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Best Management Practices To Protect Water Quality: A Review

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Southern Alberta Resource Economics Centre Publications

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Abstract

Source water protection has become an increasingly important issue over the past decade. This paper takes an in-depth look at the agents of contamination that may originate from on-farm sites, the routes these contaminants may take when entering source waters and the possible effects they may have on source water quality, the natural ecosystem and human health. Specific practices that cause the contamination of source waters as well as possible mitigation or minimization measures, termed best management practices, are discussed at length. Programs currently being implemented in Canada, Europe and Australia have been used as examples of initiatives that strive for greater water quality and more effective source water protection, while at the same time alluding to what the future holds for best management practices and their implementation at the regional scale. The topics of willingness to adopt new farming practices, financial assistance programs as well as education and training programs that are available to agriculturalists also are outlined.

1.0 Introduction

Source water protection has become an increasingly important issue over the past decade. The need for this type of practice gained a great deal of support following the Walkerton, Ontario tragedy in May of 2000 when the contamination of local drinking water supplies caused the deaths of 7 individuals and made hundreds of others sick (Patrick 2009, 209). Although these types of incidents are infrequent, the contamination of drinking water supplies does occur and in many cases the cause is due to agricultural activities within watershed. The specific practices that cause such contamination of source waters as well as possible mitigation measures, termed best management practices, will be discussed at length in this paper. Not only do specific best management practices need to be discussed, but also how they can be implemented is of great importance. The topics of willingness to adopt new farming practices, financial assistance programs as well as education and training programs that are available to agriculturalists will also be outlined.

2.0 Source Water Protection

2.1 What Is It?

Prior to discussing the sources of contamination and the best management practices that may be employed to prevent such contamination, it is important to understand what source water is. Ivey *et al.* (2006, 193) define source waters as the lakes, rivers, and aquifers from which ‘‘raw’’ drinking water is drawn. Due to the obvious importance of the cleanliness of our sources of fresh water, the concept of source water protection (SWP) was conceived. Patrick (2009, 209) broadly defines SWP as “watershed and aquifer management for the protection of drinking water supplies which is operationalized through land-use management programs with the specific goal of protecting drinking water sources against contamination." Ivey *et al.* (2006, 193-4) add that that main aim of SWP is "to preserve or enhance water quality within water bodies that currently supply drinking water, or are likely to be future sources." The latter point referring to future sources of drinking water is becoming increasingly imperative in the Canadian context as urban areas continue to expand into traditionally rural regions. These new urban areas will undoubtedly require clean sources of water to meet their domestic water needs, making it extremely crucial to ensure that headwaters are not being contaminated by current land uses.

In Canada, there is no federal SWP legislation, which means that the responsibility for SWP rests on the decisions and actions of the provinces and municipalities (Ivey *et al*. 2006, 195). Due to this variability in management across the country SWP may take a variety of forms including resource assessments; water quality monitoring; vulnerability or threats assessments; delineation of sensitive water protection areas; selection and implementation of tools to protect water quality; and public education (Ivey *et al.* 2006, 194). For the purposes of this paper the focus will remain on the possible impacts of dryland farming on source water and the best management practices that have been developed to avoid or minimize the contamination of source waters.

2.2 Possible Impacts of Agricultural Activity on Source Waters

Contamination of source waters does occur naturally, however, water quality may also be impacted by human, industrial, and agricultural activities in the watershed. Focusing specifically on agriculture, common agents of stress resulting from agricultural activities include sediment, nutrients, pathogens, hydrocarbons and pesticides, which have been demonstrated to impact stream ecosystems (Yates, Bailey and Schwindt 2007, 331). Agricultural activities may impact water quality through point- or non-point-source contamination. Unwanted materials can be emitted from non-point sources, such as tilled fields, pasturelands, and exercise yards in upland and riparian areas. Point source releases of such materials can occur from manure storage areas and wastewater outlets (Yates, Bailey and Schwindt 2007, 332). Examples of such contamination include: fertilizers and soil sediment which cause nutrient loading; soil erosion which may be caused by farming activities and runoff into water supplies; manure or animal urine are a notable source of excess nutrients, pathogenic organisms, and veterinary pharmaceuticals; pesticides are a potential source of synthetic organic contaminants; and finally fuel, oil, and waste products from agricultural practices have the potential to contaminate source waters (Corkal *et al.* 2004, 1623).

2.2.1 Nutrients

Valetin *et al.* (2004, 489) draws attention to the problem of source water contamination by noting that the use of inorganic fertilizer in the United States has increased fourfold, and the use of agricultural pesticides threefold in the past two decades. The increased use of these materials in farming practices has undoubtedly caused harm to local aquatic ecosystems. In addition, agri-environmental research has shown that intensive farming causes soil and water degradation. Degraded soils exhibit reduced productivity, and water bodies receive increased inputs of suspended matter, nutrients (N and P) and pathogenic microorganisms (Duchemin and Hogue 2009, 85). To take a specific example from the United States, the U.S. Environmental Protection Agency (1998) cites nutrient pollution as the leading cause of impairment in U.S. lakes and estuaries, and the second leading cause of impairment in rivers (U.S. EPA, 1998; Frisvold 2004, 2).

Too much nitrogen (N) in water supplies, in the form of nitrates (NO3), can harm livestock and humans through nitrate poisoning which reduces the amount of oxygen absorbed by body tissues (AAFRD, 2006). In human babies, this condition is known as "blue baby" syndrome, while the effects of nitrate poisoning on livestock cause symptoms that begin with problems standing up and staggering. With prolonged exposure, excessive nitrate levels can eventually be fatal to both humans and animals (AAFRD, 2006).

Elevated phosphorus (P) levels degrade surface water quality by promoting excessive growth of aquatic plants and algae. Algal blooms exhaust the supply of oxygen, during growth and decomposition. During decomposition, micro-organisms break down organic material, removing dissolved oxygen from the water. This reduction of oxygen can result in the death of fish and other aquatic organisms. Some types of blue-green algae can also release toxins deadly to livestock and humans during decomposition. Algae can also block water intakes, reduce the appeal of water bodies for recreation and give an unpleasant taste and odour to drinking water (AAFRD, 2006).

2.2.2 Pathogens

Microorganisms such as bacteria, parasites, protozoa and viruses occur naturally in animals, humans, soil and water. Pathogens are disease-causing microorganisms that can infect other animals and humans resulting in severe or fatal illnesses. A few common pathogens associated with farmsteads are Escherichia coli (E. coli), Salmonella species, Cryptosporidium parvum ("crypto") and Giardia lamblia ("beaver fever") (AAFRD, 2006).

Water is an important transmitter of pathogens. People who drink contaminated water or eat contaminated food will more than likely become ill. Infection and illness may also occur in people using contaminated water for recreational purposes (AAFRD, 2006).

2.2.3 Hydrocarbons

Products containing hydrocarbons such as gasoline, diesel and kerosene can be explosive and very volatile. The build up of vapours in an area can be toxic to humans or livestock (AAFRD, 2006). Fuels can potentially contaminate water bodies and water sources by moving quickly over and through the soil. Fuel can flow over the soil surface with runoff into surface water bodies or migrate downwards through the soil into groundwater supplies. It only takes a few litres of gasoline to severely pollute a farmstead's drinking water. Most soil and water contamination occurs when there is a fuel spill or a leak (AAFRD, 2006).

2.2.4 Pesticides

Pesticides are designed to suppress or kill target plants, fungal diseases, insects, animals and pathogens. Types of pesticides used in farmstead management include herbicides, fungicides, insecticides, rodenticides, pesticide-treated seed and topical parasiticides (pour-on or powders for treating parasites on livestock) (AAFRD, 2006). Pesticides can be carried great distances from target areas or application sites to non-target areas in several ways: dissolved in runoff water moving away from target areas; attached to soil particles and carried by wind or runoff water; or through spray drift onto water bodies and vegetation (AAFRD, 2006).

Following the 2007 Canadian Ag-Water Forum II it was agreed that water and source water protection is a priority for every province in Canada and concerns about agricultural contributions are common (AAFC, 2007). The agricultural issues affecting source water quality were, not surprisingly, similar across Canada; however, emphasis on the issues varied, which likely reflect geographic differences in landscapes (AAFC, 2007). Education and awareness activities were seen as valuable mechanisms for creating on-farm awareness of potential environmental risks and improving voluntary uptake of beneficial management practices (AAFC, 2007).

The next section will outline various types of best management practices with respect to the agricultural impacts on source water that are being implemented globally.

3.0 Best management practices

In order to mitigate some of the problems indicated above, agriculturalists have been encouraged to employ what are referred to as best (or beneficial) management practices, often referred to as BMPs. Alberta Agriculture, Food and Rural Development (AAFRD) defines a BMP as any management practice that reduces or eliminates an environmental risk (AAFRD, 2006). Specifically related to agriculture, BMPs are designed to minimize the release of agents of stress from agricultural areas. Another more agricultural specific summation of BMPs is found in the following citation from Corkal *et al.* (2004).

> An agricultural best management practice may be defined as a farming method that minimizes risk to the environment without sacrificing economic profitability. Most, if not all, producers use an array of BMPs in their normal agricultural operations. However, it is not always clear which BMPs are the most effective and affordable for a given situation or geographic location (Corkal *et al.* 2004, 1625).

Farmers are often encouraged to adopt these voluntary practices by government agencies, many of which have developed conservation programs that promote the benefits of using BMPs and provide funding and technical expertise for project implementation (Yates, Bailey and Schwindt 2007, 332). Agriculture and Agri-Food Canada (2007b) claim that management practices are a powerful tool for protecting water, but they cannot be expected to solve all water quality problems. Many of the factors, which reduce water quality, on the Prairies specifically, are naturally occurring and water treatment is necessary to satisfy the water quality requirements of many specific uses (AAFC, 2007b). To reiterate this point, BMPs are only the first step in the treatment process of water used for agricultural and other purposes, but they are very necessary in the overall process of securing safe and clean source waters for all foreseeable users. It was also noted during the Canadian Ag-Water Forum II, in February of 2007, that although agricultural BMP 's are heavily promoted across Canada, many of them are costly to implement and the net socio-economic and environmental impacts are neither clear nor easily measured (AAFC, 2007a). In contrast to the attitudes that BMPs may be too costly to implement for individual farmers, the cost to the larger public for treating highly contaminated water may be even more expensive. Kay, Edwards and

Foulger (2009, 68) support this idea by noting that agricultural pollutants can be treated to meet drinking water standards using engineered solutions, although the costs can be significant, in both economic and environmental terms. Control of these pollutants at the source is desirable and a range of management techniques are available that aim to achieve this.

3.1 Classes of BMPs

There are three main classes of agricultural BMPs that are related to source water protection. BMPs are typically developed to reduce runoff and/or percolation of three principal sources of contamination: nutrients (mainly nitrogen and phosphorus), pesticides (herbicides and insecticides), and sediment (Valentin et al. 2004, 490).

3.1.2 Nutrient Management

Nutrient management is the practice of applying fertilizers and manures only in the amounts that can be taken up by a crop. Agricultural activities can accelerate the movement of nutrients to surface or ground waters, particularly from overuse of fertilizers and inappropriate manure management practices. While addition of fertilizer and manure to agricultural soils is essential for soil health and optimal crop yield, application in excess of plant requirements can lead to a build-up of nutrients in the soil and their loss to the environment (AAFC, 2007b; Chambers *et al.* 2002).

3.1.3. Integrated Pest Management

The use of herbicides and insecticides can be minimized through integrated pest management. This refers to a management strategy that includes an understanding of the target pest and use of a combination of physical, chemical, biological and cultural controls. Proper storage, mixing and handling of pesticides are also essential in minimizing risk to the environment (AAFC, 2007b).

3.1.4 Erosion Control

Controlling erosion and runoff is an important best management strategy. Soil erosion moves topsoil and deposits it elsewhere. Although a natural process, soil erosion may be greatly accelerated by cultivation of soils or implementation of aggressive agricultural practices, a condition referred to as accelerated or anthropogenic erosion (Chambers *et al.* 2002, 4). The quality of receiving water bodies may be impaired by problems of turbidity and sedimentation. The eroded sediments are also very effective as carriers for pollutants such as nutrients and pesticides (Chambers *et al.* 2002, 4). Many factors combine to define the vulnerability of agricultural landscapes to erosion including erosivity or precipitation, soil erodibility, slope length and gradient, and crops and cropping practices, resulting in considerable variation in risk of soil erosion across Canada (Chambers *et al.*, 4). Practices such as vegetated buffers, strip-cropping, shelterbelts and use of cover crops prevent erosion and reduce the movement of nutrients and pesticides from agricultural land. Residue management through conservation tillage and continuous cropping is also effective at controlling erosion, but requires higher inputs of fertilizer and herbicides. A balance between erosion control and protection of water quality may have to be established to maximize conservation (AAFC, 2007b).

3.2 Specific Best Management Practices

3.2.1 Vegetated Buffers

Buffers are vegetated zones located between natural resources and adjacent areas subject to human alteration. In some locations, a buffer strip may be referred to as a vegetated filter strip (Castelle, Johnson and Conolly 1994, 878). Non-grazed, vegetated buffer zones are often proposed to attenuate nutrients and sediment in runoff from extremely grazed pastures. Buffers are also proposed to enhance riparian habitat by protecting it from physical harm by livestock (Tate *et al.* 2000, 473). The vegetative strips can trap sediments, nutrients and other contaminants transported in runoff water before the water reaches adjacent water bodies (Duchemin and Hogue 2009, 86). One of the important factors that determine the effectiveness of a buffer is size. Buffers that are undersized may place aquatic resources at risk; however, buffers that are larger than needed may unnecessarily deny landowners the use of a portion of their land. Therefore, it is important to be able to determine the minimum buffer width necessary for aquatic resource protection (Castelle, Johnson and Conolly 1994, 878). Castelle et al. (1994) reviewed the literature and concluded that riparian buffers from 3-200 metres are effective in protecting aquatic resources from adjacent agricultural land use practices. The need for a buffer and its width is site-specific and should be based on land use intensity, aquatic resource sensitivity, and availability of alternative best management measures (Tate *et al.* 2000, 473).

Four main criteria can be used when determining adequate buffer sizes for aquatic resources: (i) resource functional value, (ii) intensity of adjacent land use, (iii) buffer characteristics, and (iv) specific buffer functions required (Castelle, Johnson and Conolly

1994, 878). Generally, smaller buffers are adequate when the buffer is in good condition (e.g., dense native vegetation, undisturbed soils), the wetland or stream is of relatively low functional value (e.g., high disturbance regime, dominated by nonnative plants), and the adjacent land use has low impact potential (e.g., park land, low-density residences). Larger buffers are necessary for high value wetlands and streams that are buffered from intense adjacent land uses by buffers in poor conditions (Castelle, Johnson and Conolly 1994, 878).

One example of a jurisdiction that has realized the importance of vegetated buffers is the province of Prince Edward Island. The province's newly enacted *Environmental Protection Act* (EPA) requires the establishment of buffer zones along all watercourses in the province. It requires a 10 metre wide buffer on all watercourses bordered by agricultural land or by residential, commercial, industrial, institutional and recreational development and a 20 to 30 metre buffer (determined by slope) along all forested areas bordering on watercourse and wetlands (Chambers *et al.* 2002, 18). PEI is the first province in the country to pass legislation requiring the establishment of buffer zones adjacent to watercourses and wetlands.

3.2.2 Effective Fertilizer and Pesticide Use

The reduction of and/or use of alternative fertilizers and pesticides have a great impact on the quality of local source waters and can aid in preventing some of the harmful impacts mentioned above that may result from these materials entering the surrounding aquatic ecosystem. Effective fertilizer use considers the lowest and the most effective use of nutrients in farming. It includes soil and tissue testing to determine nutrient requirements (e.g. deficiencies and suitable fertilizer usage) and helps with the management of nutrients including rates, timing and locations (e.g., use of fertilizer buffers) (Keipert *et al.* 2008,1751).

The use of alternative methods of pest control can reduce human exposure to potentially toxic materials, avoid risk of contamination of water, soil, air and biodiversity and reduce the risk of pesticide residues in food (CSFSP 2009, 66). An integrated pest management approach involves the judicious use of approved agricultural pesticides in combination with other management options, such as crop rotation, pest resistant varieties, biological control and physical control methods (CSFSP 2009, 66). The Canada - Saskatchewan Farm Stewardship Program (CSFSP, 2009) recommend the use of the following BMPs that improve pest management: pesticide application systems (e.g., drift reduction technology), information collection and monitoring, integrated pest management for insect, non-vertebrate or vertebrate pests, integrated pest management for invasive plants, native plant re-establishment, and integrated pest management planning.

3.2.3 Reducing Manure Nutrient Content

Livestock incorporate only 20 to 40% of the phosphorus and nitrogen originally present in their diet or feed; the remainder is excreted (Chambers *et al.* 2002, 13). These nutrients contained in the manure of the livestock have the ability of being transported via runoff into local watercourses. There are, however, a variety of strategies to reduce the nutrient content of the livestock manure. The Canadian Council of Minister of the Environment (CCME) specify that there are two prevailing technologies which aim to partially mitigate this problem of excess phosphorus entering the ecosystem through livestock manure. One suggested method to reduce phosphorus content in manure being generated on hog farms is to reduce supplemental phosphate in the hog's diet and add enzyme phytase to their feed. This enzyme hydrolyzes a portion of the phytate in the feed, thereby releasing readily digestible inorganic phosphate (Chambers *et al.* 2002, 13). This practice can result in a 25-30% reduction in fecal phosphorus for pigs. Another approach that was suggested for reducing fecal phosphorus is to feed pigs cereal grains containing more bioavailable phosphorus and less phytate, which causes a similar reduction in the fecal phosphorus created as mentioned above (25-30% reduction) (Chambers *et al.* 2002, 13). Finally, a third method developed involves producing transgenic pigs that synthesize their own phytase. The pigs are able to incorporate nearly all of the phosphorus in a diet with soybean meal as the sole source of phosphorus and excrete feces with up to 75% less phosphorus than non-transgenic pigs receiving the same diet (Chambers *et al.* 2002, 13). The end result of these practices leads to manure with lower phosphorus levels that can be used to fertilize crops without excess amounts of phosphorus leaching into watercourses.

With respect to reductions in the nitrogen content of livestock manure, Chambers *et al.* (2002, 14) offers a single approach involving reducing the quantity of crude protein in the diet of livestock and replacing this with synthetic amino acids. Reduction of protein in the diet produces three desirable effects: it reduces nitrogen content in the manure and thus potential for water quality problems following field application; it reduces the quantity of ammonia and thus the release of greenhouse gas and nitrous oxide; and it reduces odorants in the livestock operation and in the manure.

3.2.4 Precision Agriculture

Precision agriculture is a method that aims to reduce the use and potential off-site transport of agrochemicals and manure by better managing the spatial variability and specificity of agricultural soils (Chambers *et al.* 2002, 16). Fields are inherently variable and this variability has increased as a result of mechanization and the ability to work larger fields. Precision farming applications including global positioning systems (GPS), information collection, and variable rate technology have developed the potential for producers to make more efficient use of farm inputs (i.e. seed, fertilizer, pesticides, and manure) which can reduce pesticide and nutrient residues in soil and water (CSFSP 2009, 88). Precision agriculture relies on three main sets of tools:

- in-field and remote monitoring tools (i.e., sensors that detect, for example, crop and soil moisture levels, crop yield, disease or weed infestations and their position in the field);
- machine controls that guide field equipment and can vary the rate, mix, and location of water, seeds, nutrients, or chemical sprays; and
- computerized GIS maps and databases that process the data produced by the first category of tools and generate the information to set the machine controls (Chambers *et al.* 2002, 16)

The CCME claim that the application of these precision agriculture techniques lead to:

- a better knowledge of the characteristics of a field (cartography);
- better understanding of the processes controlling crop yield (spatial analysis); and
- where possible, greater control of variability of soils and yields in a field through

interventions (e.g., drainage, leveling, chiseling, etc.) or variable application of inputs (e.g., lime, mineral or organic fertilizer, pesticides) at the appropriate frequency and timing (Chambers *et al.* 2002, 16).

Applied effectively, precision agriculture not only increases profitability by increasing yields and reducing inputs, but should also benefit the environment by enabling more efficient input use.

3.2.5 Fencing Around Watercourses

Another valuable best management practice that aids in source water protection involves erecting fences around watercourses adjacent to or within agricultural land. This can be done with the use of perimeter and cross fencing to manage watering sites and riparian areas (stream banks and shorelines), control invasive plants, increase biodiversity, improve health and productivity of upland areas, reduce soil erosion and improve runoff water quality (CSFSP 2009, 15). The benefits of fencing to protect source waters include: reduced soil erosion; improve and/or maintain good health in riparian areas, protection of aquatic and dry land species (plants, animals, insects, etc.), all of which are important for biodiversity (CSFSP 2009, 15). On farm upgrading may include: fencing to exclude or limit access to open water and water bodies (dugouts, sloughs, lakes, riparian areas); fencing to discourage livestock lingering at constructed watering sites (wellheads, dugouts, wet wells, water troughs); fencing to manage grazing in order to improve and/or maintain health in riparian areas and/or upland pastures or rangelands (CSFSP 2009, 16).

3.2.6 Water Troughs / Remote Livestock Watering Systems

This BMP is to be used in tandem with watercourse protection fences. Direct entry of cattle into rivers, lakes, and streams will cause environmental damage. Shorelines are eroded, and animal defecation in water will transfer nutrients and pathogens into the aquatic ecosystem (Corkal *et al.* 2008, 1629). Livestock are drawn to water. By strategically locating watering systems, the impact livestock have on an area can be managed (CSFSP 2009, 22). Watering cattle by allowing direct entry access is a common agricultural practice through the use of pasture dugouts (farm ponds). Studies have documented very high concentrations of *Escherichia coli* and other bacteria in direct-entry dugouts (Corkal *et al.* 2008, 1621). The presence of bacteria or disease-causing pathogens in animal drinking water may have impacts on animal health and weight gain (Agriculture and Agri-Food Canada and Western Beef Development Centre, 2001). Other issues, such as the presence of cyanobacterial toxins (commonly referred to as blue-green algae toxins), are regularly cited as the cause of animal deaths when present in livestock water supplies (Corkal *et al.* 2008, 1621).

Remote permanent and portable livestock watering systems can be used as a tool to protect high-risk marginal soils and riparian areas (stream banks and shorelines), for wintering site management, and in conjunction with the relocation of a livestock confinement facility (CSFSP 2009, 22).

In collaboration with producers and the Western Beef Development Centre, a series of applied research and demonstration projects were established to investigate options for remote livestock watering systems. These included nose pumps powered by the animals, electrical, wind-powered, or solar-powered pumps and a variety of designs suitable for summer and winter operations (Corkal *et al.* 2008, 1621). The adoption of these types of BMPs results in the protection of the source waters, and better and often more profitable animal production.

3.2.7 Instream Flow Needs

Perhaps a more readily accepted and easily applied management measure for reduction of constituents in runoff from irrigated pasture systems would be to reduce the runoff generated per irrigation event. Minimizing, or even, eliminating, runoff would reduce constituent transport as well as increase water use efficiency. With an average of 15% and 69% of water applied per irrigation event becoming runoff for sprinkler and flood irrigation, respectively, there is great potential to improve water quality by improving irrigation efficiency (Tate *et al.* 2000, 477).

Advancements in technology have enabled many producers to adopt more water efficient irrigation systems. Examples of improved irrigation equipment that increase water use efficiency include: conversion to low pressure, low clearance sprinkler system components, trickle or drip system components, irrigation monitoring equipment and use of fertigation technology (CSFSP 2009, 80). The incorporation of backflow prevention (for effluent, fertilizer and pesticide application) is also crucial for preventing potential crop, water and environmental pollution (CSFSP 2009, 80).

3.2.8 Simple Tips for Water Application in Times of Scarcity

As opposed to some of the more capital intensive BMPs mentioned above, there are also some simple ways to reduce the amount of water applied to agricultural crops during times of scarcity. These small changes to a farmer's regular practices can help to keep operational costs down by not having to apply additional water as well as helping to keep more water in the local watercourses to aid in meeting instream flow needs. The following simple suggestions have been offered by ATTRA—National Sustainable Agriculture Information Service (2006).

- Don't over-irrigate. Learn the water holding capacity of your soils, their allowable depletion, and the effective root depth and critical growth of your crops.
- Focus irrigation on critical growth stages. Depending on the crop, you'll usually see one of two types of responses to drought stress:
    1. *Seed crops, cereals, and oilseeds are most sensitive to drought stress during flowering or seed formation and relatively insensitive during early vegetative growth. Irrigate enough at the onset of seed formation to carry the crop through seed fill.*
    2. *Perennial crops grown primarily for forage, and some root crops, are relatively insensitive to moderate drought stress for short periods throughout the growing season. They can recover from stress periods with little reduction in yield. Focus on irrigating during periods of maximum growth.*
- Irrigate early in the season. Fill the root zone to field capacity before hot weather starts.
- Leave room in the soil for precipitation. Crop residue and cover crops help capture snow and rain and reduce evaporation.
- Aim for optimum rather than maximum yield (i.e., the greatest yield with the least input).
- Plant drought-tolerant crops or quick-maturing crops that require most of their water early in the season.
- Reduce the amount of land you irrigate and use the saved water on the remainder, or reduce the amount of water you apply over the whole irrigated area.
- Irrigate every other furrow, switching at each irrigation event. You'll still get water to one side of each row, generally using far less water.

4.0 Implementation of BMPs

The agricultural BMPs mentioned above are all excellent steps that can be taken by individual farmers. However, there is still the matter of encouraging individual farmers to adopt these practices that aim at better source water protection. Associated with most of the recommended BMPs are increased operation costs, either with their initial inception or throughout the course of yearly farm operation. The next section will discuss strategies that aim at increasing the adoption rates of these source water protection BMPs.

4.1 Social Pressure

Pressure from the community, other agriculturalists as well as various levels of government can be very effective in encouraging farmers to adopt land management practices that foster environmental protection. Morton and Weng (2009, 85) state "farmer's perceptions of local water degradation and their personal and civic connections provide social pressures (both positive and negative) toward conservation measures that have water quality protective characteristics". If farmers are to go beyond the status quo of their current practices, they must believe their current actions are inadequate and seek additional solutions. The mechanisms for change are connections and interactions with others who think differently about the environment and water issues (Morton and Weng 2009, 85). These interactions with others in the community have the power to challenge the current beliefs and values about natural resource use and management. Farmer dialogue with non-farmers may contribute to increased awareness and lead to dissatisfaction with the adequacy of current conservation practices (Morton and Weng 2009, 92). Morton and Weng (2009) argue that the more social organizations that farmers associate themselves with, the more they are exposed to diverse opinions and knowledge as well as other worldviews, the more likely they are to adopt. This exposure has the ability to lead farmers to the recognition that the status quo as they practice it might be inadequate to solve water problems.

Farmers must first realize their efforts are inadequate before they will reexamine their automatic management behaviors and then begin a search for better water quality solutions (McCown, 2005). Social pressure is seen as a more effective and lower cost adoption strategy as opposed to government sanctions largely because sanctions are costly and do not easily motivate people to engage in sustained practices that lead to better water outcomes. For the types of BMPs mentioned in the past sections to be incorporated and used year after year a conservation ethic must be present, which creates a real reason for maintaining high water quality in the watershed (Morton and Weng 2009, 86). Parisi *et al.* (2004, 98) support the use of social pressure to encourage the adoption of BMPs, whose aim is environmental protection, in the following excerpt.

> Conservation, preservation, and maintenance of environmental quality require more than the development and implementation of traditional command-and-control policies. They require the development of strategies that foster investment in civic responsibility in protecting the environment.

For the reasons stated above, social pressure can be effective in instigating long-term change in farming practices, but there is still the matter of farm profitability and the increased costs associated with adoption of new management practices.

4.2 Economic Incentives

Cost still remains a factor that stands in the way of the adoption of many BMPs for farmers. Valentin *et al.* (2004, P490) explains, "one possible explanation for producers' reluctance to adopt these practices (BMPs) is that they are uncertain of the impact on farm profitability. While most BMPs have been presented as being yield neutral (i.e., having no effect on crop yield), this does not necessarily translate to adoption having no impact on profitability." Farmers may perceive that the adoption of new management practices may cause an “income drag”. This fear is largely due to the risks associated with new farming methods and unproven technologies that may alter total yield and/or take more time to implement (Valentin *et al.* 2004). To aid with these financial pressures, many nations (and various levels of government within them) have created incentive or subsidy programs that provide funding to individual farmers.

To mitigate agricultural impacts on both freshwater and terrestrial environments, many European countries have introduced agri-environment initiatives. These are government schemes which provide financial incentives to farmers and land managers for adopting environmentally sensitive practices which maintain or enhance the natural resources, and in particular the biodiversity, of agricultural land (Davies *et al.* 2009, 439). Government direction is necessary in addition to funding. Keipert *et al.* (2008, 1755) state, “where diffuse pollution dominates it is not sufficient to rely on individuals to develop management systems, and a more considered structured framework is required to achieve large scale environmental improvements.”

In Canada, agricultural assistance programs may take on various forms. One such agricultural reform program comes in the form of *Growing Forward: A Federal - Provincial - Territorial Framework Agreement on Agriculture, Agri-Food and Agri-Based Products Policy. Growing Forward* was created in July of 2008 and replaced the *Agricultural Policy Framework* (APF) as Canada’s guiding agricultural policy. Governments are investing $1.3 billion over five years into *Growing Forward* programs. The funding represents $330 million more than the *Agricultural Policy Framework* (APF) and its cost is shared between the Government of Canada and the provincial and territorial governments on a 60-40 basis (AAFC, 2008a). *Growing Forward* offers funding for a variety of projects offered nationally or to residents of specific provinces of territories. One specific initiative of *Growing Forward* that aims at providing funding to individual farmers to fund new management practices is found in section 17.1.4 of the framework labeled *Supporting On-Farm Sustainable Agricultural Practices: Federal Priority Beneficial Management Practices (BMPs).* This initiative specifically addresses funding of BMPs for individual farm operations, and is outlined in the following quote.

> This initiative will provide additional support for supplemental on-farm action in priority areas, which will be in addition to the wider range of activities covered under the on-farm action initiative. Actions under this initiative will be targeted towards: i) Agricultural components of multi-user water infrastructure, which will focus on larger scale infrastructure projects, such as regional water pipelines, providing a long-term agricultural water source for a number of water users and promoting economic growth in an area or region; and ii) funding of BMPs to help producers improve riparian area management, grassland-management, protect water quality and reduce greenhouse-gas emissions. Actions such as erosion control structures, riparian buffers and grazing management planning will be supported (AAFC, 2008b).

Another example of a government funded agricultural assistance program is the Canada-Saskatchewan Farm Stewardship Program (CSFSP). The objective of the CSFSP is the adoption of Beneficial Management Practices (BMPs) across the agricultural landscape on Saskatchewan farms. The program will provide cost-shared incentives to producers to implement BMPs that address on-farm environmental risks (CSFSP 2009, 4). This guide outlines how to apply for financial assistance from the province of Saskatchewan to implement any one of the BMPs listed. Also included are specific conditions for eligibility for each of the BMPs. Supported BMPs include:

• Improved Manure Storage and Handling	• Improved Pest Management
• Manure Land Application	• Nutrient Recovery from Waste Water
• In - Barn Improvements	• Irrigation Management

• Runoff Control	• Shelterbelt Establishment
• Relocation of Livestock Confinement and	• Invasive Alien Plant Species Control
• Horticultural Facilities	• Enhancing Wildlife Habitat and Biodiversity
• Wintering Site Management	• Species at Risk
• Product and Waste Management	• Preventing Wildlife Damage
• Water Well Management	• Nutrient Management Planning
• Riparian Area Management	• Integrated Pest Management Planning
• Erosion Control Structures (Riparian)	• Grazing Management Planning
• Erosion Control Structures (Non-Riparian)	• Soil Erosion Control Planning
• Land Management for Soils at Risk	• Biodiversity Enhancement Planning
• Improved Cropping Systems	• Irrigation Management Planning
• Cover Crops	• Riparian Health Assessment

Programs such as these have arisen all over the globe. A very similar program to the CSFSP has been initiated in Australia called *Landcare*. *Landcare* is a voluntary community movement of about 4500 groups across Australia who are eligible to receive government funding ($189 million set aside for this initiative) for conservation activities on private land on farms, in water catchments and at the regional level (DAFF, 2009). About 40 per cent of Australian farmers are involved in *Landcare*, which encourages collective action by landholders, businesses and communities.

4.3 Education

The financial assistance programs mentioned above give farmers and ranchers a great resource economically as well as give them a source to draw upon for ways in which improvements can be made to the day-to-day operation of their business. However, a major factor that must be associated with the commencement of new practices is education. An example of a successful, far-reaching education initiative can be found with the Rural Water Quality Program (RWQP), conducted in Saskatchewan from 1997 to 2002, delivered by Agriculture and Agri-Food Canada and Saskatchewan Agriculture, Food and Rural Development (Corkal *et al.* 2004, 1623). The program involved research projects, carried out by technical experts and academics, which aimed at addressing four primary themes: protection of water supplies (BMP research and demonstration); enhancement of farm water sources (well and farm pond investigations); innovative treatment for farm water needs (technology studies and adaptation); and technology transfer (giving new knowledge to the agri-food sector and Canadians) (Corkal *et al.* 2004, 1624). This section will focus on the last theme of technology transfer. In an effort to communicate the findings of this initiative to the public and the farmers who would be implementing the source water protection BMPs, the RWQP researchers were continually challenged to think of creative ways to communicate each study and its findings to the agri-food sector and the public in simple terms, and not simply in terms only understood by the scientific community. This was done through field demonstrations, written articles for agriculture publications or news groups, web sites, newsletters, fact sheets, trade-show displays, presentations at workshops and conferences, scientific publications, interaction with associations, advertising, signage, public service announcements, youth education and other mechanisms of information transfer (Corkal *et al.* 2004, 1636). The RWQP generated great media interest, which led to information being shared with a variety of audiences. Finally, a publication entitled "Water is Life" was also produced by Agriculture in the Classroom, an agency providing educational materials for schools. The book was developed collaboratively as a reference for teachers and students covering topics involving general information on water, water quality and management, and linkages between water and agriculture (Corkal *et al.* 2004, 1638). The program and the associated classroom materials proved so successful that demand from similar educational programs in seven other provinces (in Canada) required a second printing of the document.

Other examples of similar education tools can be found across Canada. The non-governmental organization, Cows and Fish, based in southern Alberta, regularly produces publications directed towards ranchers, farmers and livestock producers that are written in terms that are relatable and readily understood by those who are implementing the source water protection BMPs. One such publication entitled *Caring for the Greenzone: Riparian areas and Grazing Management* provides some basic insights on grazing management principles and how to apply the principles to riparian areas. Also included are practical examples of successful riparian grazing management that are useful to show what is possible to sustain livestock production, maintain biodiversity and care for water quality (Fitch, 2003).

It is extremely important to not only conduct research regarding which BMPs are deemed to be the most effective, but to make sure that those who will be implementing the new practices understand how to implement them properly and most importantly why their efforts are so important to the health of the watershed. Kay, Edwards and Foulger (2009, 72) support this idea by noting that “when implementing stewardship measures in a catchment (…) farmers/land managers have to be given responsibility for implementing certain measures and it is, therefore, essential that they are adequately trained and can be relied upon to carry out the task effectively”.

5.0 Conclusion

As described throughout the paper, source water protection is a fundamental element that ensures the safety of all members of society's drinking water. Agriculturalists, being some of the world's largest private landowners, have a very large role to play in ensuring that source waters remain pristine. However, they are not expected to take on this task alone, as demonstrated by tools mentioned that are readily accessible (government financial assistance, hands-on education programs, publications and community support). Improvements in on-farm management are possible and affordable, but the first step seems to be the realization that a 'business as usual' attitude may not be the best approach to ensuring that safe and reliable drinking water sources are available for those residing within the watershed.

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