104	-391,104
Coldwell	11.09	-0.44	352,050	510,297	115,664
Daly	7.69	-0.69	565,933	959,946	150,355
De Salaberry	6.98	-0.74	606,713	1,060,476	-597,996
Dufferin	5.63	-0.83	876,428	1,618,020	119,767
Edward	7.29	-0.71	669,827	1,155,742	203,053
Elton	5.31	-0.86	1,153,144	2,155,294	303,243
Eriksdale	12.49	-0.34	299,558	403,803	78,941
Fisher	6.17	-0.80	976,851	1,765,232	130,659
Franklin	6.69	-0.76	747,134	1,321,538	201,887
Gimli	14.26	-0.22	179,187	218,560	57,096
Glenella	9.95	-0.52	404,068	619,060	58,908
Glenwood	7.98	-0.67	535,733	897,685	149,426
Grahamdale	12.36	-0.35	239,259	324,774	63,891
Grey	5.95	-0.81	824,962	1,503,699	199,405
Hanover	7.17	-0.72	264,791	459,255	-261,106
Headingley	16.39	-0.06	98,118	104,456	6,918
La Broquerie	21.17	0.28	0	0	-90,341
Lac du Bonnet	11.89	-0.39	259,962	361,706	61,132
Lakeview	12.71	-0.33	235,116	313,224	77,246
Lansdowne	7.90	-0.67	574,328	965,553	155,274
Lorne	5.60	-0.84	874,872	1,617,171	39,662
Louise	5.74	-0.83	984,983	1,810,306	234,041
Macdonald	4.62	-0.91	1,163,888	2,234,333	-1,147,165
Montcalm	7.13	-0.73	529,046	919,149	110,512
Morris	4.78	-0.89	987,050	1,883,208	-972,868
Morton	6.50	-0.77	774,713	1,381,424	180,199

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	6.13	-0.80	923,924	1,672,060	206,144
North Norfolk	5.90	-0.81	887,887	1,621,913	184,778
Oakland	8.08	-0.66	540,332	901,229	142,683
Pemina	5.58	-0.84	1,006,669	1,862,245	105,589
Piney	14.32	-0.21	151,279	183,854	-149,108
Pipestone	6.34	-0.78	837,495	1,502,759	244,523
Portage la Prairie	4.29	-0.93	1,726,810	3,355,537	214,243
Reynolds	18.30	0.07	93,273	86,350	-91,934
Rhineland	5.11	-0.87	986,929	1,859,102	34,972
Ritchot	9.73	-0.54	304,571	471,500	24,902
Riverside	8.38	-0.64	440,156	724,711	1,321
Roblin	7.09	-0.73	683,447	1,189,449	117,372
Rockwood	6.22	-0.79	910,759	1,642,403	93,862
Roland	7.05	-0.73	508,160	885,625	139,077
Rosser	7.79	-0.68	553,803	935,515	156,402
Sifton	9.63	-0.55	436,204	678,592	134,104
Siglunes	10.39	-0.49	431,982	648,070	141,925
South Cypress	8.42	-0.63	495,730	814,590	68,859
South Norfolk	6.89	-0.74	497,987	873,927	-490,832
Springfield	6.56	-0.77	766,276	1,362,950	172,941
St. Andrews	7.12	-0.73	658,406	1,144,098	159,396
St. Clements	8.17	-0.65	485,826	807,360	80,257
St. Francois Xavier	12.39	-0.35	198,733	269,283	54,659
St. Laurent	17.70	0.03	140,413	136,149	46,132
Stanley	5.64	-0.83	1,089,847	2,011,301	268,898
Ste. Anne	10.44	-0.49	149,356	223,548	-147,210
Strathcona	10.30	-0.50	319,722	481,864	87,101
Stuartburn	11.31	-0.43	286,846	411,219	59,329
Tache	8.06	-0.66	302,960	505,840	-298,607
Thompson	8.07	-0.66	456,662	762,130	31,847
Turtle Mountain	5.93	-0.81	886,727	1,617,717	4,794
Victoria	9.15	-0.58	414,179	658,846	103,116
Wallace	5.97	-0.81	995,715	1,813,623	225,032
West St. Paul	22.46	0.37	65,547	40,904	21,535
Westbourne	5.36	-0.85	1,137,498	2,122,179	214,025
Whitehead	7.84	-0.68	571,448	963,078	174,289
Whitemouth	12.08	-0.37	156,436	215,535	-154,188
Whitewater	7.40	-0.71	590,028	1,013,420	121,804

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	6.63	-0.76	777,935	1,379,915	255,180
Winnipeg	13.37	-0.28	105,233	135,103	15,534
Woodlands	6.59	-0.76	881,557	1,565,919	178,120
Woodworth	7.19	-0.72	693,179	1,201,106	184,267
CAR 3	2.18	-1.08	7,183,300	15,061,866	1,902,342
CAR 4	3.34	-1.00	3,201,408	6,442,998	1,051,481
CAR 5	3.37	-1.00	2,879,001	5,787,860	881,882
CAR 6	2.45	-1.06	6,036,871	12,538,761	1,919,314

Average Manure Transportation Distance (miles)	8.48
Average Effective Manure Cost ($)	-0.63
Total Manure Phosphorus Demand (lbs P)	65,481,804
Total Net Manure Benefit ($)	120,407,306
Total Hog Capacity (animals per year)	9,677,016

Table A4: Simulation Results with 25% Manure Acceptance Rate and a 25% Increase in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	6.92	-1.34	926,389	1,933,313	180,728
Alexander	17.57	-0.58	143,307	210,375	31,628
Argyle	6.99	-1.33	892,124	1,857,706	157,475
Armstrong	9.83	-1.13	523,536	1,004,001	89,871
Aurthur	6.34	-1.38	1,083,811	2,298,176	284,427
Bifrost	5.81	-1.42	1,303,537	2,804,084	267,599
Brenda	6.27	-1.38	1,055,102	2,241,805	211,286
Brokenhead	7.36	-1.31	818,883	1,687,648	142,171
Cameron	7.24	-1.32	826,788	1,709,924	182,978
Cartier	6.83	-1.34	496,007	1,037,732	-391,104
Coldwell	11.09	-1.04	440,063	811,618	115,664
Daly	7.69	-1.28	707,416	1,444,331	150,355
De Salaberry	6.98	-1.33	758,392	1,579,765	-597,996
Dufferin	5.63	-1.43	1,095,534	2,368,159	119,767
Edward	7.29	-1.31	837,284	1,729,051	203,053
Elton	5.31	-1.45	1,441,430	3,142,276	303,243
Eriksdale	12.49	-0.94	374,447	660,196	78,941
Fisher	6.17	-1.39	1,221,064	2,601,324	130,659
Franklin	6.69	-1.35	933,918	1,961,014	201,887
Gimli	14.26	-0.81	223,984	371,928	57,096
Glenella	9.95	-1.12	505,085	964,904	58,908
Glenwood	7.98	-1.26	669,666	1,356,221	149,426
Grahamdale	12.36	-0.95	299,074	529,558	63,891
Grey	5.95	-1.41	1,031,203	2,209,788	199,405
Hanover	7.17	-1.32	330,989	685,891	-261,106
Headingley	16.39	-0.66	122,647	188,436	6,918
La Broquerie	21.17	-0.32	0	0	-90,341
Lac du Bonnet	11.89	-0.98	324,952	584,209	61,132
Lakeview	12.71	-0.92	293,894	514,460	77,246
Lansdowne	7.90	-1.27	717,911	1,457,124	155,274
Lorne	5.60	-1.43	1,093,589	2,365,978	39,662
Louise	5.74	-1.42	1,231,229	2,653,359	234,041
Macdonald	4.62	-1.50	1,454,861	3,230,511	-1,147,165
Montcalm	7.13	-1.32	661,307	1,371,962	110,512
Morris	4.78	-1.49	1,233,813	2,728,030	-972,868

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Morton	6.50	-1.37	968,391	2,044,505	180,199
North Cypress	6.13	-1.39	1,154,904	2,462,851	206,144
North Norfolk	5.90	-1.41	1,109,858	2,381,860	184,778
Oakland	8.08	-1.25	675,415	1,363,702	142,683
Pemina	5.58	-1.43	1,258,336	2,723,858	105,589
Piney	14.32	-0.81	189,098	313,334	-149,108
Pipestone	6.34	-1.38	1,046,869	2,219,575	244,523
Portage la Prairie	4.29	-1.53	2,158,512	4,833,523	214,243
Reynolds	18.30	-0.52	116,591	166,183	-91,934
Rhineland	5.11	-1.47	1,233,661	2,703,820	34,972
Ritchot	9.73	-1.14	380,714	732,184	24,902
Riverside	8.38	-1.23	550,195	1,101,443	1,321
Roblin	7.09	-1.33	854,309	1,774,416	117,372
Rockwood	6.22	-1.39	1,138,448	2,421,926	93,862
Roland	7.05	-1.33	635,200	1,320,561	139,077
Rosser	7.79	-1.28	692,253	1,409,517	156,402
Sifton	9.63	-1.14	545,255	1,051,942	134,104
Siglunes	10.39	-1.09	539,977	1,017,806	141,925
South Cypress	8.42	-1.23	619,662	1,238,887	68,859
South Norfolk	6.89	-1.34	622,484	1,300,156	-490,832
Springfield	6.56	-1.36	957,844	2,018,809	172,941
St. Andrews	7.12	-1.32	823,007	1,707,631	159,396
St. Clements	8.17	-1.25	607,282	1,223,181	80,257
St. Francois Xavier	12.39	-0.95	248,417	439,380	54,659
St. Laurent	17.70	-0.57	175,517	256,329	46,132
Stanley	5.64	-1.43	1,362,309	2,944,107	268,898
Ste. Anne	10.44	-1.09	186,695	351,383	-147,210
Strathcona	10.30	-1.10	399,652	755,515	87,101
Stuartburn	11.31	-1.02	358,557	656,731	59,329
Tache	8.06	-1.26	378,700	765,145	-298,607
Thompson	8.07	-1.26	570,827	1,152,990	31,847
Turtle Mountain	5.93	-1.41	1,108,409	2,376,671	4,794
Victoria	9.15	-1.18	517,724	1,013,344	103,116
Wallace	5.97	-1.41	1,244,643	2,665,860	225,032
West St. Paul	22.46	-0.23	81,934	97,006	21,535
Westbourne	5.36	-1.45	1,421,873	3,095,770	214,025
Whitehead	7.84	-1.27	714,311	1,452,184	174,289
Whitemouth	12.08	-0.97	195,545	349,429	-154,188

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Whitewater	7.40	-1.30	737,535	1,518,428	121,804
Winchester	6.63	-1.36	972,419	2,045,753	255,180
Winnipeg	13.37	-0.88	131,541	225,172	15,534
Woodlands	6.59	-1.36	1,101,946	2,320,449	178,120
Woodworth	7.19	-1.32	866,474	1,794,401	184,267
CAR 3	2.18	-1.68	8,979,125	21,210,090	1,902,342
CAR 4	3.34	-1.59	4,001,760	9,183,099	1,051,481
CAR 5	3.37	-1.59	3,598,751	8,252,011	881,882
CAR 6	2.45	-1.66	7,546,088	17,705,750	1,919,314

Average Manure Transportation Distance (miles)	8.48
Average Effective Manure Cost ($)	-1.23
Total Manure Phosphorus Demand (lbs P)	81,852,255
Total Net Manure Benefit ($)	176,453,527
Total Hog Capacity (animals per year)	9,677,016

Table A5: Simulation Results with a 25% Manure Acceptance Rate and a 50% Increase in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	6.92	-1.94	1,111,666	2,567,634	180,728
Alexander	17.57	-1.17	171,968	308,501	31,628
Argyle	6.99	-1.93	1,070,549	2,468,565	157,475
Armstrong	9.83	-1.73	628,244	1,362,479	89,871
Aurthur	6.34	-1.98	1,300,574	3,040,288	284,427
Bifrost	5.81	-2.01	1,564,245	3,696,647	267,599
Brenda	6.27	-1.98	1,266,122	2,964,258	211,286
Brokenhead	7.36	-1.90	982,660	2,248,357	142,171
Cameron	7.24	-1.91	992,146	2,276,046	182,978
Cartier	6.83	-1.94	595,209	1,377,361	-391,104
Coldwell	11.09	-1.64	528,075	1,112,940	115,664
Daly	7.69	-1.88	848,899	1,928,716	150,355
De Salaberry	6.98	-1.93	910,070	2,099,054	-597,996
Dufferin	5.63	-2.03	1,314,641	3,118,298	119,767
Edward	7.29	-1.91	1,004,741	2,302,359	203,053
Elton	5.31	-2.05	1,729,716	4,129,258	303,243
Eriksdale	12.49	-1.54	449,337	916,589	78,941
Fisher	6.17	-1.99	1,465,277	3,437,416	130,659
Franklin	6.69	-1.95	1,120,701	2,600,490	201,887
Gimli	14.26	-1.41	268,781	525,295	57,096
Glenella	9.95	-1.72	606,101	1,310,747	58,908
Glenwood	7.98	-1.86	803,599	1,814,758	149,426
Grahamdale	12.36	-1.55	358,889	734,341	63,891
Grey	5.95	-2.00	1,237,444	2,915,878	199,405
Hanover	7.17	-1.92	397,186	912,527	-261,106
Headingley	16.39	-1.26	147,177	272,416	6,918
La Broquerie	21.17	-0.92	0	0	-90,341
Lac du Bonnet	11.89	-1.58	389,943	806,711	61,132
Lakeview	12.71	-1.52	352,673	715,697	77,246
Lansdowne	7.90	-1.86	861,493	1,948,694	155,274
Lorne	5.60	-2.03	1,312,307	3,114,785	39,662
Louise	5.74	-2.02	1,477,475	3,496,411	234,041
Macdonald	4.62	-2.10	1,745,833	4,226,689	-1,147,165
Montcalm	7.13	-1.92	793,569	1,824,775	110,512
Morris	4.78	-2.09	1,480,576	3,572,851	-972,868
Morton	6.50	-1.97	1,162,070	2,707,586	180,199

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	6.13	-1.99	1,385,885	3,253,642	206,144
North Norfolk	5.90	-2.01	1,331,830	3,141,807	184,778
Oakland	8.08	-1.85	810,498	1,826,176	142,683
Pemina	5.58	-2.03	1,510,003	3,585,470	105,589
Piney	14.32	-1.41	226,918	442,814	-149,108
Pipestone	6.34	-1.98	1,256,242	2,936,392	244,523
Portage la Prairie	4.29	-2.12	2,590,214	6,311,508	214,243
Reynolds	18.30	-1.12	139,910	246,016	-91,934
Rhineland	5.11	-2.06	1,480,393	3,548,538	34,972
Ritchot	9.73	-1.73	456,857	992,868	24,902
Riverside	8.38	-1.83	660,234	1,478,175	1,321
Roblin	7.09	-1.92	1,025,171	2,359,382	117,372
Rockwood	6.22	-1.99	1,366,138	3,201,449	93,862
Roland	7.05	-1.93	762,240	1,755,498	139,077
Rosser	7.79	-1.87	830,704	1,883,520	156,402
Sifton	9.63	-1.74	654,306	1,425,291	134,104
Siglunes	10.39	-1.69	647,973	1,387,541	141,925
South Cypress	8.42	-1.83	743,595	1,663,185	68,859
South Norfolk	6.89	-1.94	746,981	1,726,386	-490,832
Springfield	6.56	-1.96	1,149,413	2,674,668	172,941
St. Andrews	7.12	-1.92	987,609	2,271,164	159,396
St. Clements	8.17	-1.85	728,738	1,639,002	80,257
St. Francois Xavier	12.39	-1.54	298,100	609,477	54,659
St. Laurent	17.70	-1.16	210,620	376,510	46,132
Stanley	5.64	-2.03	1,634,771	3,876,913	268,898
Ste. Anne	10.44	-1.68	224,034	479,218	-147,210
Strathcona	10.30	-1.69	479,582	1,029,167	87,101
Stuartburn	11.31	-1.62	430,269	902,244	59,329
Tache	8.06	-1.85	454,440	1,024,450	-298,607
Thompson	8.07	-1.85	684,993	1,543,849	31,847
Turtle Mountain	5.93	-2.01	1,330,091	3,135,626	4,794
Victoria	9.15	-1.78	621,268	1,367,842	103,116
Wallace	5.97	-2.00	1,493,572	3,518,098	225,032
West St. Paul	22.46	-0.82	98,321	153,109	21,535
Westbourne	5.36	-2.05	1,706,247	4,069,360	214,025
Whitehead	7.84	-1.87	857,173	1,941,290	174,289
Whitemouth	12.08	-1.57	234,653	483,323	-154,188
Whitewater	7.40	-1.90	885,042	2,023,436	121,804

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	6.63	-1.96	1,166,903	2,711,592	255,180
Winnipeg	13.37	-1.47	157,849	315,242	15,534
Woodlands	6.59	-1.96	1,322,335	3,074,978	178,120
Woodworth	7.19	-1.92	1,039,768	2,387,697	184,267
CAR 3	2.18	-2.27	10,774,950	27,358,314	1,902,342
CAR 4	3.34	-2.19	4,802,112	11,923,201	1,051,481
CAR 5	3.37	-2.19	4,318,501	10,716,163	881,882
CAR 6	2.45	-2.25	9,055,306	22,872,740	1,919,314

Average Manure Transportation Distance (miles)	8.48
Average Effective Manure Cost ($)	-1.82
Total Manure Phosphorus Demand (lbs P)	98,222,706
Total Net Manure Benefit ($)	232,499,748
Total Hog Capacity (animals per year)	9,677,016

Table A6: Simulation Results with a 50% Manure Acceptance Rate and a 50% Decrease in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	5.65	0.36	741,112	197,296	424,217
Alexander	14.35	0.98	0	0	-75,332
Argyle	5.71	0.37	713,700	183,304	391,957
Armstrong	8.02	0.53	0	0	-275,210
Aurthur	5.18	0.33	867,050	290,153	569,291
Bifrost	4.74	0.30	1,042,830	414,277	610,215
Brenda	5.12	0.32	844,082	289,826	488,604
Brokenhead	6.01	0.39	655,107	139,602	357,403
Cameron	5.91	0.38	661,431	150,724	400,288
Cartier	5.57	0.36	396,806	109,859	-260,736
Coldwell	9.06	0.61	0	0	-231,330
Daly	6.28	0.41	565,933	98,404	336,289
De Salaberry	5.70	0.37	606,713	156,698	15,940
Dufferin	4.60	0.29	876,428	366,976	407,711
Edward	5.95	0.38	669,829	148,423	423,121
Elton	4.34	0.27	1,153,144	525,977	682,102
Eriksdale	10.20	0.69	0	0	-196,838
Fisher	5.04	0.32	976,852	346,673	451,598
Franklin	5.47	0.35	747,135	218,476	447,354
Gimli	11.64	0.79	0	0	-117,742
Glenella	8.13	0.54	0	0	-265,509
Glenwood	6.51	0.42	535,733	75,133	325,438
Grahamdale	10.09	0.68	0	0	-157,216
Grey	4.86	0.31	824,962	313,896	470,441
Hanover	5.97	0.38	264,837	58,143	-174,081
Headingley	13.38	0.91	0	0	-64,472
La Broquerie	19.60	1.36	0	0	-90,341
Lac du Bonnet	9.71	0.65	0	0	-170,819
Lakeview	10.38	0.70	0	0	-154,492
Lansdowne	6.45	0.42	574,328	85,764	343,966
Lorne	4.57	0.28	874,872	369,629	327,095
Louise	4.69	0.29	984,983	399,167	557,651
Macdonald	3.77	0.23	1,163,888	627,150	371,364
Montcalm	5.82	0.37	529,046	127,541	284,326
Morris	3.90	0.24	987,050	512,842	240,355
Morton	5.31	0.34	774,713	244,674	434,726

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	5.01	0.32	923,924	331,921	509,694
North Norfolk	4.82	0.30	887,887	343,585	476,488
Oakland	6.60	0.43	540,332	68,980	320,206
Pemina	4.55	0.28	1,006,669	427,686	436,324
Piney	11.69	0.79	0	0	-99,406
Pipestone	5.18	0.33	837,496	279,829	519,677
Portage la Prairie	3.51	0.21	1,726,810	996,711	781,575
Reynolds	14.95	1.03	0	0	-61,289
Rhineland	4.17	0.26	986,929	473,796	359,222
Ritchot	7.95	0.53	0	0	-200,130
Riverside	6.84	0.45	440,156	40,785	145,932
Roblin	5.79	0.37	683,448	168,109	341,915
Rockwood	5.08	0.32	910,759	317,672	393,086
Roland	5.76	0.37	508,160	127,016	306,030
Rosser	6.36	0.41	553,803	89,997	338,350
Sifton	7.86	0.52	0	0	-286,627
Siglunes	8.49	0.56	0	0	-283,853
South Cypress	6.88	0.45	495,730	43,287	231,728
South Norfolk	5.62	0.36	497,987	134,314	23,249
Springfield	5.36	0.34	766,276	236,409	424,697
St. Andrews	5.82	0.37	658,406	159,059	375,712
St. Clements	6.67	0.43	485,826	57,193	239,872
St. Francois Xavier	10.12	0.68	0	0	-130,585
St. Laurent	14.45	0.99	0	0	-92,265
Stanley	4.60	0.29	1,089,847	455,159	626,961
Ste. Anne	8.53	0.57	0	0	-98,140
Strathcona	8.41	0.56	0	0	-210,088
Stuartburn	9.24	0.62	0	0	-188,485
Tache	6.58	0.43	302,960	39,521	16,385
Thompson	6.59	0.43	456,662	59,042	181,880
Turtle Mountain	4.84	0.30	886,727	339,745	296,123
Victoria	7.47	0.49	414,179	668	239,192
Wallace	4.87	0.31	995,716	376,724	552,169
West St. Paul	18.34	1.27	0	0	-43,071
Westbourne	4.38	0.27	1,137,498	512,518	587,743
Whitehead	6.40	0.42	571,449	89,199	362,035
Whitemouth	9.86	0.66	0	0	-102,792
Whitewater	6.04	0.39	590,028	123,175	315,654

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	5.41	0.34	777,936	233,844	510,767
Winnipeg	10.92	0.74	0	0	-69,147
Woodlands	5.38	0.34	881,557	268,583	467,751
Woodworth	5.87	0.38	693,180	161,880	412,007
CAR 3	1.78	0.08	7,183,300	5,947,826	4,262,371
CAR 4	2.73	0.15	3,201,408	2,210,404	2,103,284
CAR 5	2.75	0.15	2,879,001	1,977,548	1,827,760
CAR 6	2.00	0.10	6,036,872	4,803,784	3,902,691

Average Manure Transportation Distance (miles)	6.95
Average Effective Manure Cost ($)	0.45
Total Manure Phosphorus Demand (lbs P)	60,041,478
Total Net Manure Benefit ($)	28,346,579
Total Hog Capacity (animals per year)	28,149,985

Table A7: Simulation Results with a 50% Manure Acceptance Rate and a 25% Decrease in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	5.65	-0.24	1,111,668	1,465,940	424,217
Alexander	14.35	0.39	171,968	81,930	69,294
Argyle	5.71	-0.23	1,070,550	1,405,023	391,957
Armstrong	8.02	-0.07	628,245	683,798	227,475
Aurthur	5.18	-0.27	1,300,575	1,774,379	569,291
Bifrost	4.74	-0.30	1,564,245	2,199,405	610,215
Brenda	5.12	-0.27	1,266,122	1,734,733	488,604
Brokenhead	6.01	-0.21	982,661	1,261,022	357,403
Cameron	5.91	-0.22	992,147	1,282,970	400,288
Cartier	5.57	-0.24	595,209	789,115	-260,736
Coldwell	9.06	0.01	528,077	522,021	231,328
Daly	6.28	-0.19	848,900	1,067,174	336,289
De Salaberry	5.70	-0.23	910,070	1,195,277	15,940
Dufferin	4.60	-0.31	1,314,641	1,867,254	407,711
Edward	5.95	-0.21	1,004,743	1,295,042	423,121
Elton	4.34	-0.33	1,729,716	2,499,941	682,102
Eriksdale	10.20	0.09	449,338	394,532	177,360
Fisher	5.04	-0.28	1,465,278	2,018,859	451,598
Franklin	5.47	-0.25	1,120,702	1,497,429	447,354
Gimli	11.64	0.19	268,782	198,465	115,967
Glenella	8.13	-0.06	606,103	653,635	191,663
Glenwood	6.51	-0.17	803,599	992,206	325,438
Grahamdale	10.09	0.08	358,890	318,796	142,498
Grey	4.86	-0.29	1,237,444	1,726,075	470,441
Hanover	5.97	-0.21	397,255	511,493	-174,081
Headingley	13.38	0.32	147,177	83,817	39,154
La Broquerie	19.60	0.76	0	0	-90,341
Lac du Bonnet	9.71	0.06	389,943	360,799	146,541
Lakeview	10.38	0.10	352,673	303,597	154,492
Lansdowne	6.45	-0.18	861,493	1,068,906	343,966
Lorne	4.57	-0.31	1,312,307	1,867,243	327,095
Louise	4.69	-0.30	1,477,475	2,085,271	557,651
Macdonald	3.77	-0.37	1,745,833	2,619,507	371,364
Montcalm	5.82	-0.22	793,569	1,033,167	284,326
Morris	3.90	-0.36	1,480,576	2,202,485	240,355

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Morton	5.31	-0.26	1,162,070	1,570,836	434,726
North Cypress	5.01	-0.28	1,385,885	1,913,503	509,694
North Norfolk	4.82	-0.29	1,331,830	1,863,479	476,488
Oakland	6.60	-0.17	810,499	993,927	320,206
Pemina	4.55	-0.31	1,510,003	2,150,911	436,324
Piney	11.69	0.20	226,920	166,468	33,887
Pipestone	5.18	-0.27	1,256,244	1,713,464	519,677
Portage la Prairie	3.51	-0.39	2,590,214	3,952,682	781,575
Reynolds	14.95	0.43	139,910	58,534	11,248
Rhineland	4.17	-0.34	1,480,393	2,163,232	359,222
Ritchot	7.95	-0.07	456,857	500,645	124,967
Riverside	6.84	-0.15	660,234	794,250	145,932
Roblin	5.79	-0.23	1,025,171	1,338,042	341,915
Rockwood	5.08	-0.28	1,366,138	1,876,718	393,086
Roland	5.76	-0.23	762,240	996,890	306,030
Rosser	6.36	-0.18	830,704	1,038,003	338,350
Sifton	7.86	-0.08	654,308	722,437	277,417
Siglunes	8.49	-0.03	647,975	676,327	283,851
South Cypress	6.88	-0.15	743,595	891,882	231,728
South Norfolk	5.62	-0.24	746,981	986,774	23,249
Springfield	5.36	-0.26	1,149,414	1,548,129	424,697
St. Andrews	5.82	-0.22	987,609	1,286,125	375,712
St. Clements	6.67	-0.16	728,739	888,835	239,872
St. Francois Xavier	10.12	0.08	298,100	264,012	119,952
St. Laurent	14.45	0.39	210,621	98,173	92,264
Stanley	4.60	-0.31	1,634,771	2,320,771	626,961
Ste. Anne	8.53	-0.03	224,034	232,882	-98,140
Strathcona	8.41	-0.04	479,585	504,176	192,145
Stuartburn	9.24	0.02	430,270	417,882	153,571
Tache	6.58	-0.17	454,440	558,131	16,385
Thompson	6.59	-0.17	684,993	840,761	181,880
Turtle Mountain	4.84	-0.29	1,330,091	1,857,654	296,123
Victoria	7.47	-0.11	621,268	709,664	239,192
Wallace	4.87	-0.29	1,493,574	2,081,201	552,169
West St. Paul	18.34	0.67	98,321	8,837	43,070
Westbourne	4.38	-0.33	1,706,247	2,459,699	587,743
Whitehead	6.40	-0.18	857,174	1,067,412	362,035
Whitemouth	9.86	0.07	234,653	213,628	-102,792

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Whitewater	6.04	-0.21	885,042	1,133,191	315,654
Winchester	5.41	-0.25	1,166,904	1,565,523	510,767
Winnipeg	10.92	0.14	157,849	127,558	50,107
Woodlands	5.38	-0.25	1,322,335	1,777,641	467,751
Woodworth	5.87	-0.22	1,039,769	1,348,472	412,007
CAR 3	1.78	-0.51	10,774,950	18,244,275	4,262,371
CAR 4	2.73	-0.44	4,802,112	7,690,608	2,103,284
CAR 5	2.75	-0.44	4,318,501	6,905,852	1,827,760
CAR 6	2.00	-0.50	9,055,307	15,137,765	3,902,691

Average Manure Transportation Distance (miles)	6.95
Average Effective Manure Cost ($)	-0.14
Total Manure Phosphorus Demand (lbs P)	98,222,817
Total Net Manure Benefit ($)	138,719,164
Total Hog Capacity (animals per year)	34,402,143

Table A8: Simulation Results with a 50% Manure Acceptance Rate and a 25% Increase in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	5.65	-1.43	1,852,781	4,003,227	424,217
Alexander	14.35	-0.81	286,614	474,433	69,294
Argyle	5.71	-1.42	1,784,249	3,848,460	391,957
Armstrong	8.02	-1.26	1,047,076	2,117,714	227,475
Aurthur	5.18	-1.46	2,167,626	4,742,830	569,291
Bifrost	4.74	-1.49	2,607,075	5,769,660	610,215
Brenda	5.12	-1.47	2,110,204	4,624,549	488,604
Brokenhead	6.01	-1.40	1,637,769	3,503,862	357,403
Cameron	5.91	-1.41	1,653,579	3,547,460	400,288
Cartier	5.57	-1.43	992,015	2,147,628	-260,736
Coldwell	9.06	-1.19	880,128	1,727,311	231,328
Daly	6.28	-1.38	1,414,833	3,004,714	336,289
De Salaberry	5.70	-1.43	1,516,783	3,272,433	15,940
Dufferin	4.60	-1.50	2,191,069	4,867,809	407,711
Edward	5.95	-1.41	1,674,571	3,588,282	423,121
Elton	4.34	-1.52	2,882,860	6,447,870	682,102
Eriksdale	10.20	-1.10	748,897	1,420,108	177,360
Fisher	5.04	-1.47	2,442,131	5,363,231	451,598
Franklin	5.47	-1.44	1,867,837	4,055,335	447,354
Gimli	11.64	-1.00	447,969	811,936	115,967
Glenella	8.13	-1.25	1,010,171	2,037,012	191,663
Glenwood	6.51	-1.37	1,339,332	2,826,351	325,438
Grahamdale	10.09	-1.11	598,150	1,137,932	142,498
Grey	4.86	-1.49	2,062,406	4,550,434	470,441
Hanover	5.97	-1.41	662,091	1,418,193	-174,081
Headingley	13.38	-0.88	245,295	419,735	39,154
La Broquerie	19.60	-0.43	0	0	-90,341
Lac du Bonnet	9.71	-1.14	649,905	1,250,811	146,541
Lakeview	10.38	-1.09	587,789	1,108,544	154,492
Lansdowne	6.45	-1.37	1,435,821	3,035,189	343,966
Lorne	4.57	-1.51	2,187,179	4,862,471	327,095
Louise	4.69	-1.50	2,462,458	5,457,481	557,651
Macdonald	3.77	-1.56	2,909,721	6,604,220	371,364
Montcalm	5.82	-1.42	1,322,614	2,844,419	284,326
Morris	3.90	-1.55	2,467,626	5,581,772	240,355
Morton	5.31	-1.45	1,936,783	4,223,160	434,726

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	5.01	-1.47	2,309,809	5,076,668	509,694
North Norfolk	4.82	-1.49	2,219,717	4,903,267	476,488
Oakland	6.60	-1.36	1,350,831	2,843,821	320,206
Pemina	4.55	-1.51	2,516,671	5,597,363	436,324
Piney	11.69	-1.00	378,200	684,393	33,887
Pipestone	5.18	-1.46	2,093,740	4,580,733	519,677
Portage la Prairie	3.51	-1.58	4,317,024	9,864,623	781,575
Reynolds	14.95	-0.76	233,184	377,867	11,248
Rhineland	4.17	-1.53	2,467,322	5,542,102	359,222
Ritchot	7.95	-1.26	761,428	1,543,382	124,967
Riverside	6.84	-1.34	1,100,391	2,301,178	145,932
Roblin	5.79	-1.42	1,708,619	3,677,907	341,915
Rockwood	5.08	-1.47	2,276,896	4,994,810	393,086
Roland	5.76	-1.42	1,270,399	2,736,636	306,030
Rosser	6.36	-1.38	1,384,507	2,934,013	338,350
Sifton	7.86	-1.27	1,090,514	2,215,839	277,417
Siglunes	8.49	-1.23	1,079,958	2,155,273	283,851
South Cypress	6.88	-1.34	1,239,325	2,589,074	231,728
South Norfolk	5.62	-1.43	1,244,968	2,691,693	23,249
Springfield	5.36	-1.45	1,915,690	4,171,568	424,697
St. Andrews	5.82	-1.42	1,646,015	3,540,258	375,712
St. Clements	6.67	-1.36	1,214,564	2,552,118	239,872
St. Francois Xavier	10.12	-1.11	496,833	944,399	119,952
St. Laurent	14.45	-0.80	351,035	578,897	92,264
Stanley	4.60	-1.50	2,724,618	6,051,994	626,961
Ste. Anne	8.53	-1.22	373,390	744,221	-98,140
Strathcona	8.41	-1.23	799,308	1,598,787	192,145
Stuartburn	9.24	-1.17	717,116	1,399,936	153,571
Tache	6.58	-1.36	757,399	1,595,350	16,385
Thompson	6.59	-1.36	1,141,655	2,404,199	181,880
Turtle Mountain	4.84	-1.49	2,216,818	4,893,472	296,123
Victoria	7.47	-1.30	1,035,447	2,127,655	239,192
Wallace	4.87	-1.48	2,489,290	5,490,155	552,169
West St. Paul	18.34	-0.52	163,869	233,247	43,070
Westbourne	4.38	-1.52	2,843,745	6,354,062	587,743
Whitehead	6.40	-1.37	1,428,623	3,023,837	362,035
Whitemouth	9.86	-1.13	391,089	749,205	-102,792
Whitewater	6.04	-1.40	1,475,070	3,153,223	315,654

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	5.41	-1.45	1,944,840	4,228,881	510,767
Winnipeg	10.92	-1.05	263,082	487,836	50,107
Woodlands	5.38	-1.45	2,203,892	4,795,757	467,751
Woodworth	5.87	-1.41	1,732,949	3,721,657	412,007
CAR 3	1.78	-1.71	17,958,250	42,837,172	4,262,371
CAR 4	2.73	-1.64	8,003,519	18,651,015	2,103,284
CAR 5	2.75	-1.64	7,197,502	16,762,460	1,827,760
CAR 6	2.00	-1.69	15,092,179	35,805,725	3,902,691

Average Manure Transportation Distance (miles)	6.95
Average Effective Manure Cost ($)	-1.34
Total Manure Phosphorus Demand (lbs P)	163,704,695
Total Net Manure Benefit ($)	362,904,302
Total Hog Capacity (animals per year)	34,402,143

Table A9: Simulation Results with a 50% Manure Acceptance Rate and a 50% Increase in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	5.65	-2.03	2,223,337	5,271,871	424,217
Alexander	14.35	-1.40	343,937	670,685	69,294
Argyle	5.71	-2.02	2,141,099	5,070,179	391,957
Armstrong	8.02	-1.86	1,256,491	2,834,672	227,475
Aurthur	5.18	-2.06	2,601,151	6,227,056	569,291
Bifrost	4.74	-2.09	3,128,490	7,554,787	610,215
Brenda	5.12	-2.06	2,532,245	6,069,457	488,604
Brokenhead	6.01	-2.00	1,965,322	4,625,282	357,403
Cameron	5.91	-2.01	1,984,294	4,679,706	400,288
Cartier	5.57	-2.03	1,190,418	2,826,885	-260,736
Coldwell	9.06	-1.78	1,056,153	2,329,955	231,328
Daly	6.28	-1.98	1,697,799	3,973,485	336,289
De Salaberry	5.70	-2.02	1,820,140	4,311,011	15,940
Dufferin	4.60	-2.10	2,629,283	6,368,087	407,711
Edward	5.95	-2.00	2,009,486	4,734,901	423,121
Elton	4.34	-2.12	3,459,433	8,421,834	682,102
Eriksdale	10.20	-1.70	898,676	1,932,896	177,360
Fisher	5.04	-2.07	2,930,557	7,035,417	451,598
Franklin	5.47	-2.04	2,241,404	5,334,288	447,354
Gimli	11.64	-1.60	537,563	1,118,671	115,967
Glenella	8.13	-1.85	1,212,205	2,728,701	191,663
Glenwood	6.51	-1.96	1,607,198	3,743,424	325,438
Grahamdale	10.09	-1.71	717,780	1,547,500	142,498
Grey	4.86	-2.08	2,474,887	5,962,613	470,441
Hanover	5.97	-2.00	794,510	1,871,543	-174,081
Headingley	13.38	-1.47	294,354	587,695	39,154
La Broquerie	19.60	-1.03	0	0	-90,341
Lac du Bonnet	9.71	-1.74	779,887	1,695,817	146,541
Lakeview	10.38	-1.69	705,347	1,511,017	154,492
Lansdowne	6.45	-1.97	1,722,985	4,018,330	343,966
Lorne	4.57	-2.10	2,624,615	6,360,086	327,095
Louise	4.69	-2.09	2,954,950	7,143,586	557,651
Macdonald	3.77	-2.16	3,491,665	8,596,576	371,364
Montcalm	5.82	-2.01	1,587,137	3,750,045	284,326
Morris	3.90	-2.15	2,961,151	7,271,415	240,355
Morton	5.31	-2.05	2,324,139	5,549,322	434,726

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	5.01	-2.07	2,771,771	6,658,250	509,694
North Norfolk	4.82	-2.09	2,663,660	6,423,161	476,488
Oakland	6.60	-1.96	1,620,997	3,768,767	320,206
Pemina	4.55	-2.10	3,020,006	7,320,589	436,324
Piney	11.69	-1.59	453,840	943,355	33,887
Pipestone	5.18	-2.06	2,512,488	6,014,368	519,677
Portage la Prairie	3.51	-2.18	5,180,429	12,820,594	781,575
Reynolds	14.95	-1.36	279,820	537,533	11,248
Rhineland	4.17	-2.13	2,960,787	7,231,538	359,222
Ritchot	7.95	-1.86	913,714	2,064,750	124,967
Riverside	6.84	-1.94	1,320,469	3,054,642	145,932
Roblin	5.79	-2.02	2,050,343	4,847,840	341,915
Rockwood	5.08	-2.07	2,732,276	6,553,856	393,086
Roland	5.76	-2.02	1,524,479	3,606,509	306,030
Rosser	6.36	-1.97	1,661,408	3,882,019	338,350
Sifton	7.86	-1.87	1,308,617	2,962,540	277,417
Siglunes	8.49	-1.82	1,295,949	2,894,746	283,851
South Cypress	6.88	-1.94	1,487,190	3,437,669	231,728
South Norfolk	5.62	-2.03	1,493,961	3,544,152	23,249
Springfield	5.36	-2.05	2,298,828	5,483,287	424,697
St. Andrews	5.82	-2.01	1,975,218	4,667,324	375,712
St. Clements	6.67	-1.95	1,457,477	3,383,759	239,872
St. Francois Xavier	10.12	-1.71	596,200	1,284,593	119,952
St. Laurent	14.45	-1.40	421,242	819,260	92,264
Stanley	4.60	-2.10	3,269,541	7,917,606	626,961
Ste. Anne	8.53	-1.82	448,068	999,890	-98,140
Strathcona	8.41	-1.83	959,170	2,146,093	192,145
Stuartburn	9.24	-1.77	860,540	1,890,963	153,571
Tache	6.58	-1.96	908,879	2,113,960	16,385
Thompson	6.59	-1.96	1,369,986	3,185,917	181,880
Turtle Mountain	4.84	-2.08	2,660,182	6,411,381	296,123
Victoria	7.47	-1.90	1,242,537	2,836,651	239,192
Wallace	4.87	-2.08	2,987,147	7,194,632	552,169
West St. Paul	18.34	-1.12	196,643	345,452	43,070
Westbourne	4.38	-2.12	3,412,494	8,301,243	587,743
Whitehead	6.40	-1.97	1,714,347	4,002,050	362,035
Whitemouth	9.86	-1.72	469,307	1,016,993	-102,792
Whitewater	6.04	-2.00	1,770,084	4,163,239	315,654

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	5.41	-2.04	2,333,808	5,560,560	510,767
Winnipeg	10.92	-1.65	315,699	667,975	50,107
Woodlands	5.38	-2.04	2,644,670	6,304,815	467,751
Woodworth	5.87	-2.01	2,079,539	4,908,249	412,007
CAR 3	1.78	-2.30	21,549,900	55,133,621	4,262,371
CAR 4	2.73	-2.23	9,604,223	24,131,218	2,103,284
CAR 5	2.75	-2.23	8,637,002	21,690,763	1,827,760
CAR 6	2.00	-2.29	18,110,615	46,139,705	3,902,691

Average Manure Transportation Distance (miles)	6.95
Average Effective Manure Cost ($)	-1.93
Total Manure Phosphorus Demand (lbs P)	196,445,634
Total Net Manure Benefit ($)	474,996,871
Total Hog Capacity (animals per year)	34,402,143

Table A10: Simulation Results with a 75% Manure Acceptance Rate and a 50% Decrease in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	3.99	0.24	1,111,669	562,962	667,705
Alexander	10.14	0.68	0	0	-37,666
Argyle	4.04	0.25	1,070,550	535,039	626,439
Armstrong	5.67	0.36	628,246	164,716	365,080
Aurthur	3.66	0.22	1,300,576	721,557	854,156
Bifrost	3.35	0.20	1,564,245	937,102	952,830
Brenda	3.62	0.22	1,266,123	710,247	765,922
Brokenhead	4.25	0.26	982,662	460,723	572,634
Cameron	4.18	0.26	992,148	475,538	617,597
Cartier	3.94	0.24	595,209	305,842	91,124
Coldwell	6.40	0.42	528,077	82,502	346,993
Daly	4.44	0.28	848,900	374,466	522,222
De Salaberry	4.03	0.25	910,070	455,754	215,272
Dufferin	3.25	0.19	1,314,641	807,504	695,656
Edward	4.21	0.26	1,004,743	477,104	643,189
Elton	3.07	0.18	1,729,716	1,108,224	1,060,960
Eriksdale	7.21	0.47	449,339	17,535	275,778
Fisher	3.56	0.21	1,465,279	833,908	772,538
Franklin	3.87	0.23	1,120,702	588,301	692,820
Gimli	8.23	0.55	0	0	-58,871
Glenella	5.75	0.37	606,103	152,480	324,417
Glenwood	4.61	0.29	803,599	335,370	501,449
Grahamdale	7.14	0.47	358,890	17,909	221,106
Grey	3.44	0.20	1,237,444	726,645	741,478
Hanover	4.46	0.28	397,278	174,514	-87,056
Headingley	9.46	0.63	0	0	-32,236
La Broquerie	17.89	1.24	0	0	-90,341
Lac du Bonnet	6.87	0.45	389,943	34,753	231,950
Lakeview	7.34	0.48	352,673	7,335	231,737
Lansdowne	4.56	0.28	861,493	365,066	532,658
Lorne	3.23	0.19	1,312,307	809,574	614,529
Louise	3.32	0.19	1,477,475	893,467	881,261
Macdonald	2.67	0.15	1,745,833	1,220,651	753,752
Montcalm	4.12	0.25	793,569	387,762	458,141
Morris	2.76	0.15	1,480,576	1,015,004	564,644
Morton	3.75	0.23	1,162,070	629,250	689,253

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	3.54	0.21	1,385,885	792,993	813,243
North Norfolk	3.40	0.20	1,331,830	788,165	768,198
Oakland	4.67	0.29	810,499	331,039	497,729
Pemina	3.22	0.19	1,510,003	934,065	767,059
Piney	8.27	0.55	0	0	-49,703
Pipestone	3.66	0.22	1,256,245	696,502	794,832
Portage la Prairie	2.48	0.13	2,590,214	1,881,299	1,348,908
Reynolds	10.57	0.71	0	0	-30,645
Rhineland	2.95	0.17	1,480,393	973,543	683,471
Ritchot	5.62	0.36	456,857	123,375	225,032
Riverside	4.84	0.30	660,234	253,323	290,543
Roblin	4.09	0.25	1,025,171	504,484	566,457
Rockwood	3.59	0.21	1,366,138	771,604	692,310
Roland	4.07	0.25	762,240	377,235	472,982
Rosser	4.50	0.28	830,704	359,761	520,299
Sifton	5.56	0.36	654,309	182,443	420,730
Siglunes	6.00	0.39	647,975	139,188	425,777
South Cypress	4.86	0.31	743,595	282,500	394,597
South Norfolk	3.98	0.24	746,981	380,095	186,859
Springfield	3.79	0.23	1,149,414	616,457	676,452
St. Andrews	4.11	0.25	987,609	482,934	592,027
St. Clements	4.72	0.29	728,739	292,524	399,487
St. Francois Xavier	7.16	0.47	298,100	14,041	185,244
St. Laurent	10.22	0.69	0	0	-46,133
Stanley	3.26	0.19	1,634,771	1,002,903	985,023
Ste. Anne	6.04	0.39	224,034	46,773	-49,070
Strathcona	5.95	0.38	479,586	106,842	297,188
Stuartburn	6.53	0.42	430,270	59,316	247,813
Tache	4.65	0.29	454,440	186,449	115,920
Thompson	4.66	0.29	684,993	280,565	331,914
Turtle Mountain	3.42	0.20	1,330,091	783,546	587,451
Victoria	5.28	0.34	621,268	198,376	375,268
Wallace	3.45	0.20	1,493,574	874,786	879,306
West St. Paul	12.97	0.89	0	0	-21,535
Westbourne	3.10	0.18	1,706,247	1,086,480	961,461
Whitehead	4.53	0.28	857,174	367,336	549,782
Whitemouth	6.98	0.46	234,653	17,168	44,423
Whitewater	4.27	0.26	885,042	412,239	509,504

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	3.83	0.23	1,166,904	619,302	766,353
Winnipeg	7.72	0.51	0	0	-34,574
Woodlands	3.81	0.23	1,322,335	705,601	757,381
Woodworth	4.15	0.25	1,039,770	502,522	639,747
CAR 3	1.26	0.05	10,774,950	9,736,890	6,622,400
CAR 4	1.93	0.10	4,802,112	3,872,375	3,155,087
CAR 5	1.94	0.10	4,318,501	3,471,524	2,773,638
CAR 6	1.41	0.06	9,055,308	7,976,311	5,886,069

Average Manure Transportation Distance (miles)	4.97
Average Effective Manure Cost ($)	0.31
Total Manure Phosphorus Demand (lbs P)	96,801,304
Total Net Manure Benefit ($)	59,873,681
Total Hog Capacity (animals per year)	55,155,431

Table A11: Simulation Results with a 75% Manure Acceptance Rate and a 25% Decrease in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	3.99	-0.35	1,667,504	2,465,929	667,705
Alexander	10.14	0.09	257,953	227,836	106,960
Argyle	4.04	-0.35	1,605,825	2,367,617	626,439
Armstrong	5.67	-0.23	942,369	1,240,154	365,080
Aurthur	3.66	-0.38	1,950,864	2,947,896	854,156
Bifrost	3.35	-0.40	2,346,368	3,614,793	952,830
Brenda	3.62	-0.38	1,899,184	2,877,609	765,922
Brokenhead	4.25	-0.34	1,473,992	2,142,853	572,634
Cameron	4.18	-0.34	1,488,222	2,173,907	617,597
Cartier	3.94	-0.36	892,813	1,324,727	91,124
Coldwell	6.40	-0.18	792,116	986,470	346,993
Daly	4.44	-0.32	1,273,350	1,827,621	522,222
De Salaberry	4.03	-0.35	1,365,105	2,013,621	215,272
Dufferin	3.25	-0.41	1,971,962	3,057,921	695,656
Edward	4.21	-0.34	1,507,115	2,197,034	643,189
Elton	3.07	-0.42	2,594,574	4,069,171	1,060,960
Eriksdale	7.21	-0.12	674,008	786,718	275,778
Fisher	3.56	-0.38	2,197,919	3,342,189	772,538
Franklin	3.87	-0.36	1,681,053	2,506,731	692,820
Gimli	8.23	-0.05	403,172	430,783	174,839
Glenella	5.75	-0.23	909,154	1,190,014	324,417
Glenwood	4.61	-0.31	1,205,398	1,710,979	501,449
Grahamdale	7.14	-0.13	538,336	632,261	221,106
Grey	3.44	-0.39	1,856,165	2,844,914	741,478
Hanover	4.46	-0.32	595,917	854,579	-87,056
Headingley	9.46	0.04	220,765	209,515	71,390
La Broquerie	17.89	0.64	0	0	-90,341
Lac du Bonnet	6.87	-0.15	584,915	702,262	231,950
Lakeview	7.34	-0.11	529,010	611,045	231,737
Lansdowne	4.56	-0.31	1,292,239	1,839,779	532,658
Lorne	3.23	-0.41	1,968,461	3,055,996	614,529
Louise	3.32	-0.40	2,216,212	3,422,624	881,261
Macdonald	2.67	-0.45	2,618,749	4,209,186	753,752
Montcalm	4.12	-0.34	1,190,353	1,746,201	458,141
Morris	2.76	-0.44	2,220,863	3,549,469	564,644
Morton	3.75	-0.37	1,743,104	2,618,493	689,253

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	3.54	-0.39	2,078,828	3,165,366	813,243
North Norfolk	3.40	-0.40	1,997,745	3,068,005	768,198
Oakland	4.67	-0.31	1,215,748	1,718,460	497,729
Pemina	3.22	-0.41	2,265,004	3,518,903	767,059
Piney	8.27	-0.05	340,380	362,536	83,589
Pipestone	3.66	-0.38	1,884,367	2,846,955	794,832
Portage la Prairie	2.48	-0.46	3,885,321	6,315,255	1,348,908
Reynolds	10.57	0.12	209,865	176,747	41,893
Rhineland	2.95	-0.43	2,220,590	3,507,697	683,471
Ritchot	5.62	-0.24	685,285	905,427	225,032
Riverside	4.84	-0.29	990,352	1,383,519	290,543
Roblin	4.09	-0.35	1,537,757	2,259,383	566,457
Rockwood	3.59	-0.38	2,049,207	3,110,173	692,310
Roland	4.07	-0.35	1,143,359	1,682,045	472,982
Rosser	4.50	-0.32	1,246,056	1,781,768	520,299
Sifton	5.56	-0.24	981,464	1,302,497	420,730
Siglunes	6.00	-0.21	971,963	1,248,399	425,777
South Cypress	4.86	-0.29	1,115,392	1,555,394	394,597
South Norfolk	3.98	-0.35	1,120,471	1,658,785	186,859
Springfield	3.79	-0.37	1,724,122	2,584,037	676,452
St. Andrews	4.11	-0.35	1,481,413	2,173,533	592,027
St. Clements	4.72	-0.30	1,093,108	1,539,986	399,487
St. Francois Xavier	7.16	-0.13	447,150	524,332	185,244
St. Laurent	10.22	0.09	315,932	276,742	138,397
Stanley	3.26	-0.41	2,452,156	3,801,320	985,023
Ste. Anne	6.04	-0.21	336,051	430,277	-49,070
Strathcona	5.95	-0.21	719,378	927,801	297,188
Stuartburn	6.53	-0.17	645,406	795,857	247,813
Tache	4.65	-0.31	681,660	964,364	115,920
Thompson	4.66	-0.31	1,027,489	1,453,143	331,914
Turtle Mountain	3.42	-0.39	1,995,136	3,060,410	587,451
Victoria	5.28	-0.26	931,902	1,261,870	375,268
Wallace	3.45	-0.39	2,240,362	3,431,502	879,306
West St. Paul	12.97	0.29	147,482	89,951	64,606
Westbourne	3.10	-0.42	2,559,371	4,007,252	961,461
Whitehead	4.53	-0.32	1,285,761	1,834,655	549,782
Whitemouth	6.98	-0.14	351,980	418,851	44,423
Whitewater	4.27	-0.33	1,327,563	1,927,263	509,504

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	3.83	-0.37	1,750,356	2,616,821	766,353
Winnipeg	7.72	-0.09	236,774	264,618	84,681
Woodlands	3.81	-0.37	1,983,503	2,969,188	757,381
Woodworth	4.15	-0.34	1,559,655	2,282,411	639,747
CAR 3	1.26	-0.55	16,162,425	28,181,563	6,622,400
CAR 4	1.93	-0.50	7,203,167	12,092,680	3,155,087
CAR 5	1.94	-0.50	6,477,752	10,863,979	2,773,638
CAR 6	1.41	-0.54	13,582,961	23,477,282	5,886,069

Average Manure Transportation Distance (miles)	4.97
Average Effective Manure Cost ($)	-0.28
Total Manure Phosphorus Demand (lbs P)	147,334,281
Total Net Manure Benefit ($)	227,617,902
Total Hog Capacity (animals per year)	56,233,148

Table A12: Simulation Results with a 75% Manure Acceptance Rate and the Current Price of Mineral Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	3.99	-0.95	2,223,338	4,368,896	667,705
Alexander	10.14	-0.51	343,937	522,213	106,960
Argyle	4.04	-0.95	2,141,099	4,200,195	626,439
Armstrong	5.67	-0.83	1,256,492	2,315,592	365,080
Aurthur	3.66	-0.97	2,601,152	5,174,236	854,156
Bifrost	3.35	-1.00	3,128,491	6,292,485	952,830
Brenda	3.62	-0.98	2,532,245	5,044,972	765,922
Brokenhead	4.25	-0.93	1,965,323	3,824,983	572,634
Cameron	4.18	-0.94	1,984,295	3,872,275	617,597
Cartier	3.94	-0.95	1,190,418	2,343,612	91,124
Coldwell	6.40	-0.78	1,056,154	1,890,438	346,993
Daly	4.44	-0.92	1,697,800	3,280,777	522,222
De Salaberry	4.03	-0.95	1,820,140	3,571,488	215,272
Dufferin	3.25	-1.00	2,629,283	5,308,338	695,656
Edward	4.21	-0.94	2,009,487	3,916,965	643,189
Elton	3.07	-1.02	3,459,433	7,030,117	1,060,960
Eriksdale	7.21	-0.72	898,678	1,555,901	275,778
Fisher	3.56	-0.98	2,930,558	5,850,469	772,538
Franklin	3.87	-0.96	2,241,404	4,425,161	692,820
Gimli	8.23	-0.65	537,563	890,886	174,839
Glenella	5.75	-0.83	1,212,206	2,227,547	324,417
Glenwood	4.61	-0.91	1,607,198	3,086,589	501,449
Grahamdale	7.14	-0.73	717,781	1,246,614	221,106
Grey	3.44	-0.99	2,474,887	4,963,183	741,478
Hanover	4.46	-0.92	794,555	1,534,643	-87,056
Headingley	9.46	-0.56	294,354	461,454	71,390
La Broquerie	17.89	0.04	0	0	-90,341
Lac du Bonnet	6.87	-0.75	779,887	1,369,771	231,950
Lakeview	7.34	-0.71	705,347	1,214,755	231,737
Lansdowne	4.56	-0.91	1,722,985	3,314,491	532,658
Lorne	3.23	-1.01	2,624,615	5,302,417	614,529
Louise	3.32	-1.00	2,954,950	5,951,781	881,261
Macdonald	2.67	-1.05	3,491,665	7,197,720	753,752
Montcalm	4.12	-0.94	1,587,137	3,104,640	458,141
Morris	2.76	-1.04	2,961,151	6,083,934	564,644
Morton	3.75	-0.97	2,324,139	4,607,736	689,253

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	3.54	-0.98	2,771,771	5,537,739	813,243
North Norfolk	3.40	-0.99	2,663,660	5,347,846	768,198
Oakland	4.67	-0.90	1,620,998	3,105,881	497,729
Pemina	3.22	-1.01	3,020,006	6,103,742	767,059
Piney	8.27	-0.64	453,841	750,981	83,589
Pipestone	3.66	-0.97	2,512,489	4,997,408	794,832
Portage la Prairie	2.48	-1.06	5,180,429	10,749,211	1,348,908
Reynolds	10.57	-0.48	279,820	416,247	41,893
Rhineland	2.95	-1.03	2,960,787	6,041,850	683,471
Ritchot	5.62	-0.83	913,714	1,687,480	225,032
Riverside	4.84	-0.89	1,320,469	2,513,715	290,543
Roblin	4.09	-0.94	2,050,343	4,014,282	566,457
Rockwood	3.59	-0.98	2,732,276	5,448,742	692,310
Roland	4.07	-0.94	1,524,479	2,986,855	472,982
Rosser	4.50	-0.91	1,661,408	3,203,776	520,299
Sifton	5.56	-0.84	1,308,618	2,422,550	420,730
Siglunes	6.00	-0.81	1,295,951	2,357,610	425,777
South Cypress	4.86	-0.89	1,487,190	2,828,287	394,597
South Norfolk	3.98	-0.95	1,493,961	2,937,474	186,859
Springfield	3.79	-0.97	2,298,829	4,551,617	676,452
St. Andrews	4.11	-0.94	1,975,218	3,864,132	592,027
St. Clements	4.72	-0.90	1,457,477	2,787,449	399,487
St. Francois Xavier	7.16	-0.72	596,200	1,034,623	185,244
St. Laurent	10.22	-0.51	421,243	637,285	138,397
Stanley	3.26	-1.00	3,269,541	6,599,738	985,023
Ste. Anne	6.04	-0.80	448,068	813,781	-49,070
Strathcona	5.95	-0.81	959,171	1,748,761	297,188
Stuartburn	6.53	-0.77	860,541	1,532,399	247,813
Tache	4.65	-0.90	908,879	1,742,279	115,920
Thompson	4.66	-0.90	1,369,986	2,625,721	331,914
Turtle Mountain	3.42	-0.99	2,660,182	5,337,273	587,451
Victoria	5.28	-0.86	1,242,537	2,325,363	375,268
Wallace	3.45	-0.99	2,987,149	5,988,219	879,306
West St. Paul	12.97	-0.31	196,643	258,259	64,606
Westbourne	3.10	-1.01	3,412,494	6,928,024	961,461
Whitehead	4.53	-0.91	1,714,348	3,301,975	549,782
Whitemouth	6.98	-0.74	469,307	820,533	44,423
Whitewater	4.27	-0.93	1,770,084	3,442,287	509,504

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	3.83	-0.96	2,333,809	4,614,340	766,353
Winnipeg	7.72	-0.68	315,699	534,826	84,681
Woodlands	3.81	-0.96	2,644,670	5,232,775	757,381
Woodworth	4.15	-0.94	2,079,539	4,062,300	639,747
CAR 3	1.26	-1.15	21,549,900	46,626,236	6,622,400
CAR 4	1.93	-1.10	9,604,223	20,312,985	3,155,087
CAR 5	1.94	-1.10	8,637,002	18,256,435	2,773,638
CAR 6	1.41	-1.14	18,110,615	38,978,253	5,886,069

Average Manure Transportation Distance (miles)	4.97
Average Effective Manure Cost ($)	-0.88
Total Manure Phosphorus Demand (lbs P)	196,445,708
Total Net Manure Benefit ($)	395,756,818
Total Hog Capacity (animals per year)	56,233,148

Table A13: Simulation Results with a 75% Manure Acceptance Rate and a 25% Increase in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	3.99	-1.55	2,779,173	6,271,863	667,705
Alexander	10.14	-1.11	429,921	816,590	106,960
Argyle	4.04	-1.54	2,676,374	6,032,774	626,439
Armstrong	5.67	-1.43	1,570,615	3,391,031	365,080
Aurthur	3.66	-1.57	3,251,440	7,400,576	854,156
Bifrost	3.35	-1.59	3,910,613	8,970,177	952,830
Brenda	3.62	-1.57	3,165,307	7,212,334	765,922
Brokenhead	4.25	-1.53	2,456,654	5,507,114	572,634
Cameron	4.18	-1.53	2,480,369	5,570,644	617,597
Cartier	3.94	-1.55	1,488,022	3,362,497	91,124
Coldwell	6.40	-1.37	1,320,193	2,794,406	346,993
Daly	4.44	-1.52	2,122,250	4,733,933	522,222
De Salaberry	4.03	-1.54	2,275,175	5,129,356	215,272
Dufferin	3.25	-1.60	3,286,603	7,558,754	695,656
Edward	4.21	-1.53	2,511,858	5,636,895	643,189
Elton	3.07	-1.61	4,324,291	9,991,064	1,060,960
Eriksdale	7.21	-1.32	1,123,347	2,325,084	275,778
Fisher	3.56	-1.58	3,663,198	8,358,749	772,538
Franklin	3.87	-1.56	2,801,756	6,343,591	692,820
Gimli	8.23	-1.24	671,954	1,350,989	174,839
Glenella	5.75	-1.42	1,515,257	3,265,081	324,417
Glenwood	4.61	-1.50	2,008,997	4,462,198	501,449
Grahamdale	7.14	-1.32	897,226	1,860,966	221,106
Grey	3.44	-1.59	3,093,609	7,081,452	741,478
Hanover	4.46	-1.51	993,194	2,214,707	-87,056
Headingley	9.46	-1.16	367,942	713,393	71,390
La Broquerie	17.89	-0.55	0	0	-90,341
Lac du Bonnet	6.87	-1.34	974,859	2,037,281	231,950
Lakeview	7.34	-1.31	881,684	1,818,465	231,737
Lansdowne	4.56	-1.51	2,153,732	4,789,203	532,658
Lorne	3.23	-1.60	3,280,768	7,548,838	614,529
Louise	3.32	-1.60	3,693,687	8,480,938	881,261
Macdonald	2.67	-1.64	4,364,582	10,186,255	753,752
Montcalm	4.12	-1.54	1,983,921	4,463,079	458,141
Morris	2.76	-1.64	3,701,439	8,618,399	564,644
Morton	3.75	-1.56	2,905,174	6,596,979	689,253

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	3.54	-1.58	3,464,713	7,910,112	813,243
North Norfolk	3.40	-1.59	3,329,575	7,627,687	768,198
Oakland	4.67	-1.50	2,026,247	4,493,301	497,729
Pemina	3.22	-1.60	3,775,007	8,688,581	767,059
Piney	8.27	-1.24	567,301	1,139,426	83,589
Pipestone	3.66	-1.57	3,140,612	7,147,861	794,832
Portage la Prairie	2.48	-1.66	6,475,536	15,183,167	1,348,908
Reynolds	10.57	-1.08	349,776	655,747	41,893
Rhineland	2.95	-1.62	3,700,984	8,576,003	683,471
Ritchot	5.62	-1.43	1,142,142	2,469,532	225,032
Riverside	4.84	-1.49	1,650,586	3,643,911	290,543
Roblin	4.09	-1.54	2,562,928	5,769,181	566,457
Rockwood	3.59	-1.58	3,415,345	7,787,311	692,310
Roland	4.07	-1.54	1,905,599	4,291,665	472,982
Rosser	4.50	-1.51	2,076,760	4,625,784	520,299
Sifton	5.56	-1.44	1,635,773	3,542,603	420,730
Siglunes	6.00	-1.40	1,619,938	3,466,821	425,777
South Cypress	4.86	-1.49	1,858,987	4,101,181	394,597
South Norfolk	3.98	-1.55	1,867,452	4,216,163	186,859
Springfield	3.79	-1.56	2,873,536	6,519,197	676,452
St. Andrews	4.11	-1.54	2,469,022	5,554,732	592,027
St. Clements	4.72	-1.50	1,821,846	4,034,911	399,487
St. Francois Xavier	7.16	-1.32	745,250	1,544,913	185,244
St. Laurent	10.22	-1.10	526,553	997,829	138,397
Stanley	3.26	-1.60	4,086,926	9,398,155	985,023
Ste. Anne	6.04	-1.40	560,085	1,197,285	-49,070
Strathcona	5.95	-1.41	1,198,964	2,569,720	297,188
Stuartburn	6.53	-1.37	1,075,676	2,268,940	247,813
Tache	4.65	-1.50	1,136,099	2,520,193	115,920
Thompson	4.66	-1.50	1,712,482	3,798,299	331,914
Turtle Mountain	3.42	-1.59	3,325,227	7,614,137	587,451
Victoria	5.28	-1.46	1,553,171	3,388,857	375,268
Wallace	3.45	-1.59	3,733,936	8,544,935	879,306
West St. Paul	12.97	-0.91	245,804	426,567	64,606
Westbourne	3.10	-1.61	4,265,618	9,848,795	961,461
Whitehead	4.53	-1.51	2,142,935	4,769,294	549,782
Whitemouth	6.98	-1.33	586,634	1,222,215	44,423
Whitewater	4.27	-1.53	2,212,605	4,957,311	509,504

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	3.83	-1.56	2,917,261	6,611,859	766,353
Winnipeg	7.72	-1.28	394,624	805,034	84,681
Woodlands	3.81	-1.56	3,305,838	7,496,363	757,381
Woodworth	4.15	-1.54	2,599,424	5,842,188	639,747
CAR 3	1.26	-1.74	26,937,375	65,070,909	6,622,400
CAR 4	1.93	-1.70	12,005,279	28,533,291	3,155,087
CAR 5	1.94	-1.69	10,796,253	25,648,890	2,773,638
CAR 6	1.41	-1.73	22,638,269	54,479,224	5,886,069

Average Manure Transportation Distance (miles)	4.97
Average Effective Manure Cost ($)	-1.48
Total Manure Phosphorus Demand (lbs P)	245,557,135
Total Net Manure Benefit ($)	563,895,735
Total Hog Capacity (animals per year)	56,233,148

Table A14: Simulation Results with a 75% Manure Acceptance Rate and a 50% Increase in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	3.99	-2.14	3,335,007	8,174,830	667,705
Alexander	10.14	-1.70	515,905	1,110,968	106,960
Argyle	4.04	-2.14	3,211,649	7,865,352	626,439
Armstrong	5.67	-2.02	1,884,738	4,466,469	365,080
Aurthur	3.66	-2.17	3,901,728	9,626,915	854,156
Bifrost	3.35	-2.19	4,692,736	11,647,869	952,830
Brenda	3.62	-2.17	3,798,368	9,379,696	765,922
Brokenhead	4.25	-2.13	2,947,985	7,189,244	572,634
Cameron	4.18	-2.13	2,976,443	7,269,013	617,597
Cartier	3.94	-2.15	1,785,627	4,381,382	91,124
Coldwell	6.40	-1.97	1,584,231	3,698,375	346,993
Daly	4.44	-2.11	2,546,699	6,187,088	522,222
De Salaberry	4.03	-2.14	2,730,210	6,687,223	215,272
Dufferin	3.25	-2.20	3,943,924	9,809,171	695,656
Edward	4.21	-2.13	3,014,230	7,356,825	643,189
Elton	3.07	-2.21	5,189,149	12,952,010	1,060,960
Eriksdale	7.21	-1.91	1,348,016	3,094,266	275,778
Fisher	3.56	-2.18	4,395,837	10,867,029	772,538
Franklin	3.87	-2.15	3,362,107	8,262,021	692,820
Gimli	8.23	-1.84	806,345	1,811,092	174,839
Glenella	5.75	-2.02	1,818,309	4,302,614	324,417
Glenwood	4.61	-2.10	2,410,797	5,837,807	501,449
Grahamdale	7.14	-1.92	1,076,671	2,475,319	221,106
Grey	3.44	-2.18	3,712,331	9,199,721	741,478
Hanover	4.46	-2.11	1,191,833	2,894,771	-87,056
Headingley	9.46	-1.75	441,531	965,332	71,390
La Broquerie	17.89	-1.15	0	0	-90,341
Lac du Bonnet	6.87	-1.94	1,169,830	2,704,790	231,950
Lakeview	7.34	-1.91	1,058,020	2,422,175	231,737
Lansdowne	4.56	-2.10	2,584,478	6,263,915	532,658
Lorne	3.23	-2.20	3,936,922	9,795,260	614,529
Louise	3.32	-2.19	4,432,425	11,010,095	881,261
Macdonald	2.67	-2.24	5,237,498	13,174,790	753,752
Montcalm	4.12	-2.14	2,380,706	5,821,518	458,141
Morris	2.76	-2.23	4,441,727	11,152,863	564,644

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Morton	3.75	-2.16	3,486,209	8,586,222	689,253
North Cypress	3.54	-2.18	4,157,656	10,282,486	813,243
North Norfolk	3.40	-2.19	3,995,490	9,907,528	768,198
Oakland	4.67	-2.10	2,431,497	5,880,722	497,729
Pemina	3.22	-2.20	4,530,008	11,273,419	767,059
Piney	8.27	-1.84	680,761	1,527,870	83,589
Pipestone	3.66	-2.17	3,768,734	9,298,314	794,832
Portage la Prairie	2.48	-2.25	7,770,643	19,617,124	1,348,908
Reynolds	10.57	-1.67	419,731	895,247	41,893
Rhineland	2.95	-2.22	4,441,180	11,110,156	683,471
Ritchot	5.62	-2.03	1,370,571	3,251,584	225,032
Riverside	4.84	-2.08	1,980,703	4,774,108	290,543
Roblin	4.09	-2.14	3,075,514	7,524,080	566,457
Rockwood	3.59	-2.17	4,098,413	10,125,881	692,310
Roland	4.07	-2.14	2,286,719	5,596,475	472,982
Rosser	4.50	-2.11	2,492,112	6,047,792	520,299
Sifton	5.56	-2.03	1,962,927	4,662,656	420,730
Siglunes	6.00	-2.00	1,943,926	4,576,031	425,777
South Cypress	4.86	-2.08	2,230,785	5,374,074	394,597
South Norfolk	3.98	-2.15	2,240,942	5,494,853	186,859
Springfield	3.79	-2.16	3,448,243	8,486,776	676,452
St. Andrews	4.11	-2.14	2,962,827	7,245,331	592,027
St. Clements	4.72	-2.09	2,186,216	5,282,373	399,487
St. Francois Xavier	7.16	-1.92	894,300	2,055,204	185,244
St. Laurent	10.22	-1.70	631,864	1,358,373	138,397
Stanley	3.26	-2.20	4,904,312	12,196,572	985,023
Ste. Anne	6.04	-2.00	672,102	1,580,789	-49,070
Strathcona	5.95	-2.00	1,438,757	3,390,680	297,188
Stuartburn	6.53	-1.96	1,290,811	3,005,481	247,813
Tache	4.65	-2.10	1,363,319	3,298,108	115,920
Thompson	4.66	-2.10	2,054,979	4,970,877	331,914
Turtle Mountain	3.42	-2.19	3,990,273	9,891,000	587,451
Victoria	5.28	-2.05	1,863,805	4,452,351	375,268
Wallace	3.45	-2.18	4,480,723	11,101,651	879,306
West St. Paul	12.97	-1.50	294,964	594,874	64,606
Westbourne	3.10	-2.21	5,118,742	12,769,567	961,461
Whitehead	4.53	-2.11	2,571,522	6,236,614	549,782
Whitemouth	6.98	-1.93	703,960	1,623,898	44,423

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Whitewater	4.27	-2.12	2,655,125	6,472,335	509,504
Winchester	3.83	-2.16	3,500,713	8,609,378	766,353
Winnipeg	7.72	-1.88	473,548	1,075,243	84,681
Woodlands	3.81	-2.16	3,967,005	9,759,950	757,381
Woodworth	4.15	-2.13	3,119,309	7,622,077	639,747
CAR 3	1.26	-2.34	32,324,850	83,515,581	6,622,400
CAR 4	1.93	-2.29	14,406,335	36,753,596	3,155,087
CAR 5	1.94	-2.29	12,955,503	33,041,346	2,773,638
CAR 6	1.41	-2.33	27,165,923	69,980,195	5,886,069

Average Manure Transportation Distance (miles)	4.97
Average Effective Manure Cost ($)	-2.07
Total Manure Phosphorus Demand (lbs P)	294,668,562
Total Net Manure Benefit ($)	732,034,652
Total Hog Capacity (animals per year)	56,233,148

Table A15: Simulation Results with a 5% Manure Acceptance Rate and a 50% Decrease in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	7.78	0.51	0	0	-925,257
Alexander	19.77	1.37	0	0	-143,131
Argyle	7.87	0.52	0	0	-891,031
Armstrong	11.06	0.75	0	0	-522,898
Aurthur	7.13	0.47	86,704	4,354	56,535
Bifrost	6.54	0.43	104,283	14,237	-1,301,939
Brenda	7.05	0.46	84,408	5,253	-1,053,809
Brokenhead	8.29	0.55	0	0	-817,881
Cameron	8.15	0.54	0	0	-825,777
Cartier	7.68	0.51	0	0	-495,399
Coldwell	12.48	0.85	0	0	-439,526
Daly	8.66	0.58	0	0	-706,549
De Salaberry	7.86	0.52	0	0	-757,461
Dufferin	6.34	0.41	87,643	14,558	-1,094,191
Edward	8.21	0.54	0	0	-836,261
Elton	5.98	0.39	115,314	25,100	157
Eriksdale	14.06	0.96	0	0	-373,991
Fisher	6.94	0.45	97,684	7,631	-1,219,570
Franklin	7.53	0.50	0	0	-932,774
Gimli	16.04	1.11	0	0	-223,710
Glenella	11.20	0.76	0	0	-504,467
Glenwood	8.98	0.60	0	0	-668,845
Grahamdale	13.91	0.95	0	0	-298,709
Grey	6.70	0.44	82,496	9,357	-1,029,938
Hanover	8.00	0.53	0	0	-330,727
Headingley	18.45	1.28	0	0	-122,497
La Broquerie	22.35	1.56	0	0	-90,341
Lac du Bonnet	13.38	0.91	0	0	-324,555
Lakeview	14.30	0.98	0	0	-293,534
Lansdowne	8.89	0.59	0	0	-717,030
Lorne	6.30	0.41	87,487	14,988	-1,092,248
Louise	6.46	0.42	98,498	14,533	-1,229,719
Macdonald	5.20	0.33	116,389	38,605	-1,453,076
Montcalm	8.02	0.53	0	0	-660,496
Morris	5.38	0.34	98,705	30,118	-1,232,300

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Morton	7.31	0.48	77,471	1,881	-967,203
North Cypress	6.90	0.45	92,392	7,774	-1,153,488
North Norfolk	6.64	0.43	88,789	10,863	-1,108,497
Oakland	9.10	0.61	0	0	-674,588
Pemina	6.28	0.41	100,667	17,572	-1,256,792
Piney	16.11	1.11	0	0	-188,870
Pipestone	7.14	0.47	83,749	4,146	24,399
Portage la Prairie	4.83	0.30	172,681	66,405	-2,155,864
Reynolds	20.60	1.43	0	0	-116,449
Rhineland	5.75	0.37	98,693	24,740	-1,232,148
Ritchot	10.96	0.74	0	0	-380,247
Riverside	9.43	0.63	0	0	-549,520
Roblin	7.98	0.53	0	0	-853,262
Rockwood	7.00	0.46	91,076	6,350	-1,137,052
Roland	7.94	0.53	0	0	-634,421
Rosser	8.77	0.58	0	0	-691,404
Sifton	10.84	0.73	0	0	-544,591
Siglunes	11.70	0.79	0	0	-539,319
South Cypress	9.48	0.64	0	0	-618,902
South Norfolk	7.75	0.51	0	0	-621,720
Springfield	7.38	0.49	76,627	1,088	-956,671
St. Andrews	8.02	0.53	0	0	-821,998
St. Clements	9.19	0.62	0	0	-606,537
St. Francois Xavier	13.95	0.96	0	0	-248,112
St. Laurent	19.92	1.38	0	0	-175,303
Stanley	6.35	0.41	108,985	17,940	-1,360,638
Ste. Anne	11.75	0.80	0	0	-186,466
Strathcona	11.59	0.79	0	0	-399,167
Stuartburn	12.73	0.87	0	0	-358,120
Tache	9.07	0.61	0	0	-378,235
Thompson	9.08	0.61	0	0	-570,127
Turtle Mountain	6.67	0.43	88,673	10,381	-1,107,049
Victoria	10.29	0.69	0	0	-517,089
Wallace	6.72	0.44	99,570	10,998	-1,243,120
West St. Paul	25.28	1.77	0	0	-81,834
Westbourne	6.03	0.39	113,750	23,888	-1,420,128
Whitehead	8.83	0.59	0	0	-713,436
Whitemouth	13.59	0.93	0	0	-195,305

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Whitewater	8.33	0.55	0	0	-736,630
Winchester	7.46	0.49	77,793	255	50,711
Winnipeg	15.05	1.03	0	0	-131,380
Woodlands	7.42	0.49	88,156	784	-1,100,594
Woodworth	8.09	0.54	0	0	-865,413
CAR 3	2.45	0.13	718,330	524,573	14,319
CAR 4	3.76	0.23	320,141	173,086	210,039
CAR 5	3.79	0.23	287,900	154,242	125,179
CAR 6	2.76	0.15	603,686	414,003	332,612

Average Manure Transportation Distance (miles)	9.52
Average Effective Manure Cost ($)	0.64
Total Manure Phosphorus Demand (lbs P)	4,448,739
Total Net Manure Benefit ($)	1,649,701
Total Hog Capacity (animals per year)	-52,393,375

Table A16: Simulation Results with a 100% Manure Acceptance Rate and a 50% Increase in the Price of Fertilizer

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Albert	0.02	-2.43	4,446,678	11,755,971	911,193
Alexander	0.04	-2.43	687,874	1,817,782	144,626
Argyle	0.02	-2.43	4,282,199	11,321,092	860,921
Armstrong	0.02	-2.43	2,512,985	6,642,949	502,684
Aurthur	0.01	-2.43	5,202,305	13,753,997	1,139,020
Bifrost	0.01	-2.43	6,256,982	16,542,740	1,295,446
Brenda	0.01	-2.43	5,064,491	13,389,682	1,043,240
Brokenhead	0.02	-2.43	3,930,647	10,391,516	787,866
Cameron	0.02	-2.43	3,968,592	10,491,885	834,907
Cartier	0.10	-2.42	2,380,836	6,284,221	221,492
Coldwell	0.02	-2.43	2,112,310	5,583,493	462,658
Daly	0.02	-2.43	3,395,600	8,976,881	708,156
De Salaberry	0.03	-2.43	3,640,279	9,621,469	414,604
Dufferin	0.03	-2.43	5,258,565	13,898,749	983,601
Edward	0.02	-2.43	4,018,975	10,625,060	863,258
Elton	0.01	-2.43	6,918,865	18,292,514	1,439,819
Eriksdale	0.03	-2.43	1,797,356	4,750,701	374,197
Fisher	0.01	-2.43	5,861,118	15,495,893	1,093,477
Franklin	0.02	-2.43	4,482,809	11,851,602	938,287
Gimli	0.03	-2.43	1,075,127	2,841,526	233,710
Glenella	0.02	-2.43	2,424,413	6,408,778	457,172
Glenwood	0.02	-2.43	3,214,396	8,497,737	677,461
Grahamdale	0.03	-2.43	1,435,562	3,794,442	299,714
Grey	0.03	-2.43	4,949,774	13,083,154	1,012,514
Hanover	2.02	-2.29	1,589,157	4,047,192	-30
Headingley	0.09	-2.42	588,708	1,554,271	103,626
La Broquerie	16.00	-1.29	19,236	35,967	-86,127
Lac du Bonnet	0.03	-2.43	1,559,774	4,122,835	317,359
Lakeview	0.03	-2.43	1,410,694	3,728,657	308,983
Lansdowne	0.02	-2.43	3,445,971	9,109,968	721,350
Lorne	0.03	-2.43	5,249,229	13,873,822	901,963
Louise	0.01	-2.43	5,909,900	15,625,137	1,204,872
Macdonald	0.03	-2.43	6,983,331	18,458,886	1,136,140
Montcalm	0.03	-2.43	3,174,274	8,389,867	631,956
Morris	0.03	-2.43	5,922,302	15,651,748	888,934
Morton	0.01	-2.43	4,648,279	12,289,167	943,780

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
North Cypress	0.03	-2.43	5,543,541	14,652,536	1,116,793
North Norfolk	0.03	-2.43	5,327,320	14,080,645	1,059,908
Oakland	0.02	-2.43	3,241,996	8,570,665	675,252
Pemina	0.01	-2.43	6,040,011	15,968,867	1,097,793
Piney	0.05	-2.43	907,682	2,398,298	133,292
Pipestone	0.01	-2.43	5,024,980	13,285,179	1,069,986
Portage la Prairie	0.01	-2.43	10,360,857	27,394,619	1,916,241
Reynolds	0.04	-2.43	559,641	1,478,868	72,537
Rhineland	0.03	-2.43	5,921,574	15,652,497	1,007,721
Ritchot	0.04	-2.43	1,827,427	4,829,560	325,097
Riverside	0.03	-2.43	2,640,937	6,980,525	435,153
Roblin	0.02	-2.43	4,100,685	10,841,173	791,000
Rockwood	0.01	-2.43	5,464,551	14,447,402	991,534
Roland	0.03	-2.43	3,048,959	8,057,863	639,935
Rosser	0.02	-2.43	3,322,816	8,784,430	702,247
Sifton	0.02	-2.43	2,617,238	6,918,591	564,043
Siglunes	0.02	-2.43	2,591,902	6,851,403	567,702
South Cypress	0.02	-2.43	2,974,379	7,862,788	557,466
South Norfolk	0.07	-2.42	2,987,923	7,891,469	350,470
Springfield	0.02	-2.43	4,597,658	12,155,085	928,208
St. Andrews	0.02	-2.43	3,950,436	10,443,934	808,342
St. Clements	0.02	-2.43	2,914,954	7,706,058	559,102
St. Francois Xavier	0.04	-2.43	1,192,400	3,151,167	250,537
St. Laurent	0.04	-2.43	842,486	2,226,349	184,529
Stanley	0.01	-2.43	6,539,082	17,288,702	1,343,086
Ste. Anne	0.50	-2.39	896,136	2,348,086	0
Strathcona	0.03	-2.43	1,918,344	5,070,139	402,232
Stuartburn	0.03	-2.43	1,721,082	4,549,316	342,055
Tache	0.13	-2.42	1,817,759	4,795,812	215,456
Thompson	0.03	-2.43	2,739,972	7,242,376	481,947
Turtle Mountain	0.02	-2.43	5,320,363	14,065,629	878,780
Victoria	0.02	-2.43	2,485,073	6,569,348	511,344
Wallace	0.01	-2.43	5,974,299	15,795,255	1,206,442
West St. Paul	0.05	-2.43	393,286	1,039,046	86,141
Westbourne	0.02	-2.43	6,824,989	18,043,282	1,335,179
Whitehead	0.02	-2.43	3,428,697	9,064,323	737,528
Whitemouth	0.19	-2.42	938,614	2,473,319	95,819
Whitewater	0.02	-2.43	3,540,167	9,359,172	703,354

R.M.	Average Manure Transportation Distance (miles)	Relative Manure Cost ($)	Manure Phosphorus Demand (lbs P)	Net Manure Benefit ($)	Change in Hog Capacity (animals per year)
Winchester	0.01	-2.43	4,667,618	12,340,231	1,021,939
Winnipeg	0.24	-2.41	631,398	1,662,306	119,255
Woodlands	0.01	-2.43	5,289,340	13,983,958	1,047,011
Woodworth	0.02	-2.43	4,159,080	10,995,505	867,487
CAR 3	0.00	-2.43	43,099,800	113,967,890	8,982,429
CAR 4	0.01	-2.43	19,208,447	50,790,073	4,206,890
CAR 5	0.01	-2.43	17,274,004	45,675,055	3,719,516
CAR 6	0.01	-2.43	36,221,231	95,777,968	7,869,446
Average Manure Transportation Distance (miles)			0.26		
Average Effective Manure Cost ($)			-2.41		
Total Manure Phosphorus Demand (lbs P)			392,910,726		
Total Net Manure Benefit ($)			1,038,528,117		
Total Hog Capacity (animals per year)			77,751,054		