Nutrient Management:
Practices & Policies

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Science to Social Issues

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1 Introduction

Reducing nutrient losses and improving the efficiency of nutrient use in agriculture have been major goals of the agricultural industry, governments and some environmental groups for the last two decades. To encourage the adoption of agricultural beneficial management practices (BMPs) that target nutrient management, technical assistance has been coupled with policy and legislation in different North American jurisdictions.

Nutrient/manure management is a crucial component of livestock production. It is regarded as one of the key activities that producers should implement to ensure that their operations are environmentally sustainable (Safley, 2003).

Nutrient management planning is a process to help producers improve nutrient management. The benefits from implementing a nutrient management plan include:

- improving production efficiency,
- protecting soil, water and air resources, and
- minimizing social issues such as odour, dust and flies.

This chapter will address the following:

1. Aspects of the amended Agricultural Operation Practices Act (AOPA) relating to manure management in Alberta;
2. Step-by-step nutrient management plan (NMP) design, and definition of its components;
3. Relationship between water quality and agriculture in Alberta and the rest of North America;
4. Economics of nutrient management practices; and
5. Examples of programs to support nutrient management.

2 Agricultural Operation Practices Act

The Alberta Government passed the amended Agricultural Operation Practices Act (AOPA) in January 2002. The act deals with confined feeding operations (CFOs) in particular and manure management in general. Operations have until the end of 2004 to comply with the new manure management standards.

2.1 Key Points in AOPA Related to Manure/Nutrient Management

- All agricultural operators must manage manure in accordance with the nutrient management requirements in the AOPA standards.
- Manure can only be applied to arable land. Surface-applied manure must be incorporated within 48 hours, except for forage, direct-seeded crops, and frozen and snow-covered soils.
- When applying manure, operators must follow setback distances from water bodies as specified in the regulations.
- Livestock operators must have access to a sufficient land base to manage manure/nutrients in an agronomically and environmentally sustainable manner, as defined in the act’s standards.
- The regulations for manure application rates are based on nitrogen levels and set limits as to the levels of nitrate-nitrogen allowed in manured soils.
- Any operator who applies or transfers over 300 tonnes of manure per year, and any person who receives over 300 tonnes of manure must keep records related to manure management practices, as specified in the regulations.
- The standards for applying composted manure are the same as those for raw manure.
- Manure collection and storage systems must meet design, construction and setback standards to protect water quality.

3 Nutrient Management Practices at the Farm Level

3.1 Nutrient Management Planning

The nutrient management planning process is a method for a farm operator to improve the efficiency of the operation as related to nutrient use while minimizing the operation's environmental impacts. It is an action plan that identifies activities and/or priorities that will be followed to meet the operation's clearly defined goals, and that, when applied, will lead to meeting targeted economic, environmental, and public health objectives.

Nutrient management will only be successful if it is approached in a holistic way, using a Comprehensive Nutrient Management Plan (CNMP) approach. This approach was first developed by the USDA's Natural Resources Conservation Service. The CNMP is not required by AOPA; however, it is believed to be the most appropriate way to deal with manure/nutrient management.

Solutions to nutrient-related issues require an understanding of the cyclical flow of nutrients into, within and out of the farm operation. The cycle, shown in Figure 1, presents the factors that affect and are affected by nutrients on the farm. All these factors need to be taken into consideration for successful nutrient management.

A comprehensive nutrient management plan (Figure 2) should address site management, feed management, manure handling and storage, land application of manure, land and crop management, record keeping, and social issues.

The objective of the CNMP is to use nutrients efficiently to optimize net profits and minimize negative environmental impacts. This will be achieved by minimizing nutrient losses in all phases of the cycle, supporting a viable livestock operation, meeting crop nutrient requirements by balancing the soil nutrients with those to be applied in manure and fertilizers, and having a variety of solutions to deal with issues through a holistic approach.

Comprehensive Nutrient Management Cycle

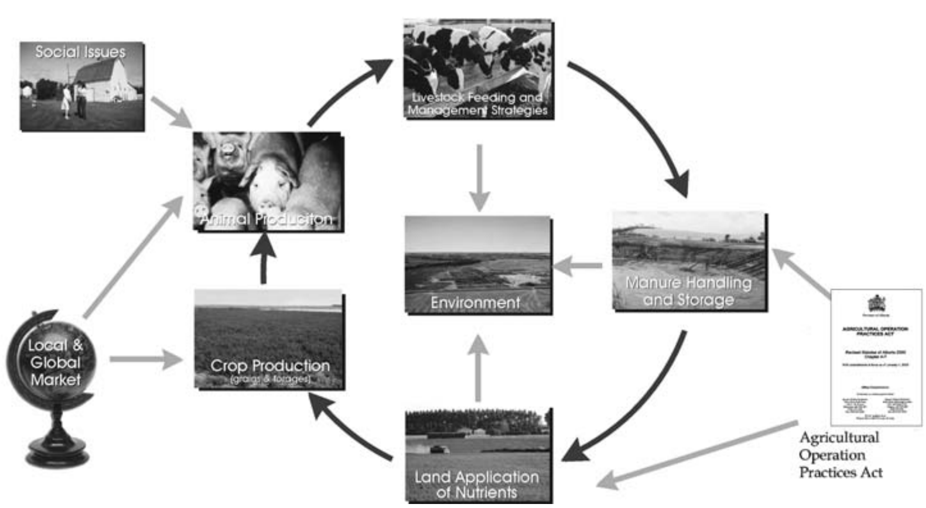

Figure 1. On-farm nutrient cycling as affected by production and management components

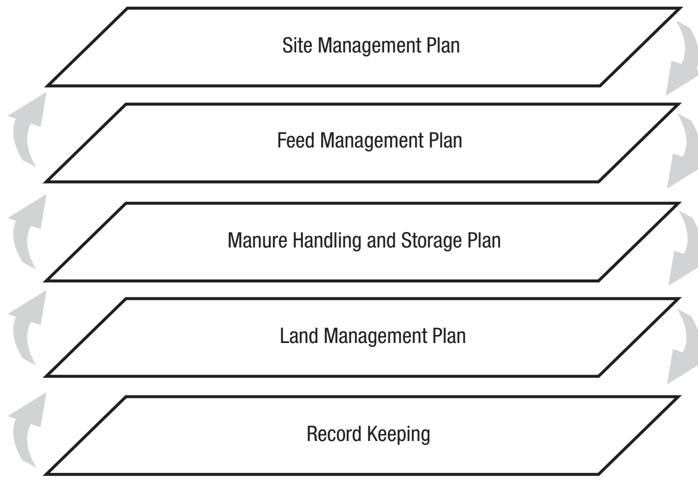

Figure 2. Comprehensive Nutrient Management Plan

3.2 Site Management

When developing a nutrient management plan, a livestock producer first needs to consider the land base available for manure application. This is important for existing livestock operations as well as new or expanding operations. Not all land is suitable for proper and safe manure application. So, an evaluation of available land is a crucial step to managing manure nutrients and minimizing environmental effects.

In this process, physical, chemical, and environmental information on soils, land use, and climate are integrated with water resources information to determine if the land is suitable for manure application or whether special management practices will be necessary.

The factors to consider in assessing land for manure suitability include:

- cost of land application;
- topography;
- soil type and texture;
- proximity to surface water bodies, sink holes and flood plains;
- depth to ground water;
- distance to neighboring residences; and
- direction of prevailing winds in relation to neighbors.

3.2.1 Cost of Land Application

The net cost of land application of manure is the difference between hauling and spreading costs and the fertilizer value for a field receiving manure. The net cost can be used to determine the economic suitability of a given area to receive manure.

3.2.2 Topography

Slope steepness significantly affects runoff. Runoff is likely to be greater from steeper areas than from flat or gently sloping areas. Therefore, slope influences both infiltration and transportation of manure/nutrients by runoff. As the slope increases, the chance that manure will run off also increases, and therefore, manure application rates should be reduced and distances from watercourses increased.

Overall, the steeper the slope, the less suitable is the land for manure application. At a slope of 12% or more, application of manure is prohibited (AOPA regulations).

3.2.3 Soil Type and Texture

Applying manure on soil with reduced permeability lowers the risk of ground water contamination. Applying manure on highly permeable soils, such as sandy or gravelly soils, greatly increases the risk of nutrients seeping into the ground water.

Soil texture determines soil permeability and, to a certain extent, sorption capacity of the soil. Both permeability and sorption determine the potential amount of nutrients that can move via runoff and/or leaching to water sources. Manure applied on excessively well-drained, coarse-textured soils (sand, sandy loam to gravel) has a relatively higher risk to move to ground water.

AOPA standards set the limits for nitrate levels in soils (Standards and Administration Regulation, Schedule 3, Table 3). Based on these limits, more manure can be applied on Luvisolic (Grey Wooded) soils, followed by Black, then Dark Brown and Brown soils. A livestock operation will need more acreage for spreading manure if the available land is in the Brown or Dark Brown soil zone than in the Black soil zone because Black soils have a low risk for nitrate leaching.

3.2.4 Proximity to Surface and Ground Water

Application of manure is restricted near water bodies under AOPA. It is required to leave buffers between water bodies and areas where manure is applied. Numerous management practices can be implemented to protect water bodies from manured runoff, such as buffer strips or setbacks, filter strips, contour strip cropping, and sediment control basins.

3.2.5 Neighbor Considerations

Social issues are as important in rating a site for suitability of manure application as technical issues. Fields close to residential neighborhoods are not suitable for manure application because of odour concerns and its perception by the public. Other alternatives should be considered for applying nutrients to these fields, such as applying compost, which emits less odour than raw manure.

3.3 Feed Management Plan

Livestock operators need to consider the close relationship between manure production and feeding practices as part of their nutrient management plan. Adjusting feeding strategies and/or feed composition can reduce the amount of nitrogen and phosphorus excreted in the manure by up to 30%. Operators will need to consult a nutritionist to discuss their options to reduce nitrogen and phosphorus excretion while also maintaining the animal's health and performance.

3.4 Manure Storage and Handling Plan

Manure collection, storage and treatment systems must be properly designed, constructed, and operated to prevent contamination of surface and ground water by nutrients and disease-causing organisms. Containing manure in every step of manure handling not only minimizes environmental impacts, but also maintains the manure's nutrient levels, which in turn reduces the required application rates and therefore reduces hauling costs for manure.

The physical characteristics of manure are determined by the livestock type and by the methods of collection, storage, treatment and utilization. Figure 3 compares the percent of solids found in manure as excreted and in liquid, slurry, semi-solid and solid forms, for different livestock types.

The main processes of potential contamination from a manure storage facility are (Figure 4):

- *seepage,* which can cause ground water contamination if the subsoil underlying the storage has a coarse texture or is geologically fractured;
- *leakage,* which is mainly due to defects (e.g. cracks) in the walls or floor of a storage facility;
- *overflow,* which is due to such factors as insufficient capacity to store all the manure produced by the operation plus precipitation added during storm events, not emptying the facility frequently enough, or plugged intake or outtake flow systems; and
- *volatilization,* which is the loss of nutrients through evaporation.

Pens and manure storage are major sources of ammonia (NH_3) emissions. Ammonia emission is the main mechanism of nitrogen (N) losses from liquid manure storage. About half of the N in manure is in the form of NH_3-N in solution. Because of the

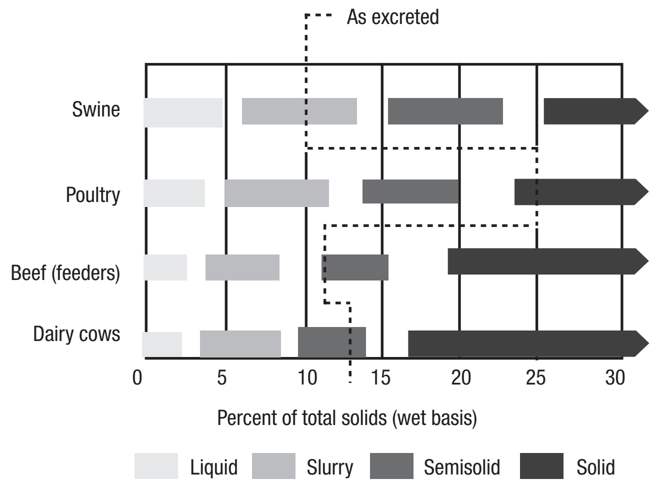

Figure 3. Relative handling characteristics of different types of manure. Source: Pfost et al. 2000

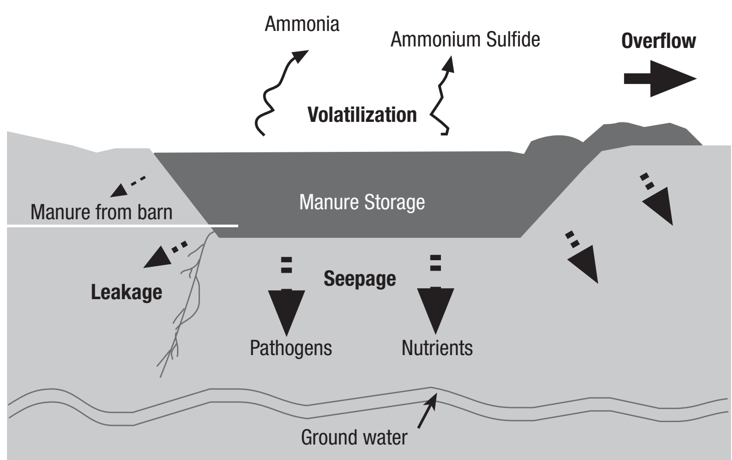

Figure 4. Paths of potential losses in a storage facility

high vapor pressure of NH_3, it will readily volatilize upon exposure of the manure to the air. The greater the exposure to air, the more NH_3 volatilization occurs.

In general, facility management and environmental conditions that promote rapid evaporation result in high ammonia losses. Overall, frequent removal of manure tends to conserve manure N. If stored immediately, there is less surface area exposed from which ammonia release can occur.

Similarly, if the manure is incorporated quickly into the soil after excretion, N losses will be reduced. Bedding and litter conditions as well as other factors (Table 1) will also affect volatilization rates. Bedded confinement of beef, dairy, and swine tends to result in lower volatilization because the litter absorbs urine and reduces ammonia release (Penn State University, 1993).

Options for reducing ammonia emission from liquid manure include:

- Cover manure storages,
- Use deep storages to reduce the surface area,
- Aerate manure to promote nitrification and reduce the ammonia concentration,
- Use chemical additives to precipitate ammonia,
- Acidify manure by liming to pH levels below 8.

3.5 Land Application Plan

Land application is the most common way of using manure in Alberta. Raw or composted manure application to land can be a sustainable practice, provided proper nutrient management practices are followed.

Proper land application involves the following eight steps:

Step 1. Determine amounts of manure produced on the farm and have manure tested to determine nutrient (N, P, K) levels.

Step 2. Soil test your fields.

Step 3. Calculate residual available N from previous manure applications.

Step 4. Determine nutrient recommendations. *Based on soil test results, planned crop and expected yield.*

Step 5. Determine the manure and commercial fertilizer application rates per field based on agronomic requirements.

Step 6. Prioritize fields for manure application suitability. *Based on slope, setbacks, hauling distance, soil tests, etc.*

Step 7. Calibrate your manure and fertilizer application equipment.

Step 8. Decide when is the best time to apply manure, taking into consideration methods to reduce odour nuisance for neighbors.

Table 1. Factors affecting N volatilization losses from top- and bottom-loaded storage tanks

Factor	Top-Loaded Storage
Manure temperature	When fresh manure is loaded on top, high surface temperatures cause increased N losses.
pH of loaded manure	The higher the pH of the loaded manure, the greater the N losses.
Manure loading	Less N is lost when manure is added all at once than when several smaller additions are made.
	Bottom-Loaded Storage
Manure temperature	When fresh manure is added to the bottom, losses are minimal because the heat must diffuse to the top before volatilization is increased.
pH of loaded manure	Will not alter volatilization if pH of surface manure does not change.
Manure loading	Little impact on N losses.

Source: Penn State University. 1993, Technical Note #8

3.6 Land and Crop Management Plan

The operator needs to ask several questions about land and crop management to optimize the benefits from manure and minimize environmental impacts. These include:

- What kind of crops should be grown?
- What is (are) the best crop rotation(s)?
- Can manure be incorporated or injected rather than being surface-applied without incorporation?
- What is (are) the conservation technique(s) needed to contain losses (e.g. buffer strips, setbacks, erosion control, reduced tillage)?

3.7 Record Keeping

Good record keeping is crucial to due diligence. Just as important, good record keeping allows the operator to review the practices used and the results achieved, a vital factor in improving the operation.

Manure calculators and farm management programs can be helpful tools to record information on livestock production, crop production, economics and management. Some programs have a built-in report that can be used for record keeping.

3.8 Social Issues

In the last two decades, the livestock industry has been under increasing scrutiny regarding environmental stewardship and animal welfare. To continue to grow in a sustainable manner, the industry needs to consider how the public views their operations.

The following are some suggestions for operators to deal with these issues:

- Implement BMPs that are economically feasible and environmentally friendly.
- Follow regulations and guidelines.
- Use consultation and participation approaches when expanding, building a new operation, and/or responding to a concern.

3.9 Continual Improvement

A CNMP should be reviewed regularly by the operator or a consultant to assess results and determine what modifications are needed to improve the plan and its implementation (Figure 5). This approach can help to demonstrate:

- a commitment to sustain the environment,
- better management of environmental risks,
- a willingness to make improvements,

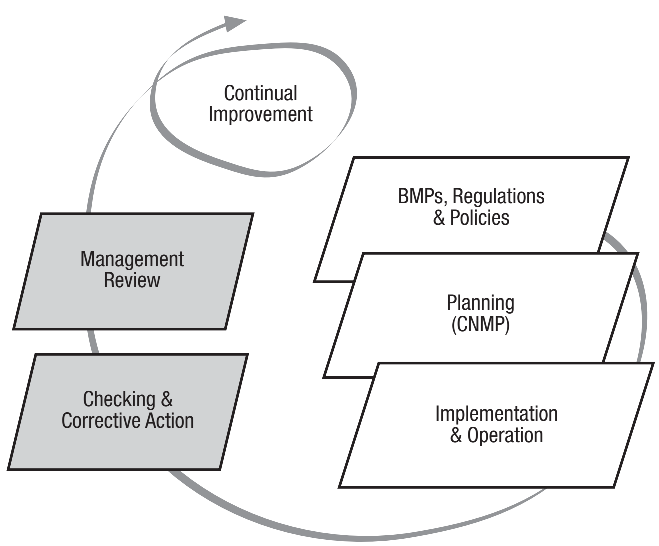

Figure 5. Nutrient Management System Source: adapted from ISO 14001 Standards

- an innovative and forward-thinking approach, and
- legal and regulatory compliance.

4 Nutrient Management at the Watershed Level

A watershed is the area of land that catches precipitation and drains or seeps the water to stream, lake or other water body. It is an entire ecosystem where components such as land, climate, vegetation, and management practices interact to define the watershed's characteristics.

Natural processes coupled with human activities directly affect the soil, water, air and biodiversity in the watershed. Watershed management is needed to sustain this living entity. Across Alberta, more and more watershed groups are developing, led by the local community with technical assistance from government and non-government organizations. These groups focus on improving the health of their watershed, using those practices best suited to the needs and concerns in their watershed.

Watershed management plans should include the following steps:

- Assessing the nature and status of the watershed ecosystem;
- Developing well defined short-term and long-term goals for the system;
- Developing well defined objectives and actions to achieve selected goals;
- Assessing the benefits and costs of each action;
- Implementing the desired actions;
- Evaluating the effects of the actions and the progress toward the goals; and
- Using the results of the evaluation to continually improve the plan and its implementation.

In assessing which BMPs to implement in the watershed, the watershed group needs to consider a balance between two factors:

- Can the BMP contribute to achieving one or more of the plan's goals? and
- Is the BMP economically feasible?

One of the main goals for many watershed groups is to improve water quality. Actions to achieve this goal include implementing BMPs to manage livestock operations and manure spreading to minimize contamination of surface and ground water.

4.1 Agricultural Practices and Water Quality

Studies across North America have shown that human activities including agriculture can contribute nutrients and other contaminants, such as pathogens and pesticides, to surface and ground water.

The U.S. Environmental Protection Agency noted that about 50 to 70% of the assessed surface waters were adversely affected by agricultural non-point source pollution caused by soil erosion from cropland and overgrazing, and from pesticide and fertilizer application (CAST 1993). More specifically, livestock and nutrient management have been identified as the major non-point source problems of the immediate and short-term future. This information was reported and analyzed by the Council for Agricultural Science and Technology (CAST 1993). In that report, the suggestion is to address the total resource by promoting practices that minimize pollution of all parts of the hydrologic cycle and avoid encouraging those practices that simply shift pollution from one area to another.

A link between agriculture and water quality was shown in a study by Scribner et al. (1996), who surveyed 76 reservoirs in the Midwest U.S. They found that most of surveyed reservoirs showed some level of herbicide contamination, and the majority of the reservoirs had between 5 and 8 of the potential 14 herbicides detected. Jaynes and Hatfield (1994) showed that nitrate-nitrogen concentrations in the early spring ranged between 10 and 15 mg L^{-1} and were below that level for the remainder of the year. Hallberg (1989) identified farming practices and hydrogeologic conditions as the main factors in the movement of agricultural chemicals into ground water in the U.S.

Agriculture was identified as the major source of nutrients in the Delaware Inland Bays Watershed (Horsley-Whitten, 1998), but not the only source. Horsley-Whitten (1998) analyzed nitrogen loadings from the entire spectrum of land uses in the watershed. Their report noted that unsewered residential developments probably contribute more N *per acre* to the watershed than cropland. However, the watershed contains about 20 times as much cropland as unsewered residential acreage.

In Ontario, recent research in the municipality of Waterloo indicates that 70% of the total phosphorus load to the river is from rural non-point sources (i.e., mainly runoff from agricultural land), and about 17% is from municipal wastewater treatment plants. More detailed work on a major tributary in this watershed indicates that 40 to 99% of the total phosphorus load is from rural non-point sources, depending on flow conditions and time of year (Agriculture and Agri-Food Canada, 2002).

4.2 Agricultural Effects on Water Quality in Alberta

A number of studies have been carried out in Alberta to look at the impacts of agriculture in water quality. For example, the CAESA (1998) study found that nutrient concentrations (especially the flow-weighted mean concentrations) in streams in agricultural watersheds were higher than the concentrations in streams in non-agricultural watersheds. The Oldman River Basin Water Quality Initiative (2000) study reported that the urban contribution was significant in that watershed. In fact, the City of Lethbridge wastewater treatment plant contributed the highest loads of fecal coliform bacteria and total phosphorus to the Oldman River. The Little Bow River, a river in an agricultural watershed, contributed the highest total nitrogen loads to the Oldman River. The study concluded that the major upgrade to the wastewater treatment plant clearly had a significant positive impact on water quality downstream of the city. On the scale of 1-10 (with 1 being best), the quality of the Oldman River improved from 7 in 1998 (before the upgrade to the treatment plant) to 3 in 1999 (after the upgrade).

Cooke et al. (2002) found levels of nutrients and water-borne pathogens in some surface waters and in shallow ground water in agricultural areas were higher than in non-agricultural watersheds. Concentrations of *Cryptosporidium* spp. and G*iardia* spp. were significantly higher in streams draining watersheds with more intensive agricultural production compared with non-agricultural watersheds. They also found that *Giardia* spp. concentrations were high in municipal sewage effluent.

Cooke et al. (2002) found that contaminant levels varied considerably in different parts of the province, but the risk of water quality degradation was most significant where intensive agriculture is practiced. However, the potential for water quality degradation also exists where only livestock densities are high, or where individual chemical inputs are high.

4.3 Practices at the Watershed Level

4.3.1 Challenge of Watershed Scale Management

Environmental quality in a watershed is influenced by many complex, interrelated factors such as the watershed's climate, topography, geology and human activities. Thus, determining the best management methods to improve environmental quality is also complex.

Watershed scale studies have been directed toward monitoring the effects of different farming and landscape management practices on the environment. For example, studies on farming practices have included changing the timing of nitrogen application, using site-specific nutrient applications, modifying crop rotations, and measuring the nitrogen status in the crop. Studies of landscape management practices include evaluation of riparian zones, wetlands, and filter strips. There are no easy answers as to which specific set of practices will be best for improving environmental quality in a particular watershed.

In the Mississippi River basin, for instance, the emerging issues of water quality and the implications for the Gulf of Mexico raise numerous questions about the linkages between farming practices and water quality. The largest challenge to agriculture is to develop studies that further document the observations that most of the nitrogen fertilizer and manure applied to the soil remains on the land, and the vast majority (over 95%) of the pesticides do not move from the field. However, these small losses are sufficient to cause potential environmental problems. Also, agricultural practices may not be the only source of nitrate moving in the streams and rivers.

One example of an approach to selecting BMPs for a large, complex watershed is the Oldman River Basin Water Quality Initiative (Oldman River Basin Water Quality Initiative 2003). The Initiative was formed in 1997 in response to serious concerns expressed in the community about protecting water quality in the basin. This Initiative adopted a comprehensive approach that included both urban and rural issues. Through detailed monitoring, the Initiative found that both urban and rural activities influenced water quality in the basin. It set up Urban and Rural Beneficial Management Practices Team to develop and test BMPs at demonstration sites in the basin.

To address agricultural impacts on environmental quality in a watershed requires continued development of tools to help producers to increase the efficiency of their nutrient and water management while improving their economic returns.

4.3.2 Nutrient Management

Runoff, leaching, and erosion are the main paths of nutrient losses to surface and ground water. Nutrient losses and soil erosion cause significant economic losses in crop production as well. Therefore, controlling sediment movement should be an integral part of any nutrient management program.

While point source pollution pathways are well defined, non-point source pollution comes from large areas and is the result of a wide range of activities that add together. Therefore, it is relatively difficult to address non-point source pollutants. In the last decade, increasing efforts have been made to find ways to minimize non-point source pollution. However, the complexity and variety of watershed systems due to differences in topography, climate, geology, soils, vegetation and most importantly land use practices, necessitates a site-specific approach to each watershed.

Proper management of nutrients within a watershed system starts by identifying the following factors:

1. Source Factors: What are the main sources of nutrients in this watershed?
2. Management Factors: What are the management practices that affect nutrients in this watershed?
3. Transport Factors: What are the transport processes that dominate the movement of nutrients in this watershed?
4. Receiving Factors: What are the types, locations, and target uses of all water bodies located in the watershed and how they are connected?

4.3.3 Water Quality Management

Reduction of nutrient concentrations in surface and ground water clearly requires management strategies that focus on optimizing nutrient use and minimizing transport of nutrients to water bodies. To be effective, these strategies need to be developed with careful consideration of the patterns and complexities of contaminant occurrence, behavior, and influences on water quality.

In Alberta, various programs and activities are under way to help producers and watershed groups to select appropriate practices to improve water quality. For example, the agricultural industry and Alberta Agriculture, Food and Rural Development have been working together over the past few years to develop BMPs, including practices related to nutrient management and water quality, for the various livestock sectors (feedlot, swine, dairy, cow-calf) as well as for the crop industry. They are publishing a series of BMP manuals for producers.

Another significant program is Alberta's Environmental Farm Plan. This industry-led program provides a voluntary, risk assessment process for producers. It offers a way for individual farmers and ranchers to evaluate their operation's environmental risks, including risks related to nutrient management and water quality, and to determine the appropriate steps to take if any changes are needed in their operation.

The Oldman River Basin Water Quality Initiative is investigating water quality in this basin and implementing steps to help producers make the changes necessary to improve water quality in the basin.

Mueller and Helsel (1996) identified four basic considerations that are critical in managing and protecting water resources:

- Local and regional management strategies are needed to account for geographic patterns in land use, chemical use, and natural factors, which govern hydrologic behavior and vulnerability to contamination.
- Environmental policies that simultaneously address the entire hydrologic system are needed to protect water quality because nutrients are readily transported among surface water, ground water, and the atmosphere.

- Reduced uncertainty in estimates of the risks of contaminants to humans and aquatic life is needed. This will require improved information on the nature and effects of exposure, and development of standards, guidelines, and monitoring programs that address the many complexities in contaminant occurrence.
- Development of reliable predictive models is an essential element of cost-effective strategies to anticipate and manage nutrient concentrations over a wide range of possible circumstances, over broad regions, and for the long term.

An understanding of these considerations will help water managers and policy makers in the implementation of environmental protection strategies, in making decisions on investments in monitoring and science, and in the development of future environmental policies, standards, and guidelines.

4.4 Alternative Uses of Manure

A fundamental principle underlying both BMPs and regulatory requirements for manure application is the efficient crop use of applied nutrients. However, there are two conditions for achieving this efficiency: first, the operator has to have sufficient land; and second, the cost of hauling and applying manure must be less than the cost of purchasing and applying commercial fertilizers. Hauling costs sometimes reduce the spreadable acreage depending on the value of manure, which in turn depends on the nutrient status of the field to which it is applied, the nutrient needs of the crop to be grown, the nutrient content of the manure, and the cost of purchased nutrients (commercial fertilizers). At regional scales, some limitations of spreading manure may occur. Some municipalities produce more nutrients than the available cropped land may be able to receive.

Therefore, research to develop safe, practical, environmentally sound and economically feasible alternative uses for manure needs to increase. The alternatives may include manure spreading in public lands, recreational areas or reclamation lands, selling raw and composted manure as fertilizer, and using raw manure to produce energy or other by-products.

Interest in alternative uses of manure is increasing all over the world. For example, a project funded by the U.S. Department of Energy, Washington State University and Pacific Northwest National Laboratory in Richland, Washington, is exploring ways of extracting valuable chemicals from manure. The manure could also provide undigested and purified proteins for making fresh feed for cattle as well as other species.

Generating methane gas from manure is an option with considerable merit. It appears to offer a partial solution to two pressing problems: the need to minimize the environmental impacts of manure nutrients, pathogens and odour; and the rising costs of energy. At present, large-scale methane generation requires rather high investments in money and management, which considerably reduce the practicality of the idea for most farmers. However, this technology may be cost efficient for large operations or for groups of producers with smaller operations.

Cost-effective alternative uses for manure will enhance industry competitiveness especially if (i) an operation is generating more manure than can be spread at agronomic rates and the farmer doesn't have the capacity to store it for future land spreading, (ii) a number of operations within a particular watershed or sub-watershed are competing for land within that area and they have too much manure to be spread at appropriate agronomic rates, and (iii) regulations further restrict the amount of manure that can be spread on land (for example, if application rates were to be based on the crop's requirements for phosphorus rather than nitrogen).

5 Nutrient Management Policies and Programs

5.1 Regulation, Education and Economic Incentives

Numerous strategies – including governmental policy and regulations, economic incentives, industry guidelines, awareness and technology transfer – have been developed and implemented to deal with nutrient management at a watershed scale. The appropriate choices among the range of options are the subject of much debate.

Carefully targeting pollution control efforts to critical watersheds and land uses can have a large impact on the cost-effectiveness of agro-environmental policies (Babcock et al., 1997; Bouzaher et al., 1990). Scientific understanding of the relationships between farm practices, landscape, weather, and nutrient movement can provide a basis for targeting critical watersheds and land uses (Shortle, 1998).

Any policy has to be designed to effectively induce changes in behavior. The least intrusive, and in most cases the least effective, method is persuasion and education combined with technical assistance to facilitate changes in behavior (Shortle, 1998). Regulations can be used to dictate implementation of practices to control nutrient losses. Economic incentives can be used to encourage adoption of specific practices.

Economic incentives for nutrient management could take a variety of forms. Options include taxes on excessive nutrient applications or nutrient losses, subsidies for the use of pollution prevention and/or control practices, liability for damages, environmental bonds, tax/subsidy schemes applied to ambient concentrations, and tradable permits in fertilizers, nutrient applications, or manure production (Shortle, 1998).

The costs of compliance with NMPs can vary greatly, depending on which specific BMPs need to be implemented, although the costs are likely to be modest in total if the reductions of pollutants are not large (Shortle, 1998).

5.2 Economic Feasibility of Nutrient Management

Research in the U.S. indicates that improved nutrient management can assist significantly in reducing losses of nutrients with little negative (or even a small positive) impact on farm profits for some, although not all, farm types (Shortle et al., 1993; Babcock and Blackmer, 1992; Bosch et al., 1995). Farms with low (or negative) profits when implementing NMPs tend to be those with inefficient current practices and farms for which manure produced on the farm has a positive effect when applied on the farm.

Pease et al. (1998) studied the before-and-after effects of nutrient management practices on farm profit and farm-level nitrogen losses for four Virginia livestock farms. On each of the studied farms, nutrient management planning was a win-win investment that significantly reduced nitrogen losses while providing moderate increases in farm income.

Pease et al. (1998) also examined the economic and environmental impacts of potential regulations affecting nutrient applications on dairy and poultry farms. They evaluated three practices to reduce nitrogen and phosphorus losses at the edge of farm fields and below the root zone. Their results indicated that, for many dairies, nitrogen application restriction reduced potential nitrogen losses by 18 to 50% and increased income by 5%. The phosphorus restriction scenario showed potentially the most significant decrease in nutrient losses, but had a serious negative impact on dairy and poultry farm incomes, which would fall by 11 to 23% if such a policy were enacted. In contrast, a study in Minnesota showed that restricting phosphorus on dairy farms would cost $1.13 per acre (Pease et al. 1998). In this same study, the increased costs associated with constraining manure applications to both nitrogen and phosphorus requirements were modest and lower than expected.

In the Delaware Inland Bays Watershed, the U.S. Environmental Protection Agency proposed a tax on poultry processors of one-half cent per pound to fund agricultural non-point source pollution control programs (Mackenzie et al., 1999). Under this tax, Inland Bays' broiler production (conservatively estimated at 12 million birds) would generate an annual tax revenue of $750,000, easily enough to fund a comprehensive riparian buffer program in the watershed. The local poultry industry is comprised of hundreds of contract growers and five regionally dominant integrated companies. These five integrated companies provide flocks and feeds to contracted growers along with transportation, slaughtering and processing of chickens, and also control the intermediate marketing of chicken products. There is a high degree of buyer-side concentration in the intermediate market for live birds. Although the tax would be levied on the integrators at the processing stage, economic theory indicates that some portion of this tax burden will be passed backward in reduced live bird prices paid to poultry growers, and another portion will be passed forward to retailers (Mackenzie et al., 1999). Prices paid to growers currently range as low as four cents per pound – evidence that the five regional integrator companies exert some oligopsony power over contract growers. Thus any significant transfer of tax burden back to growers will squeeze grower revenues (Mackenzie et al., 1999).

Camacho (1991) evaluated the marginal cost per pound of reducing nutrients from different sources (Table 2). He suggested that investing in improving

Table 2. Marginal cost per pound of reducing nutrients from different sources

Source	Cost ($/lb)
Urban best management practices	142
Public-owned treatment plants	128
Pasture controls	10
Farm plans	45

Source: Camacho (1991)

agricultural BMPs would be more beneficial for taxpayers than investing in urban and other BMPs. The cost/benefit study showed that it costs three times more to reduce nutrients from urban sources than from agricultural sources.

5.3 Programs Supporting Nutrient Management

5.3.1 Programs in Canada

Agriculture and Agri-Food Canada (AAFC) provides a number of programs that include technical assistance and economic incentives for implementing specific BMPs. In the Prairie Provinces, such programs are delivered by AAFC's Prairie Farm Rehabilitation Administration (PFRA 2003).

PFRA's Community Pasture Program has returned more than 145,000 hectares of poor quality cultivated lands to grass cover since 1937 and currently encompasses in excess of 900,000 ha of rangeland. The program's two major objectives are: to make possible the removal of lands from unsuitable or unacceptable land use and facilitate improved land use through their rehabilitation, conservation and management; and to use the resource primarily for the summer grazing of cattle while assisting in stabilizing small farms and providing breeding bulls to encourage high quality, long-term cattle production.

PFRA's Shelterbelt Tree Program is a permanent program for the distribution of seedlings for planting shelterbelts or for planting trees for conservation and land reclamation projects. The program also provides free technical assistance.

The five-year, $4-million Shelterbelt Enhancement Program of PFRA is designed to reduce greenhouse gas (GHG) emissions through increased shelterbelt plantings on agricultural lands across the prairies. The program aims to work in partnership with producers and rural organizations to achieve several objectives: to reduce GHG emissions by 0.3 megatonnes by 2010; to plant 8,000 km of shelterbelts by 2006 (in addition to the PFRA's ongoing annual planting commitments); and to contribute to fulfilling Canada's commitment to the Kyoto Protocol.

A proposed program is currently under negotiation between the provinces and federal government as part of the Agriculture Policy Framework. It would be a cost-shared program to assist producers to implement specific BMPs.

Some government and non-government agencies also provide programs that include incentives for implementation of BMPs related to nutrient management. For example, the regional municipality of Waterloo has provided $1.5 million in funding over 5 years for the Waterloo Rural Water Quality Program since 1998 (Grand River Conservation Authority, 2002). Other agencies (including the National Soil and Water Conservation Program and the Grand River Conservation Authority) are also contributing cash or in-kind support to the program. More than 90 proposals were received from interested farmers. Fifty-two projects were approved, with total program funding of $260,000. Participating farmers will contribute significant resources (cash and in-kind) to these projects, so the total value of the projects implemented will be considerably greater. Among the projects approved are manure storage facilities and associated nutrient management plans, milk-house washwater treatment systems, clean water diversions from manure storages, and restricted livestock access to waterways.

5.3.2 Programs in Alberta

The Alberta Government, municipalities and non-governmental organizations provide a wide variety of programs to encourage producers to improve nutrient management.

For example, one of the main programs of the Alberta Environmentally Sustainable Agriculture Council is a farm-based extension program. Alberta Agriculture, Food and Rural Development provides funding to support AESA's activities and plays a major role in carrying out AESA's programs. Alberta's rural municipalities, producer groups and environmental agencies have conducted local extension programs funded through AESA. Nutrient management is one of AESA's two major priorities. It is providing funding to increase local manpower for extension and developing publications and tools for producers related to nutrient management.

Another important example, mentioned earlier, is the industry-led Environmental Farm Plan program that provides a voluntary, farmer-directed, risk assessment process for producers. The risks assessed under this program include those related to nutrient management.

Community-based watershed groups across the province are creating local programs that often include activities to address nutrient management in the watershed. These groups are able to access technical assistance and/or financial assistance offered through programs of various agencies such as the Cows and Fish Program, AESA, Community Riparian Program, Ducks Unlimited, local municipalities, Alberta Agriculture, Food and Rural Development and Prairie Farm Rehabilitation Administration.

5.3.3 Programs in the U.S.

The Environmental Quality Incentives Program (EQIP) is a national program established in 1996 to provide a voluntary conservation program for farmers and ranchers who face serious threats to soil, water, and related natural resources in the U.S. It provides technical, financial, and educational assistance on farmland used for agricultural production. EQIP offers 5- to 10-year contracts that provide cost-shared and incentive payments for conservation practices called for in site-specific conservation plans. Half of the funding for EQIP is targeted to natural resource concerns related to the livestock industry. The remainder is targeted to other significant conservation priorities. The total amount of cost-shared assistance and incentive payments a person is eligible to receive is $10,000 per year for a maximum amount of $50,000 for the life of the contract. The program offers an annual payment of $3.50/ac each year (on up to 200 acres) for 3 years for development and implementation of a nutrient management plan. If manure is on the farm, it must be included in the management plan and an additional incentive of $4.50/ac is offered.

EQIP uses two types of payments for conservation practices:

- Cost-shared payments apply to structural and vegetative practices. The program may pay up to 75% of the costs of installation. Examples of eligible practices are grassed waterways, filter strips, manure management facilities, and capping abandoned wells.
- Incentive payments are made to encourage producers to perform land management practices they may not otherwise use, and may be provided for up to 3 years. Incentive payments are not directly linked to producers' costs (as opposed to cost-sharing). Rather, a payment ceiling is determined practice by practice. Eligible practices include nutrient management, manure management, integrated pest management, irrigation water management, and wildlife habitat management.

Another program that manure users can take advantage of is the Soil and Water Conservation Assistance (SWCA) program administered by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS). SWCA provides cost-shared and incentive payments to farmers and ranchers to voluntarily address threats to soil, water, and related natural resources, including grazing land, wetlands, and wildlife habitat. SWCA will help landowners comply with federal and state environmental laws and make beneficial, cost-effective changes to cropping systems, grazing management, nutrient management, and irrigation.

The NRCS also administers the Conservation Technical Assistance program. This program provides voluntary conservation technical assistance to land-users, communities, units of state and local government, and other federal agencies in planning and implementing conservation systems. This assistance is for planning and implementing conservation practices that address natural resource issues. It helps people voluntarily conserve, improve and sustain natural resources.

Many states have cost-share programs for animal waste operations, and others offer incentives for implementing beneficial management practices related to animal operations, including grants, tax credits, and limiting environmental liability. Some programs were created to assist producers to address environmental issues that are costly.

In Pennsylvania, the Department of Agriculture has some financial assistance programs available for the development of a nutrient management plan and implementation of best management practices in an approved nutrient management plan. These programs provide funding in the form of grants (to a maximum of $800) or low interest loans to offset the cost of nutrient management plan development and/or implementation of an approved plan.

A water quality program in Virginia, called the Conservation Reserve Enhancement Program, provides cost-shared payments. The state reimburses up to 25% (to a maximum of $200 per acre) of the costs for such practices as restoring buffers or wetlands. There is also a 25% state income tax credit for out-of-pocket expenses, thus further reducing the landowner's cost. Federal reimbursement is made through the Farm Service Agency (FSA) for up to 50% of a participant's eligible expenses for implementing best management practices (BMP), such as fencing or alternative watering systems.

The Illinois Environmental Protection Agency has the Non-point Source Management Program to implement innovative and traditional measures to control non-point source (NPS) pollution. Financial incentives are used to finance projects that implement cost-effective solutions to NPS problems and promote the public's awareness and knowledge of NPS pollution. Examples of funded projects include streambank stabilization, detention basin retrofitting, wetland acquisition and creation, terraces, waterways, nutrient management, and educational programs. Recipients must develop, implement and administer a project, as well as ensure its long-term maintenance. Projects are supported by 60% federal funding matched by 40% local cash or in-kind services.

In addition, the Illinois Environmental Protection Agency has a Tax Certification Program for Livestock Waste Management Facilities for pollution control improvements such as manure pits, liquid livestock waste storage facilities, feedlot runoff sediment capture basins and tanks.

Some municipalities have designed their own initiatives to help promote nutrient management. For instance, Langlade County in Wisconsin started a Nutrient Management Incentive Project to work with a select group of dairy farmers and vegetable growers to obtain maximum nutrient utilization. This project offers cash incentives to farmers of $300 per participating farmer plus $1 per acre to complete a nutrient management plan.

6 Research Needs

There is much to be learned about managing manure and livestock to improve the efficiency of production while minimizing negative environmental impacts. Research on nutrient management BMPs needs to continue to: develop and refine BMPs; assess the degree of their effectiveness in reducing environmental impacts under a range of conditions; and analyze their economic feasibility. Beneficial management practices are the key enablers to reducing nutrient levels in non-point source pollution, and such BMPs should be a research priority. An annual research update would serve to keep growers and policy makers informed of the latest research.

Economic research must also be a priority, not only to evaluate the economic feasibility of specific BMPs, but also to assess the economic effects of proposed regulations, policies and programs to reduce environmental impacts.

Research is also needed to assess options to encourage producers to develop and implement environmental farm plans (EFP) and comprehensive nutrient management plans (CNMP); this should include evaluation of the costs and benefits those options. EFPs and CNMPs will be the core of any effort to reduce nutrient losses from agricultural lands. The CNMP approach, based on the cyclical flow of nutrients, offers a way to deal with the complexities involved in nutrient management. This approach can help producers to select a set of BMPs that will have positive impacts on the whole farm and to eliminate options that will have a positive impact on one factor but a negative impact on another (e.g., composting reduces the volume of manure but may increase greenhouse gas emissions).

Regarding alternative uses of manure, opportunity is knocking for farm input suppliers and manure entrepreneurs to develop new marketable products and processes that are practical, economically feasible and environmentally sound. It is up to the livestock industry and input supply industry to seize this opportunity to create proactive, environmentally responsible solutions. As much as possible, alternative uses should meet the needs of both crop and livestock nutrient users. Entrepreneurial development of manure alternatives could also facilitate capital investment in the agriculture and food industry. The potential exists for non-agricultural industries to enter the manure product market and eventually undercut the advantages currently held by farm input suppliers. Now is the time to capitalize on these opportunities and reap the economic and environmental rewards from marketing manure products. Revenue-generating opportunities will promote BMPs more rapidly and effectively than legislation and regulations.

7 Summary

The challenge to the agricultural community is to understand the complexities of nutrient management for individual farms and to think holistically about management approaches at a watershed scale or an aggregate of farms. Current research and extension in environmental quality, especially water quality, across Canada are creating the knowledge base for actions to improve nutrient management. However, the challenge remains to expand research activities both up to the watershed scale and down to the very specific situations on individual farms so that practical tools can be provided to both policy-makers and producers.

Environmental monitoring conducted in concert with farm-scale research is needed to provide essential answers to questions on the specific level of environmental and economic benefits resulting from a specific practice under specific conditions. This is a daunting task. For example, Harker et al. (1998) concluded that it could be difficult to quantify agricultural contributions to water quality problems because of complex soil-water interactions, uncertainty in sampling/analysis protocols, and the compounding effect of monitoring diffuse-source contaminants. They also stated that even on a regional basis, findings can be significantly different.

As policy makers address both perceived and real conditions, they must be certain that solutions fit a clearly defined problem. They must assess the costs and benefits to society and to individuals of controlling pollution, and they must try to find a reasonable balance. This balancing act could include targeting research and extension activities to those areas with the most serious environmental problems in order to reap the most benefit to society for the time, effort and money spent to improve nutrient management. Partnerships between government, industry and others are important in identifying balanced solutions that consider economic, environmental, and social interests, and that are based on sound science and a thorough understanding of the diverse implications of the various alternatives.

Society requires that farmers and ranchers carry out their operations in a way the does not harm the environment. Every effort must be made to inform agricultural producers about BMPs and to encourage them to adopt those BMPs suited to the conditions on their farm.

8 References

Agriculture and Agri-Food Canada. 2002. The Health of our Water: Toward sustainable agriculture in Canada. http://res2.agr.ca/research-recherche/science/Healthy_Water/ PDF/water.pdf. Visited June 30, 2002.

Babcock, B.A., and A.M. Blackmer. 1992. The Value of Reducing Temporal Input Nonuniformities, Journal of Agricultural and Resource Economics 17:335-47.

Babcock, B.A., P.G. Lakshminarayan, J.J. Wu, and D. Zilberman. 1997. Targeting Tools For Purchasing of Environmental Amenities, Land Economics 73:325-339.

Bosch, D.L., Z.L. Cook, and K.O. Fuglie. 1995. Voluntary Versus Mandatory Agricultural Policies to Protect Water Quality: Adoption of Nitrogen Testing in Nebraska, Review of Agricultural Economics 17(1).

Bouzaher, A., J.B. Braden, and G. Johnson. 1990. A Dynamic Programming Approach to a Class of Non-point Pollution Problems, Management Science 35:1-15.

CAESA. 1998. Impacts of Agriculture on surface water quality in Alberta. Part II. Provincial Stream Survey. By A.-M. Anderson, D.O. Trew, R.D. Neilson, N.D. MacAlpine and R. Borg.

Camacho R. 1991.Financial Cost Effectiveness of Point and Non-point Source Nutrient Reduction Technologies in the Chesapeake Bay Basin. ICPRB Report, 91-8, June 1991

CAST: http://www.cast-science.org/ Visited October 28, 2002.

CAST. 1993. Water Quality: Agriculture's Role. Part 1 of 6. http://www.inform.umd.edu/EdRes/Topic/AgrEnv/ndd/watermgt/WATER_QUALITY_AGRICULTURES_ROLE_PART_1_OF_6.html. Visited October 30 2002.

Cooke, S.E., P. Mitchell, L. Roy, L. Gammie, M. Olson, C. Shepel, T.L. Heitman, M. Hiltz, B. Jackson, S. Stanley, and D. Chanasyk. 2002. Relationship Between Beef Production and Waterborne Parasites (*Cryptosporidium* spp. and *Giardia* spp.) in the North Saskatchewan River Basin, Alberta, Canada. CABIDF Project No. 97AB080.

Government of Canada, 2002. Canada's contribution to addressing climate change. http://www.climatechange.gc.ca/english/actions/what_are/canadascontribution/measures.html. Visited September 19, 2002.

Grand River Conservation Authority, 2002. Rural Water Quality Program: Waterloo Region. http://www.grandriver.ca/index/document.cfm?Sec=25&Sub1=104. Visited December 2002.

Harker, D.B., B.D. Hill, and H.H. McDuffie. 1988. The risk agriculture poses to water quality: Factors affecting our interpretation of findings. International Conference on Children's Health & Environment, Amsterdam, The Netherlands, August 11-13, 1998.

Hallberg, G.R. 1989. Pesticide pollution of groundwater in the humid United States. Agric. Ecosystem Environ. 26:299-367.

Horsley-Whitten, Inc. 1998. Assessment of Nitrogen Loading to the Delaware Inland Bays. Prepared for the Center for the Inland Bays, Nassau, DE. (May, 1998)

Jaynes, D.B., and J.L. Hatfield. 1994. Water and chemical discharge in surface and tile discharge of Walnut Creek. Toxic Substances and the Hydrologic Sciences. American Institute of Hydrology. p. 430-445.

Mackenzie J., John H. Martin, Lilian Pintea, Boonchauy Boonmee, Negede Gedamu and Theresa C. Thomas. 1999. Delaware Inland Bays Watershed Nutrient Management Project. http://www.udel.edu/FREC/spatlab/spot/#policy. Visited October 13, 2002.

Mueller M.K. and D.R. Helsel. 1996. Nutrients in the Nation's Waters – Too Much of a Good Thing?. U.S. Geological Survey Circular 1136. National Water-Quality Assessment Program.

Oldman River Basin Water Quality Initiative. 2000. Progress Summary Report.

Oldman River Basin Water Quality Initiative. 2003. About Us. http://www.oldmanbasin.org/.

Pease, J. Laura VanDyke, Darrell Bosch, and James Baker. 1998. Nutrient Management Planning: Win/Win and We Can Do Better. http://www.ctic.purdue.edu/Core4/Nutrient/ManureMgmt/Paper61.html Visited November 30, 2002.

PFRA. 2002. Programs & Services. Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada. http://www.agr.gc.ca/pfra/program_e.htm. Visited December 2003.

Pfost, D., C Fulhage, and D. Rastorfer. 2000. Beef Manure Management Systems in Missouri. Environmental Quality publication EQ377. http://muextension.missouri.edu/explore/envqual/eq0377.htm. Visited September 2002.

Penn State University. 1993. Atmospheric Disposal of Manure Nitrogen. Technical Note #8, Penn State University. 1993.

Safley Jr., L.M. 2003. Prospering under pressure: Who is the enemy? Advances in Pork Production V14:17-28.

Scribner, E.A., D.A. Goolsby, E.M. Thurman, M.T. Meyer, and W.A. Battaglin. 1996. Concentrations of selected herbicides, herbicide metabolites, and nutrients in outflow from selected Midwestern reservoirs, April 1992 through September 1993. Open File Report 96-393, United States Geological Survey, Denver, Colorado. 128 p.

Shortle J. 1998. Efficient Nutrient Management Policy. The Pennsylvania State University, University Park, PA. http://www.arec.umd.edu/Policycenter/Pfiesteria/shortle/shortle-text.htm. Visited June 22, 2002.

Shortle, J., W. Musser, W. Huang, B. Roach, K. Kreahling, D. Beegle, and R. Fox. 1993. Economic and Environmental Potential of the Pre-sidedressing Soil Nitrate Test. Final Report for U.S. Environmental Protection Agency Contract No. CR-817370-01-0.