# A Proposed Framework for Managing the Impact of Agriculture on Groundwater

## A report prepared for the Sierra-ALERT Coalition for Submission to Part 2 of the Walkerton Inquiry

by
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This draft paper has been prepared as a background document for the Walkerton Inquiry. It is intended to generate and inform discussion about the safety of drinking water among parties with standing, relevant experts, and the public. It does not represent the findings, views or recommendations of the commissioner. Written comments in response to the paper are welcome and will form part of the public record of the Inquiry. They should be submitted to:

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# EXECUTIVE SUMMARY

The tragedy at Walkerton demonstrated that there are presently insufficient safe guards in place to prevent animal derived bacteria from being transported to a water supply well. Water quality data confirm that Walkerton is not an isolated case of pathogenic and chemical contamination of private and public water supplies. A survey of farm wells in Ontario, conducted between 1991 and 1992, showed that 34% of wells were contaminated with bacteria and 14% of wells exceeded Ontario Drinking Water Standards for nitrate (Goss et al. 1998). Sources of this contamination include manure being generated, handled and spread on the farms or neighbouring farms, site septic systems and poorly constructed or maintained wells.

As was so tragically demonstrated in Walkerton, bacteria and viruses are some of the most deadly of the many potential drinking water contaminants. Research has shown that pathogenic bacteria and viruses can travel significant distances under certain geological and hydrogeological conditions. The most sensitive hydrogeological environments are at surface or near surface fractured (or karstic) bedrock and at surface or near surface sand and gravel aquifers. Unfortunately, it is still difficult to accurately predict the fate and transport of bacteria and viruses in the environment. Extra precautions, therefore, must be taken when releasing bacteria to the environment, particularly the common practice of spreading manure on farm fields across Ontario.

Livestock farming has undergone a shift in recent years that has seen the reduction in the number of small scale "family farms" and an increase in large scale operations. Goss et al. (2001) report that 20% of the farms in the high revenue categories produce 67% of the total sales. In areas of increased livestock production, manure generation rates have increased as much as 75% in the 10 years between 1986 and 1996. Although total manure production rates have fallen, statistics show that manure generation is becoming concentrated on large farms in certain parts of the province.

All farms, large or small, pose some degree of risk to the health of the natural environment. Unfortunately, existing regulations of farm practices:

- do not require rigorous site investigation prior to farm siting,
- do not require the use of BMPs in the farm operation,
- do not prohibit manure spreading at times when risk to the environment is greatest,
- do not require leak monitoring for large liquid manure storage facilities or fuel storage facilities,
- do not require monitoring of surface waters and groundwater that receive tile drainage or seepage from storage facilities,
- and do not require contingency plans in the event of facility failure or unforeseen weather.

Existing guidelines that pertain to agricultural practices include Best Management Practices, Agricultural Code of Practice, The Environmental Farm Plan and Nutrient Management Planning. These guidelines are not designed as groundwater protection tools, although some recommendations, if implemented, could minimize impacts on groundwater quality. A stronger, groundwater-focussed protection framework needs to be developed. Emphasis should be placed on activities that are likely to have significant groundwater impacts. “Best” practices should be carefully chosen. Even if these "best" practices are not within reach of many farmers today, they should be put forth as future goals so that we are not simply maintaining the practices that can result in environmental degradation.

Nutrient Management Plans in particular are being put forth as a mechanism to prevent a variety of impacts that may arise from livestock operations. Many municipalities in Ontario now require nutrient management plans prior to approval of new large facilities. However, the use of a nutrient management plan to assure the environmental safety of an operation is inaccurate and inappropriate. A key factor that is missing from nutrient management plans is an assessment of groundwater conditions at the site including depth to the water table, groundwater flow direction, types of material overlying the aquifer (other than surficial soil) and most importantly, assessment of the transport of bacteria to the groundwater zone. Nutrient management plans should either be improved to include leaching to groundwater using a solute leaching model or should only be used as one part of an entire site assessment.

A new regulatory framework should be set up for approvals of new operations and for reducing the existing environmental impacts on sensitive land. Key components of a new regulatory framework should be:

1. Strong provincial legislation that requires a more extensive evaluation of an agricultural operation before approval.

    - An applicant should have to conduct a hydrogeological investigation to show that the spreading of large amounts of manure will not cause an adverse environmental impact.
    - Minimum standards should govern farm practices.
    - Monitoring of groundwater and tile drainage to surface water should be required to show that normal practices are not adversely affecting water resources.
    - Legislation should ensure that local regulating bodies have the appropriate tools to be able to assess the vulnerability of the groundwater resources in the areas and therefore the potential for groundwater impacts.
    - This legislation would also need to ensure adequate qualification of individuals spreading, transporting and handling manure, record keeping, auditing and compliance in order to have a positive effect on the groundwater quality.

2. Aquifer vulnerability mapping across the province is required so that certain areas can be prioritized in terms of the potential for groundwater impacts.

    - The type of mapping may be employed regionally in recognition of the varied geological conditions in Ontario. Appropriate methods are available and have been tested, not only in Ontario but also in other provinces and many states in the U.S.A. The MOE is presently compiling results of thirty-three studies conducted in Ontario and will soon be in a position to put forth methods that worked well in different regions. Aquifer vulnerability mapping would point out drinking water sources that are particularly sensitive to environmental degradation. These areas need to be rigorously protected.

3. Wellhead recharge area mapping is required to delineate the land area where drinking water resources originate. Wellhead protection strategies should be implemented for all municipal water supplies. Recharge areas for drinking water wells should be rigorously protected.

4. Province-wide groundwater monitoring is necessary to determine the impacts of agricultural land uses and to track the changes in groundwater quality with changes in land use.

5. Watershed modelling could use all of the above information to track the environmental health of an entire watershed. This modelling could perhaps be used to delineate areas where no further degradation of water quality should take place and other areas where some capacity still exists to assimilate agriculturally derived pollutants such as bacteria and nitrates.

6. Site assessments are required prior to site approval. Assessments need to include hydrogeological parameters such as groundwater flow direction, groundwater flow rate, potential receptors, travel time to water table etc. More detailed site assessments would require proponents to conduct a checklist type evaluation of their operation, allowing regulators to more appropriately assess potential impacts from a proposed operation.

Agricultural operations have been shown to adversely affect groundwater quality, but they are largely unregulated. Regulations need to be developed beginning with new, large operations that carry a relatively higher risk to water resources followed by existing operations that are in susceptible hydrogeological environments. Incentives must be made available to existing operations to ensure that changes being made for the greater environmental good do not seriously affect farm economics.

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# 1.0 INTRODUCTION

The tragedy at Walkerton was the result of animal derived bacteria being transported to a drinking water well and the subsequent distribution of a contaminated water supply to residents and visitors of Walkerton. Water quality data confirm that Walkerton is not an isolated case of pathogenic and chemical contamination of private and public water supplies. A survey of farm wells in Ontario, conducted between 1991 and 1992, showed that 34% of wells were contaminated with bacteria and 14% of wells exceeded Ontario Drinking Water Standards for nitrate (Goss et al. 1998). Nitrate, the single most common chemical contaminant in the world's aquifers (Spalding and Exner, 1993), has rendered several municipal supply wells in Ontario unusable, resulting in the need to develop other source areas. In Cabool, Missouri, four people died from *Escherichia coli* (*E. coli)* originating from farms and contaminating the water supply (Geldrieich et al. 1992). History shows that human activities are resulting in groundwater becoming contaminated, entering water supply wells and making people sick.

Although the various factors culminating in the Walkerton tragedy will eventually be identified, it has been suggested that the contamination originated from a farm that was following normal farm practices. This is a troubling but not surprising reality. Normal farm practices include the storage and surface spreading of animal wastes that contain very high concentrations of pathogenic bacteria and other contaminants. A variety of voluntary Best Management Practices (BMPs) and educational programs have been recommended by government agencies to reduce impacts on the environment from manure. The farming community has suggested that these voluntary measures are slowly being adopted and will result in protection of our water resources. Upon review, it is found that these measures are not directed at groundwater protection, and even if adhered to, they are unlikely to provide adequate safeguards that groundwater will remain clean enough to drink. This is of particular concern because farming practices in Ontario are more and more being dictated by "global economics" rather than family farm economies.

Livestock farming has undergone a shift in recent years that has seen the reduction in the number of small scale “family farms” and a significant increase in large scale operations. Goss et al. (2001) report that 20% of the farms in the high revenue categories produce 67% of the total sales. In areas of increased livestock production, manure generation rates have increased as much as 75% in the 10 years between 1986 and 1996. Although total manure production rates have fallen, statistics show that manure generation is becoming concentrated on large farms in certain parts of the province.

In the face of intense opposition to large livestock operations from rural residents and other farmers, municipalities have struggled to find a reasonable method to assess and ultimately approve the buildings necessary for these large operations. Municipalities have enacted “Nutrient Management By-laws”, requiring an adequate Nutrient Management Plan (NMP) to ensure that sufficient land is available for manure spreading. The Nutrient Management Plan is the cornerstone of these by-laws and is designed to prevent over application of plant nutrients. Like many of the BMPs, even if the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) enforced NMPs, they generally fail to protect groundwater quality in both their design and implementation. Regardless of any role they play in protecting groundwater, both farmers and OMAFRA find the by-laws too restrictive and are contesting them in court.

We are left with the misconception that there are standards for farming being implemented that will protect groundwater resources. In this paper, we show that despite its useful role in agricultural sustainability, the current reliance on the NMP as a core environmental protection tool is inadequate. We recommend a groundwater focussed method of approvals for new livestock operations that will incorporate the vulnerability of local groundwater resources with a more detailed site assessment to provide a greater degree of protection to water resources. We also present a framework addressing existing operations that may be impacting water quality.

This paper is divided into five parts including:

1. A background section providing discussion on contaminant movement in groundwater, pathogen transport
2. Review of legislation and guidelines pertaining to water quality protection and guidelines pertaining to agricultural operations; emphasis in this section is on how these guidelines fail to protect groundwater quality
3. A proposed framework for approvals of new agricultural operations
4. Wellhead protection strategies
5. Recommendations and conclusions

### 1.1 Contaminant Movement in Groundwater

Agricultural sources of groundwater and surface water contamination are generally divided into two categories: point sources of pollution, such as spills and leaky storage tanks, and non-point sources of pollution, such as farm fields receiving manure and pesticide applications. Non-point source contamination has received significantly less attention and less funding, in part because some non-point contaminants are considered less dangerous, and because non-point application of fertilizer, manure and pesticides is a necessary part of agriculture.

There are several pathways for agricultural chemicals to reach the groundwater regime and specifically water supply wells. The most direct route and the one that can result in immediate degradation of water quality is direct ingress of surface runoff into poorly sited, improperly constructed or abandoned wells. Surface Water may travel down the inside or the outside of a well casing, by-passing the natural geologic strata that could have provided some degree of natural attenuation of the chemicals. In this way the well, and possibly the aquifer, can be directly contaminated by surface activities. This may be the easiest route of contamination to eliminate, through properly siting, constructing and decommissioning wells. Unfortunately, there are many abandoned wells in Ontario whose locations are unknown. These wells continue to threaten even the most protected aquifers. Several government programs target the identification and proper abandonment of wells.

Pathogens and contaminants can also move through the unsaturated zone with infiltrating water. Contaminant movement is generally downwards, directly beneath a spill, leak or prescribed surface application. Permeable materials, such as gravel or fractured rock, exposed at the surface, are well recognized as pathways for contaminants to enter and impact aquifers. Layers such as silt and clay provide a hydraulic barrier and can protect underlying aquifers, if these layers are continuous and competent. The small pore spaces in silt and clay deposits can result in a slow transport rate. Although it appears that silt and clay environments are ideal to minimize groundwater contamination, fracturing of these materials near the ground surface or the presence of root holes and wormholes create "secondary permeability" that can render these materials highly permeable. Fractures can penetrate meters downward, facilitating the movement of contaminants from the surface to the groundwater regime. Once in the aquifer, contaminants can quickly move towards a well, assisted by natural groundwater flow and increased flow rates induced by pumping.

Shallow wells are considered to be particularly susceptible to contamination from surface activities. Shallow dug wells are closer to the contaminant sources and because of their limited depth, are less likely to have encountered geologic media that would provide natural barriers to contaminant transport. Conboy and Goss (2000) found that even shallow wells in clay rich sediments were susceptible to contamination presumably due to the presence of fractures or macropores. Drilled wells with steel casing installed to the target aquifer represent the least susceptible well type.

Once introduced to groundwater, geological and geochemical environments control the rate and direction of contaminant movement. Groundwater movement is typically faster in larger grained, more permeable sediments (e.g., gravel), relative to finer grained, less permeable (e.g., clay) sediments (Table 1) making the former type of geologic environment a higher risk for contamination.

**TABLE 1: Estimated Time for Groundwater Movement Through 100 metres of Different Media**

| Media | Grain Size [mm] | Hydraulic Conductivity [m/s] | Approximate* Time to Travel 100 m |
|---|---|---|---|
| Clay | <0.002 | $10^{-11}$ | >100,000 years |
| Silt | 0.002-0.0625 | 0.0000001 | 500 years |
| Sand | 0.0625-2 | 0.0001 | 200 days |
| Gravel | 2-64 | 0.01 | 2 days |
| Fracture | - | Variable | Possibly <1 day |

* Hydraulic gradient of 0.02

The fact that we can identify many contaminant sources such as underground fuel storage tanks, manure, fertilizer and pesticide storage facilities gives us the opportunity to eliminate or minimize their effect on the environment. Minimizing the introduction of contaminants to the environment, particularly very vulnerable environments, is the most reliable method of reducing risks from bacterial and chemical contamination.

### 1.2 Pathogen Transport in Groundwater

Until recently in Ontario, groundwater contamination from bacteria, viruses and protozoa has received little attention compared to contamination from organic and inorganic chemicals. The Love Canal and Smithville sites are well known groundwater contamination cases. But how many people followed stories of bacteriological contamination such as Cabool, Missouri (four deaths), or New York State Fair (one death)? Pathogenic microorganisms (including bacteria, viruses and protozoa) are known to cause the majority of waterborne diseases (Payment, 2001). Pathogenic bacteria may be found in human and animal feces, but pathogenic viruses are typically restricted to human feces.

The introduction of fecal matter to the environment is a significant source of biological contaminants for groundwater. Biosolid application, manure spreading and septic system effluent are three mechanisms for pathogenic release to the groundwater environment. The farms in Ontario are projected to produce over 29 billion litres of manure for 2001 (Goss, 2000). The 2.5 million people serviced by septic systems in Ontario (MOE, 1982**)** produce approximately 675 million litres of septage a year, while 1.5 billion litres of biosolids are applied to land each year (MOE pamphlet). Although all farming operations are capable of contaminating groundwater, livestock farms producing large volumes of manure are more likely to result in pathogen transport to groundwater and contamination of water supply wells. Storing, handling and transporting large volumes of manure increases the probability of a spill occurring.

The travel distance of a microorganism in the subsurface is governed by its own lifecycle (e.g., nutrient and respiratory needs) as well as hydrogeological properties of the underlying geological media (e.g., porosity). Exposure to the water, temperature and geologic media are the primary controls for pathogen transport in groundwater. The broadcasting of manure and biosolids on agricultural fields subjects the microorganisms to several environmental pressures. Exposed microorganisms may be killed by lack of moisture (desiccation) and ultraviolet radiation. These processes often require extended periods of time and cannot be considered as treatment because of the possibility of a precipitation event, which would diminish desiccation and promote infiltration thus removing the potential for ultraviolet treatment. In a study where bacteria was applied to a rye-grass covered field, *E. coli* was observed to survive for 13 years in the soil (Sjogren, 1995). The greater the concentration of waste application (septage, biosolids and manure), the more likely that bacteria will survive. High volume applications may reduce the time that pathogens are exposed to drying conditions and ultraviolet radiation on the surface. Microorganisms that have been pre-stressed by somewhat toxic mixing environments have also been shown to have higher survival rates in the natural environment (Chappelle, 1998). For this reason, studies using inoculated laboratory strains of *E. coli* should not be considered indicative of in-situ survival conditions.

Perhaps the most significant parameter for the longevity of bacteria and virus survival is temperature. Buswell et al. (1998) found that *Campylobacter* survived longer in water microcosms at 4 °C than 22 °C and longer at 22 °C than 37 °C.

Pathogen transport by groundwater is also controlled by physical filtration of microorganisms by the media. Table 2 compares the approximate sizes of microorganisms and pore sizes. Due to the larger size of parasites, most geologic media will filter them out, while the smaller bacteria and even smaller viruses are able to travel through even the finest grained soils. Most geological media are now conceptualized as possessing dual porosity. The primary porosity, as described above, comes from the arrangement of individual grains. The secondary porosity comes from such features as fractures, desiccation cracks, bedding planes, and other discontinuities. The secondary porosity, unfortunately, may be several orders of magnitude larger than the primary porosity. The implication is that even fine grain sediments like clay may be able to transmit the largest of the microorganisms.

**TABLE 2: Approximate Cross-sectional Areas of Microorganisms and Geologic Media**

| Microorganism | Approximate Size [$cm^2$] | Media | Approximate Pore Size [$cm^2$] |
|---|---|---|---|
| Virus | $10^{-10}$ | Clay | $10^{-12}$ to $10^{-15}$ |
| Bacteria | $10^{-7}$ | Silt | $10^{-8}$ to $10^{-12}$ |
| Parasite | $10^{-5}$ | Sand | $10^{-5}$ to $10^{-8}$ |
| | | Gravel | $10^{-3}$ to $10^{-6}$ |

In the subsurface macropores are inherent in tilled and untilled soils and provide large diameter pore spaces for less restricted transport of bacteria and viruses. Murray et al. (1998) found that preferential water movement occurred through well-structured silt loam soil. A non-uniform distribution of drainage through the soil was observed, with fecal coliform organisms consistently exceeding 200,000 CFU/100 ml at a depth of 32.5 cm.

Studies have shown that pathogen transport through soil is promoted by heavy rainfall, and bacterial contamination of wells was found to coincide with periods of heavy rainfall (Lamka et al. 1980; Zyman and Sorber, 1988).

The physical properties of geologic media cause microorganisms to travel different distances due to factors such as pore size and mineralogy of the media. Generally, microorganisms will travel farther in more permeable sediments, but heterogeneity in each medium will result in varying transport distances. Gerba et al. (1975) observed coliform bacteria to travel 0.6 m in fine sand and 830 m in sand-gravel. Harvey et al. (1989) found bacteria to move more than one kilometer in a "loamy sand aquifer", and Gerba and Bitton (1984) found transport up to several kilometers in fissured karstic aquifers. Malard et al. (1994) observed that sampled wells in fractured limestone had high, instantaneous, and localized fecal contamination, created by continually percolating secondary sewage sludge and sludge particles through large fractures.

Champ and Schroeter (1975) observed *E. coli* to be transported faster than a bromide tracer in fractured crystalline rock. Under forced-gradient conditions, DeBorde et al. (1998) observed that in sand and gravel, a portion of the injected virus traveled at least as fast as a bromide tracer. Virus transport was observed to be at least 38 m from the injection site.

A simple estimate for the survival or transport of pathogens in groundwater is not plausible. The risk of pathogen transport in groundwater, however, is increased in more permeable media, and bacteria impact one in three wells in Ontario. Little can be done to protect shallow dug wells other than proper siting, construction, and an elimination of surface and subsurface sources. Widespread contamination of regional aquifers can be greatly minimized by evaluating the sensitivity of the aquifer to contamination and adjusting farm practices accordingly. One cannot, within reason, significantly control contaminant pathways leading away from individual farms. One can, however, with knowledge of regional geologic and hydrogeologic conditions gauge the relative risk of certain farming practices and direct these types of farms into less vulnerable areas. Section 5 presents a framework through which this evaluation can be made. Minimum distance separations or Best Management Practices (BMPs) are not universal answers for protecting wells or groundwater resources.

Historical and recent initiatives by the Ministry of the Environment (MOE), OMAFRA and the Ministry of Natural Resources (MNR) are providing regionally based tools that allow for relatively detailed hydrogeological information to be readily available. A framework for utilizing this information is presented in Section 5.

### 1.3 Impacts of Large Livestock Operations

The shift from family farms to large-scale livestock production operations has triggered discussion and debate regarding the environmental sustainability of agricultural adaptation to economic pressures. Manure spills data in the United States and Canada show that large operations do not necessarily provide a sufficient degree of protection even though there are generally more staff, more of the operation is automated and more financial resources are invested. The spills that occur from the larger operations are often extremely large spills resulting in significant environmental impacts.

Scale and density control the environmental risk between large farms and traditional family farms. These very large farms resemble an industrial operation in many ways; animal production is maximized in a controlled, confined environment. Some of the large farm operators are contract farmers; the owners of the animals are often large companies and generally do not participate in day to day animal production. Animal feeds are imported to the production site, while crops grown on site sold for cash. Waste generation is far greater than on smaller farms, and close animal confinement enhances transfer of pathogens between animals (Halverson, 2000).

Large agricultural operations should be regulated more stringently than small operations. Examples of the influence of scale on regulation include single septic systems versus systems designed to service 20 homes, the latter requiring an extensive site investigation. In general, the transition from a small cottage industry to factory-scale production is accompanied by greater environmental restrictions. The existing nitrate impacts to groundwater in Ontario must be the result of small-scale operations since larger operations have only become commonplace in the past 10 years or so. Therefore, these small operations also need to be more strongly regulated. The increasing number of large-scale operations concentrated in certain parts of the province, however, have the potential to produce an even more damaging affect on our groundwater resources, if they remain unregulated.

The argument in favour of larger scale production is that large, well-financed farms have the resources to better manage their manure issues. Unfortunately, accidents do happen, and when they do, an accident may turn into a catastrophe. For example, in April 1999 a lagoon at Murphy Family Farms in North Carolina burst, spilling 1.5 million gallons of manure. The pollution entered a tributary of the North East Cape Fear River. The cause of the catastrophe was believed to be tree roots that had degraded the integrity of the lagoon wall.

The cumulative impacts of multiple smaller spills may also degrade water quality. From 1995 to 1998, over 3.3 million fish were killed in 250 manure spills in the five Midwest states bordering the Upper Mississippi River. The impacts of these spills and seepage were felt down to the Gulf of Mexico. Over a four year period in ten states approximately 1000 spills or other pollution incidences originated from feedlots (Clean Water Network, 2000). While the causes of pollution varies from state to state, runoff from over application of manure, spills from lagoons, equipment failures and purposeful dumping were sited as the primary causes of pollution.

Accidental spills aside, evidence has not been published to show that larger corporate owned, multi-site production facilities have better onsite environmental protection.

The large single site generation of manure at intensive livestock operations is not regulated as rigorously as other organic wastes in Ontario (e.g. Biosolids, Sewage Lagoons, etc.). Guidelines, approvals and exemptions are not consistent and result in unknown environmental impacts. The handling and application of 29 billions litres of manure is controlled by far fewer approvals and guidelines than the handling and application of 1.5 billion litres of biosolids and the 675 million litres of effluent that passes through septic systems every year.

Municipal and industrial sewage lagoons are covered by Section 52 and 53 of the Ontario Water Resources Act. The application of biosolids to land is covered by Ontario Regulation 347, which is supplemented by the Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land. The Ontario Building Code, Ministry of the Environment Approval, and Ontario Guideline

B-7 (Ontario Water Resources Act) regulate large or communal septic systems. The Ontario Building Code and Ontario Guideline B-7 regulate communities using individual septic systems. In addition, sewage works and biosolid applications are subject to approval by the Planning Act, the Environmental Protection Act and Ontario Water Resources Act. The handling and application of manure by agricultural operators is not subjected to equivalent rules and regulations.

Using manure and nutrient production values obtained from Goss et al. (2000), the nitrogen produced from a Livestock Unit can be estimated at 120 g of nitrogen per day. Using MOE values for septic tank effluent, a 2.5 person house, producing 1000 L of effluent with 40 mg/L equates to 4 g of nitrogen per person per day. The population of Huron County, which in 1996 was approximately 59,000, would produce approximately 86,000 kg of nitrogen in a year. The nitrogen production from livestock operations in Huron County in 1996 was estimated by Goss et al. (2000) to be over nine million kilograms of nitrogen. These numbers, coupled with a permissive regulatory environment, present a clear threat to water resources in Ontario. The following section examines the current regulatory framework in more detail.

## 2.0 EXISTING LEGISLATION PERTAINING TO GROUNDWATER

The MOE is the provincial agency specifically responsible for groundwater management and protection, as well as for the legislation and development of policies and guidelines that control the use of groundwater resources and the possible interference with the natural resource. Ontario does not have legislation governing agricultural practices, providing for the designation and protection of aquifers or legislation that requires the development of wellhead protection programs.

In the absence of adequate groundwater protection legislation, municipal governments have begun to implement restrictions for certain land uses. In some cases this has meant including land use restrictions in official plans for protecting wellhead capture zones. For many years, municipalities have required hydrogeologic studies prior to approval of various types of development including rural residential developments and gravel pits. The approval process has required the proponent to show that there will not be any negative impacts to groundwater resources from the new land use. Similar requirements should be in place for proposals where large quantities of manure will be stored and spread on a site.

The existing legislation that was designed to protect all water resources, although not specifically groundwater, is described below.

### 2.1 The Environmental Protection Act (1990)

The Environmental Protection Act (EPA) is one of the two main environmental statutes that can be used to protect groundwater quality in Ontario. The emphasis of the EPA is to prohibit discharge of contaminants to the environment that may impair or damage the environment. The Act focuses on point source pollution and does not specifically apply to animal wastes used in normal farm practices.

Remedial orders can be issued for repair of the damage to the environment, prevent damage to the environment or to provide water supplies where water resources have been or may be impacted. Orders from the MOE may require a hydrogeological study and require a remediation plan. Orders can be issued on reasonable and probable grounds of a contaminant discharge to the environment.

Orders have been issued by the MOE under the EPA to address situations where drinking water has been threatened. Failing to comply with an Order is an offence and may result in fines or convictions. The Act has also been used when there was no environmental harm from a spill but it was proven that the potential for harm to a river and municipal drinking water well fields was high.

Part X of the EPA requires the reporting of any chemical spill, including manure spills, in Ontario. This portion of the act has been used to require investigations or remediation at farms where spills have occurred or are suspected.

A conviction for an offence of contaminating groundwater may take place without proof of the actual groundwater contamination. It must be shown that the activity has caused or is likely to cause an adverse effect on the environment.

The application of biosolids to lands is controlled by Regulation 347 under the Environmental Protection Act and must comply with the Ministry of the Environment Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land. A Certificate of Approval for a Waste Disposal Site (Organic Soil Conditioning) must be obtained before biosolids can be applied to agricultural land.

An additional Certificate of Approval for an Organic Waste Management System is required for transporting the waste from the waste generator to the transfer an/or the receiving sites. This Certificate of Approval also covers the application procedure of the operating company. The Certificates of Approval for a Waste Disposal Site (Organic Soil Conditioning) and for an Organic Waste Management System must be renewed every five years.

Despite the latitude supported by this piece of legislation and the similarities between large manure applications and biosolid applications, it has not been used to restrict agricultural practices on the basis of potential future groundwater impacts.

### 2.2 Water Resources Act (1990)

The Ontario Water Resources Act (OWRA) is intended to preserve the quantity and quality of natural waters. The Act prohibits the discharge, from public or private buildings or undertakings, of any material to a water body or watercourse that impairs the quality of water. Each discharge to the environment must be reported to the MOE.

Guideline B7 or the "Reasonable Use of Groundwater Policy" was established to protect groundwater quality at property boundaries. The guideline is applied to developments that include landfill sites, communal septic systems and multi-unit developments with individual on-site sewage treatment. This is an example of a guideline that has become a requirement prior to approval of new systems by the Ministry of the Environment. Large septic systems receiving more than 10,000 L a day or receiving waste from five or more homes must conform to Guideline B-7 and must obtain a Certificate of Approval from the Ministry of the Environment.

Guideline B-7 requires the proponent of a development to show that the new land use will not adversely impact groundwater quality. An estimate of the contaminant loading is diluted by the available recharge on the property and the underlying groundwater. Although the procedure has been over-simplified in its application, it provides an example of how protection of groundwater quality can be incorporated into land development applications. A comparison of the estimated 20g of nitrogen released to the environment from 5 septic systems compared to the 600g from a small livestock operation (5 livestock units) that may have a similar land base, suggests that it is appropriate to extend some similar requirement to livestock operations.

The construction of sewage lagoons is also regulated under the OWRA. A Certificate of Approval is required under Sections 52 and 53 for construction of a new sewage works or modification to an existing sewage works. Site investigation and pre-application consultation with the Ministry of the Environment is required for the design of each sewage works. This type of approval process is not required for the storage of animal manure.

### 2.3 The Environmental Assessment Act (1990)

The Environmental Assessment Act (EAA) is intended to protect, conserve and properly manage the environment. This Act does not specifically deal with groundwater, but water resources as a whole. Concerns for groundwater impairment are not laid out, but are left to the discretion of the MOE.

Certain types of land use applications are subject to the detailed planning and approvals process of the Environmental Assessment Act. In this process the public and interest groups may question the application on the basis of many factors, one being environmental impacts. Therefore, protection of groundwater resources can be questioned and therefore needs to be addressed if the potential to impact groundwater exists.

### 2.4 Planning Act (1990)

The first policy statement of provincial interest under the planning act states that:

2. *The Minister, the council of a municipality, a local board, a planning board and the Municipal Board, in carrying out their responsibilities under this Act, shall have regard to, among other matters, matters of provincial interest such as, the protection of ecological systems, including natural areas, features and functions*;

Unfortunately, this policy has been largely dormant, unlike other policies that seem to have been coupled with good guidance documents and have been well implemented. Other policy statements that could also pertain to drinking water and groundwater resources are following:

*(c) the conservation and management of natural resources and the mineral resource base;*
*(e) the supply, efficient use and conservation of energy and water;*
*(f) the adequate provision and efficient use of communication, transportation, sewage and water services and waste management systems;*
*(o) the protection of public health and safety;*
*(p) the appropriate location of growth and development. 1994, c. 23, s. 5; 1996, c. 4, s. 2.*

The Planning Act allows municipalities to restrict the use of lands through zoning by-laws. Section 34 (3.1) specifically addresses groundwater:

*3.1 For prohibiting any use of land and the erecting, locating or using of any class or classes of buildings or structures on land that is contaminated, that is a sensitive ground water recharge area or head-water area or on land that contains a sensitive aquifer.*

It would appear that this definition is broad enough to allow municipalities to restrict land uses in any area shown to overlie a sensitive aquifer.

## 2.5 Drainage Act (1980)

The Tile Drainage Act (TDA) prohibits the discharge of any material except for unpolluted drainage water into any drainage network. The Act does not define polluted waters nor does it specifically deal with the pollution of groundwater. Most tile drains would fail this criterion at certain times during the year (Flemming and Bradshaw, 1992, Wall et al. 1996)

## 2.6 Ontario Regulation 459/00

The new Ontario Regulation 459/00 for Drinking Water Protection specifically addresses groundwater as a separate source of water. Groundwater is recognized to have different behaviour, impacts and requirements for monitoring and treatment than surface water sources. Any system that withdraws more than 50,000 l/day of water is required to monitor the source and report the results to MOE. This regulation will likely result in more rigorous monitoring of drinking water source areas.

### 2.7 The Fisheries Act

The Fisheries Act is a federal statute stating that no activity can harmfully alter, disrupt or destroy fish habitat. The fisheries act has been used in numerous cases in Ontario where poor agricultural practices have been employed.

## 3.0 EXISTING GUIDELINES FOR MANAGING FARM OPERATIONS

Ontario does not yet have specific legislation or regulations to govern water quality impacts from agriculture. Ontario does not have the specialized regulations and targeted guidelines that focus on manure management practices and water quality impairment that have been documented in other jurisdictions (Goss, 2000). There are several guideline documents available to assist farmers in making environmentally friendly decisions on their farms. In this section, we will examine each of the guidelines that are available as environmental protection tools and discuss how they in fact fall short of being groundwater protection tools.

The guidelines that have been developed to assist farmers in making environmentally friendly choices on their farms include:

- Best Management Practices Documents (BMP) prepared by Agriculture and Agri-food Canada
- Guide to Agricultural Land Use prepared by Ontario Ministry of Agriculture, Food and Rural Affairs
- Environmental Farm Plan (EFP) prepared by Ontario Farm Environment Coalition through Agriculture and Agri-food Canada
- Nutrient Management Planning (NMP) support materials (NMAN, NM Factsheet) prepared by Ontario Ministry of Agriculture, Food and Rural Affairs

Each of these documents provides constructive advice to reduce the impact of farming on the environment. However, they were not designed specifically as groundwater protection tools, and they generally do not target impacts to groundwater quality. Most of these voluntary guidelines were intended as educational tools and as such have great value, however, they do not guarantee any degree of groundwater protection. Some of the recommended farming methods deviate from conventional farming methods and there has been no conclusive analysis of the level of adoption of these practices.

As background to the following discussion, it is important to note what information is necessary to estimate impacts on the groundwater regime. Table 3 shows what factors are important and why.

**TABLE 3: Factors Affecting Groundwater Contamination**

| FACTOR | IMPORTANCE |
|---|---|
| Depth to water table | The greater the travel distance of any potential contaminant prior to reaching the groundwater regime increases the potential for geochemical reactions or physical retention of contaminants. |
| Type of surficial deposit, type of deposit separating the surface from the groundwater regime | The type of material that a contaminant travels through to reach the groundwater regime is a very important factor dictating what degree of filtration or treatment is achieved prior to reaching the groundwater regime. For example, bacteria would be unable to travel significant distances in fine sand or silt. |
| Type of aquifer material | The type of aquifer material dictates the speed with which a contaminant would travel in the groundwater and the amount of filtration or treatment that could be expected in the groundwater regime. |
| Direction of groundwater flow | This influences what receptors may be adversely impacted. |
| Depth to bedrock (bedrock wells only) | Because certain types of bedrock provide little or no treatment of contaminants in the subsurface, the amount of material overlying bedrock dictates the amount of treatment possible prior to reaching the groundwater regime. |
| Type of bedrock (bedrock wells only) | The type of bedrock would allow an assessment of the speed with which contaminants may travel. |
| Soil Chemistry | The potential for treatment of potential contaminants in the soil zone is partially defined by the soil chemistry. |

It is common practice in the guideline documents developed for farming practices to make reference to the soil type as an indication of whether or not certain practices will affect groundwater. The use of the soil type, which generally represents the top ten to forty centimetres of the earth's surface, to estimate the level of protection available for groundwater resources has limited applicability. Even a “very slow” soil like clay may be subject to secondary permeability from fractures, desiccation cracks, root holes or other factors that would allow rapid transport of water and contaminants. It may also be underlain by highly permeable rock or sediments. The presence of root-holes or fractures in a clay rich soil will result in a permeability that is just as high as a sand rich soil. This can be demonstrated in instances where tile drains run immediately after a manure application despite the surficial soil’s clay rich nature (Fleming and Bradshaw, 1992a.). Lammers-Helps (1997) discusses three independent groups in southwestern Ontario that have shown that liquid manure applied to fields can enter tile drains in as little as five minutes. Fleming also demonstrated that presence of macro-pores connecting the soil surface to the tile drains, by blowing smoke into tiles and observing its pattern immediately above the tile (Fleming and Bradshaw, 1992a.). Intact and unfractured surficial soil has some capacity to attenuate certain contaminants but the degree of attenuation for many contaminants is unknown, also the ability of the soil to attenuate may be degraded by certain stresses, including the agricultural use of land (Vrba and Zaporozec, 1994).

In most cases, there are at least several metres of geologic material separating the surface from the groundwater regime with the surficial soil being only one of several layers. It would be more useful to combine the soil type with the full range of subsurface materials above the aquifer. On a regional scale, this can be assessed using quaternary geology mapping and water well records. On a site-specific scale, the surficial deposits can be investigated with sampling probes or a drilling rig. Investigations may determine the presence of fine sand above the water table that may provide effective filtration of bacteria; or the presence of an organic carbon rich deposit that may be conducive to denitrification reducing the nitrate inputs to the aquifer. If, however, deposits separating the surface from the aquifer are thin or highly permeable, then the presence of a clay rich soil at surface will not likely provide the necessary protection to the aquifer.

Another issue commonly omitted from guidance documents is any discussion related to bacterial transport. The Walkerton tragedy demonstrates the necessity of having bacterial transport treated as scientifically as nitrate and phosphate have been.

Finally, currently these guidelines do not differentiate between small and large operations. It stands to reason that an operation that stores, handles and spreads much larger volumes of manure, poses a higher risk to the environment and should be required to have a higher standard of practice. In many other sectors, there exist small generator exemptions and a scale of operations at which regulation becomes more stringent.

### 3.1 Best Management Practices (BMPs)

The series of BMP documents prepared by Agriculture Canada and OMAFRA are excellent resource documents with information to help farmers choose better ways of managing many aspects of their farms. The BMP documents represent the backbone of environmental management guidance for farms. In addition to best management practices, these documents provide information including the costs and benefits of many farm related systems like manure storage and applications systems, types of manure treatment, detecting water quality problems etc. The documents discuss the potential for groundwater contamination and diagrams demonstrate the water cycle and partially demonstrate the connection of the surficial activity to the groundwater below. The BMP documents that are relevant to protecting groundwater are:

- Water Management
- Nutrient Planning
- Nutrient Planning Management

- Livestock and Poultry Waste Management
- Water Wells

These documents contain sufficient information to enable a farmer to make environmentally wise choices. In general, they give many options to achieve certain goals. As education tools, they are informative and easily understood. They provide guidance which, if followed, may help to maintain or improve groundwater quality.

Some problems with the BMP documents with respect to groundwater are as follows:

- They do not focus on groundwater as a local resource that supplies neighbours with water and provides baseflow to surface watercourses. Any discussion of groundwater is directed at the farm-well, and not at the resource as a whole. Although the quality of the farm-well is of primary importance to the farm owner, contaminating activities may take place down-gradient of the well and contaminants may move with groundwater flow offsite, impacting the groundwater aquifer, neighbouring wells, or surface water features. For example, the BMP for fertilizer storage and handling states *"Spilled fertilizer can leach to ground water and harm your water supply. Nitrate contamination of well water is of particular concern"*. The groundwater resource could be impacted down-gradient from the farm well but upgradient from other wells. Simply focussing on the farm well is important but not sufficient.

- The BMP program needs a much stronger conceptual model of groundwater contamination from surface activities. For example, the Water Wells BMP states that *"The existence of these contaminants (biological) in water results from poor sanitation, improper handling of human and animal wastes and poor well construction or maintenance"*. Actually, these contaminants could be transported to groundwater from manure spreading, transfer, storage or other "normal" farm practices. Those responsible for manure management should know that what happens on the surface affects both ground and surface water quality.

- The environmental risk of some activities is not clearly highlighted. For example, in the Water Management BMP, the discussion of leakage from fuel storage tanks states that *"A fuel oil, gasoline or diesel leakage can move easily through soil to ground water. Once there, it will float on the surface of the water table and will usually not travel far from the leakage site. This can pose a threat to your farm's well water*". This discussion does not fully represent the danger of groundwater contamination from fuel oil or gasoline. Not only could a leak render the farm well unusable, it may also contaminate neighbours' wells, or an entire community's water supply. Contaminated water could be consumed without the owner's knowledge, possibly resulting in negative health effects. Explosive gases could also build up in confined spaces from a fuel leak. These documents need to emphasize that serious health and safety risks arise from inadequate practices.

- There is limited discussion of bacterial contamination of groundwater resources in these documents and how this can be avoided.

- Many agricultural practices are not clearly recommended or condemned. A range of practices is described as "best management practices" in some cases. These really represent a range of alternatives. A **Best** practice needs to be defined and strongly recommended. It is a challenge, however, to define a best practice that protects air, water and soil. For example, in the manure storage discussion the text states that *"some form of storage for manure and contaminated liquids is the best management practice"*. However, manure storage facilities can range from the uncovered manure pile in a field to a well designed, covered storage system with all surface water diverted around the structure and a year of storage to optimize the crop uptake of nutrients. Only the latter example should be an example of a "best" management practice.

- The lists of "best management practices" are not highlighted adequately in the BMP manuals. Practices such *as "keep constant supervision to ensure that there are no (pesticide) overflows"* and *"locate the area where you mix and load (pesticides) as far away as is practical from any water source"* are contained in a list titled "Here are some tips and considerations". These recommendations should not be considered "tips". Stronger recommendations need to be put forth so farmers are aware of what they should be doing and what practices are optional.

- There are contradictions in the desired manure storage capacity at farms. The Livestock and Poultry Waste document recommends that at least 200 days of manure storage be provided. This would require spreading manure in the spring <u>and</u> fall. The BMP for manure application recommends that *one "make sure crops can use fertilizers or manure at time of application"* and indicates that applying manure between November and March should only be conducted in emergencies. Even in August to October, they suggest only applying to grassland or lands that will be planted with winter cover crops. Various other studies agree that the greatest nutrient uptake occurs in the spring and summer and that fall spreading may waste (i.e. release to the environment) the nutrients that were present in the manure (Goss, 2001). OMAFRA's documentation states that only half of the nitrogen in fall applied manure should be considered as available for crop growth. The remaining 50% must by default be released to the environment (OMAF, 1988). Therefore, data shows that a full year of storage would be the minimum **best** practice to facilitate spreading in the spring, and something greater than 365 days storage would allow the full flexibility to operate around an early spring followed by a late spring and climate variables. The BMP documents, on the other hand, do not recommend or specify 365 days of storage.

- In some cases, the BMP is simply not adequate to protect groundwater resources. In the section describing manure application systems it states that "*Groundwater will be contaminated if: manure is stored on bare ground and the soils are sandy and gravelly or* *storage is for more than 30 days when soils are loamy or clayey or the stacked compost or compost pile is never moved. Composting should be done on concrete in a roofed structure to prevent excessive leaching of nitrates"*. Although this statement recognizes the potential for groundwater contamination, best management practices should dictate that all manure on sandy or gravelly soils should be stored on concrete surfaces and covered, not just composting manure.

- Some data that are necessary to carry out BMPs are not routinely collected. The Nutrient Management BMP contains detailed instructions on how to sample the farm soil and the manure to determine the nutrient content prior to manure spreading. "Analyses should be performed on samples collected from areas no larger than 25 acres using a minimum of one core per acre and collected from random points over the field area. Use a zigzag pattern to ensure you cover evenly the areas being sampled. Cores should be taken to a depth of six inches." The majority of farmers do not sample soil and manure on a regular basis. Without the actual site data, some of the nutrient management calculations are meaningless.

- Some recommended practices are not standard farm practice and therefore are not commonly adopted. Equipment calibration is necessary to estimate the amount of manure added to fields. *"Often overlooked, calibrating your nutrient application equipment is an essential step in getting your crops the recommended levels of nutrients*". Not only is calibration necessary to estimate the amount of nutrients being applied but also the amount of liquid applied may have an effect on bacterial penetration into the subsurface, which may in turn affect their persistence in the soil.

### 3.1.1 Recommendations to Improve BMPs

Despite the promotion of BMPs, Agriculture and Agri-food Canada found in 1995 that between 25 and 50% of farms within several different regions of Canada stored liquid manure in unlined storage facilities. Between 5 and 45% of farms were spreading manure in the winter. These statistics show that the adoption of voluntary measures can be slow, possibly too slow to address environmental concerns.

Some flexibility in the recommended farm practices is appropriate; certain practices make sense for certain farm operations. Where groundwater protection is at risk, however, it makes sense that the flexibility depends on the vulnerability of the groundwater at the site to contamination from surface activities. In certain hydrogeological scenarios, many different manure treatment techniques could be practiced and groundwater would not become contaminated. In other cases, anything but the most stringent practices may result in groundwater contamination. For existing landowners, it may not be appropriate to restrict operations without compensation, but for new operations in sensitive areas, clear, stringent management practices should be advocated.

In order to protect groundwater and drinking water source areas, the BMPs need to acknowledge the entire groundwater regime rather than focussing solely on the farm well. Contamination of groundwater at points distant from the farm well may not impact the well but may cause other detrimental effects on surface water, other wells or render the resource unusable so that new wells installed in the future would not have adequate water quality.

The BMP documents contain large amounts of information. Recommendations, therefore, need to be emphasized more strongly. This will clearly show which practices are good environmental practices, and equally importantly, which practices are unacceptable.

As an education tool, these documents need to strongly emphasize the connection between surface activities and groundwater contamination.

In order to protect groundwater resources BMPs need to recommend more wide-ranging protective measures. Livestock yards need to be sited adequately to prevent infiltration and areas of chemical or manure storage need to be either lined with an impermeable material or be located in an area of low susceptibly for groundwater contamination.

In order to minimize nitrate contamination of groundwater, samples need to be taken at a given farm site to assess if nitrate is being over applied. If nitrate contaminated groundwater is found, then practices should be altered, and less nitrogen fertilizer should be used. Perhaps different cropping rotations should be implemented, or perhaps nutrient management plans need to be revised to account for the surplus. New large operations have the opportunity to protect groundwater if they conduct groundwater monitoring.

Tile drains and their effluent need to be included more systematically as a key component in the overall water protection strategy. Drains need to be inspected before and after manure spreading and the flow of contaminated water to surface water bodies needs to be monitored. More research must be focussed on abatement of contaminated tile flow.

Existing BMP development lacks performance monitoring and assessment of BMP utility. Ongoing research into alternative and cost effective systems, and into the main risk factors on farms needs to be promoted and funded. Many of the assumptions inherent in BMPs have not been adequately tested.

### 3.2 Guide to Agricultural Land Use

The Guide to Agricultural Land Use replaced the 1976 Agricultural Code of Practice. It advises farmers on how to avoid or reduce conflicts with neighbours and environmental impacts through the use of appropriate farm practices and equipment. It is an entirely voluntary program that emphasizes the importance and potential impacts of farming practices on the environment and neighbouring land uses.

The Guide to Agricultural Land Use lacks information on how to accomplish some of the environmental goals that are stated. Some examples of how this document addresses groundwater are discussed below.

- This document contains contradictory recommendations regarding the length of manure storage required and the optimal time for manure spreading. In the manure management section the guide indicates that *"From an environmental viewpoint the system chosen should be able to provide: Protection for groundwater and surface water, …. A storage period of at least 200 days with 250 days recommended for optimum flexibility. This ensures that the manure can be stored until it can be used efficiently on the land …..".* However, 200 days of storage does not allow farmers to spread manure solely in the spring and early summer as recommended in the same document. *"…when the manure is…incorporated into the soil just prior to crop planting or during crop growth …This practice reduces odours, reduces nitrogen losses, improves crop responses and guards against runoff.".* Again, 365 days of storage needs to be recommended as the desired manure storage capacity.

- The guideline references some of the important hydrogeological factors in assessing potential for groundwater impacts but no recommendations are given as to how they could be incorporated into a design. This document notes that special precautions are required when siting earthen manure storage facilities due to the potential for leakage. The factors to be considered include hydraulic conductivity of the soil, depth to the water table, depth to bedrock, location of field tiles etc. No guidance on how these factors are important to groundwater protection is included.

- The need for hydrogeologic assessment in a wide variety of farming practices and landscape is overlooked. The ability for the environment to attenuate contaminants should be considered when examining any location where manure is to be stored and released to the environment.

- Statements such as *"When high manure application rates are used, groundwater can be contaminated by bacteria and nitrogen…"* are used. However, rather than indicate what would be considered excessive rates, or how to avoid groundwater contamination, the paragraph concludes with *"Farm drinking water should be tested at least annually to assure adequate quality."* The document needs to give guidance on appropriate rates to avoid contamination.

- The Guide to Agricultural Land Use suggests procedures that are not commonly practiced or are very difficult to practice. For example, when spreading liquid manure this guideline suggests regular checking of tile discharge for polluted water. If a problem occurs, spreading should be stopped, the contaminated tile discharge prevented from leaving the farm, and MOEE staff notified. All excellent suggestions, but because tile outlets may be overgrown and division of farms may have resulted in tile outlets no longer being on any one farmer's land, many farmers are unaware of where their tile drains discharge. They are therefore unable to check them or follow the remainder of the protocol. Although the number of farmers that do not check their tile drains while spreading manure is unknown, the lack of adequate advice, support, and enforcement makes inadequate practices a common alternative.

Minimum distance separation (MDS) calculations are part of this code of practice. MDS calculations were designed to reduce odour impacts and have no value in predicting or avoiding a groundwater impact. In some instances, it appears that these calculations have been confused with a distance separation to prevent environmental impacts from a farming operation. The MDS documents make it very clear that they apply to odour impacts only.

In addressing the potential for odour impacts, the distance from the barn to a neighbouring land use is calculated. In estimating groundwater impacts, the full extent of manure spreading would also have to be addressed as impacts to the resource could occur anywhere where manure is spread. The barn may have a much greater loading rate if storage facilities are leaking but geologic conditions may dictate that other locations on the farm pose a greater risk. Therefore, the calculation of minimum distance separation as laid out in the Guide to Agricultural Practice is not applicable to protection of groundwater.

### 3.2.1 Certificate of Compliance

The Certificate of Compliance program was established in 1972 and was designed to provide assurance that a farmer is conducting acceptable farm practices and is following good environmental practices. A Certificate of Compliance suggests that a farmer has followed the Guide to Agricultural Land Use. The Certificate of Compliance has been used in the past to demonstrate to banking institutions that the farm business is not likely to be unsuccessful due to environmental risks. This program is voluntary, however, some municipalities have passed by-laws requiring a Certificate of Compliance for proposed livestock buildings and manure storage structures.

The Certificate of Compliance process involved a site visit from an OMAFRA representative who examined the farm operation and noted both physical characteristics as well as agricultural practices. A field assessment by a trained expert is much more effective than a farmer filling out a question form about the operation. The assessment did not, however, specifically include a hydrogeological component, such as depth to the water table or the geologic formation underlying the farm. Although the certificate highlighted environmental concerns like inadequate manure storage, manure spreading too close to a well etc., it did not specifically highlight groundwater concerns. In addition, after issuance of the Certificate of Compliance, there was no obligation for the farmer to alter the operation to meet any standard.

The provincial nutrient management planning strategy, which does not include a third party site visit or verification, has largely replaced this program. It is contingent, however, upon a municipality implementing a nutrient management by-law.

### 3.2.2 Recommendations

This guide is very general in nature and should not be used to assess the environmental impact of an operation.

## 3.3 The Environmental Farm Plan

The Environmental Farm Plan program was designed to heighten farmers' awareness of environmental issues related to agricultural practices. The Environmental Farm Plan was originally funded by the federal Green Plan program, but more recently has also been supported by local municipalities. The program requires farmers to attend workshops and assess their operation with respect to 23 different risk assessments including soil management, water wells, pesticide storage etc. Farmers complete a comprehensive assessment of their farm where farm practices or characteristics are ranked as "best", "good", "fair" or "poor". All items that are ranked poor or fair are transferred to the action plan and improvements are proposed to move the practice into the good or best categories. There is no follow up to see whether action has been taken, even when items represent a violation of existing legislation.

The program is voluntary and the action plans, which may highlight areas of serious environmental concern, are completely confidential. Of the estimated 60,000 farms in Ontario approximately 20,000 have attended EFP workshops and almost 9,000 have applied for the $1,500 cash incentive to perform part of the action plan. Of the incentives granted to date, 17% have been related to water wells and 10% for the storage of agricultural waste. The completion of an appropriate environmental farm plan is a requirement to obtain other funds available through water quality programs such as the Wellington County Water Quality program. Therefore, this program represents a starting point for farmers to change their operations with some assistance to do so.

The risk of groundwater contamination is assessed in each farm field by two factors; a hydrologic soil group classification that estimates the percolation rate and the depth to the water table. This risk is used throughout the plan workbook to estimate the threat of a farm operation impacting the farm well or wells. This is a good start in acknowledging that adoption of certain practices may result in risk of groundwater contamination at a particular site. However, problems with the way that groundwater is addressed by the EFP include:

- Soil type is not a scientific measure of the vulnerability of groundwater resources. Although making the farm plan more complex may result in fewer participants, it would be more informative and accurate to include surficial geology or aquifer sensitivity to contamination instead of soil type.

- Groundwater is not treated as a local or regional resource to be protected other than in the context of the owners' well.

- The location of neighbouring wells is not specifically dealt with.

- The only way to have a "poor" ranking in any of the categories addressing the potential for groundwater contamination is if the conditions violate provincial legislation or guidelines in terms of separation of any activity from the farm well. For example, if the activity in question (e.g., pesticide transfer, septic system, manure storage) is within 15 metres of a drilled well or 30 metres from a dug or bored well, a poor rating results. Having a high risk of groundwater contamination (i.e. permeable soil and shallow water table) combined with other high risk activities like fuel storage on a permeable pad does not result in a poor rating unless the pad is too close to the well

- The EFP does not foster a sufficient appreciation of the relationship between actions on the ground surface and contamination of the local groundwater resource. Sections such as pesticide storage would give a farm a "fair" rating if a cracked concrete or wood floor is present in the storage area. In terms of the potential for groundwater contamination, a poor rating would seem more appropriate.

- With respect to manure storage, it is considered "fair" to have 90 to 180 days of storage with some applications during wet or frozen periods. Less than 90 days of storage is considered poor. The "best" category is achieved with 250 day of storage. Best should be not less than 365 days. There is ample evidence to suggest that manure should be spread just prior to planting or when the plant is in an active growth phase.

The EFP is a good educational tool because it provides a lot of information to farmers about the impacts that can result from normal farm practices. Although it is voluntary, FitzGibbon et al. (2000) have estimated that 41% of participants have taken some action to prevent "environmental peril" on their farms. 50% of these actions were in the field of soil management. The overall benefit to water resources that has occurred as a result of the EFP is presently unknown but the FitzGibbon report shows promising results and the process may give farmers a long term vision of how their farms should be operated.

### 3.3.1 Recommendations

In combination with updating the BMPs to highlight important practices and problems on the farm, the EFP needs to also differentiate between small problems and big problems. Groundwater needs to be more appropriately dealt with.

### 3.4 Nutrient Management Planning

The first approach to environmental protection in Ontario from livestock-agriculture was rooted in the notion that impacts could be managed by controlling animal densities. An arbitrary threshold such as 1.5 animal units per acre was often used, but was not based on a sound scientific foundation. The Agricultural Code of Practice (1976) stated that:

> *This is the rate (1.5 AU/acre) at which the nitrogen in manure may be applied to soils without representing groundwater pollution problems or reduced crop yields. This rate represents twice the amount of nitrogen (300 to 340 lb. N application) required for one acre of corn.*

It should be noted that, in addition to this amount of nutrients from manure, farmers were encouraged to apply the full crop fertility recommendation.

Then came the use of nutrient management planning as an improved site-specific environmental protection tool. The premise of nutrient management planning is that by balancing crop nutrient demands with nutrient supply, adverse environmental impacts on air, soil, and water from nutrients can be eliminated or minimized. The nutrients in question are nitrogen and phosphorus. This method recognizes that excessive soil build-up of nutrients can lead to unacceptable runoff, and that over-application of water-soluble nutrients can lead to unacceptable leaching to groundwater.

In the broadest sense, nutrient management planning can be applied equally to the exclusive use of chemical fertilizers in a cash crop system or to a system using a combination of manure and chemical fertilizer. It has always been more difficult, however, to account for the availability of nutrients from animal manure. Complicating factors include the variability of manure application methods, variability of the source concentration, weather conditions at the time of application, soil parameters such as texture, type, and chemistry, and the many transformation pathways of organic nitrogen. A key improvement in this new system is the accounting for the nutrient content of the manure and the soil nutrient levels.

At the core of the nutrient management planning process is the production of a Nutrient Management Plan (NMP) that outlines the type of operation, the number of proposed animal units, location of nearby water wells, the available land base and other site information. The NMP depends on a balance sheet, where nutrient inputs minus outputs are not allowed to exceed a pre-determined level. A single tool plays a pivotal role in the nutrient management strategy in Ontario, NMAN2001, or its earlier versions. NMAN2001 is a computerized advisory system that simplifies and speeds-up the process of calculating a crop nutrient balance. It is imbedded in a graphical-user-interface that allows the user to simulate a multitude of scenarios. NMAN2001 has been instrumental in fostering the transition from a universal cap on livestock-density toward a scientific accounting of nutrient supply and demand.

In 1997, the Ontario Farm Environmental Coalition (OFEC) published their Nutrient Management Planning Strategy. During the intervening years, several dozen area-municipalities have passed nutrient management by-laws, based largely on the use of NMAN. One of the strengths of this strategy is that it recognizes the need for managing both the environmental and societal impacts of livestock production in an increasingly mixed rural landscape.

Taken in its entirety, nutrient management planning also encompasses important components like neighbour notification, setbacks from watercourses, lot lines, and buildings, the use of methods to reduce odour, spill contingency plans, and record keeping. The twin components of a good neighbour policy and the use of alternate dispute resolution do not directly benefit drinking water, but they compliment a sound strategy designed to minimize the over-application of manure.

The strategy also calls for the development of a process to determine the impact of NMPs. In other words, there needs to be a method of assessing compliance with, and benefits of the NMP, one of the factors lacking in the development and use of BMPs.

In the past several years nutrient management planning has been used as a method of approving large livestock operations. Many municipalities now require a NMP before issuing a building permit as dictated by newly developed nutrient management by-laws. New operations are being designed based on the results of NMPs that dictate the amount of manure that can be applied to the land surface. Mandatory NMPs have been proposed as confirmation that certain operations will not cause adverse environmental impacts.

Despite the key role in appropriating the amounts of manure and synthetic fertilizer that should be applied to optimize crop yields, NMPs do not predict or protect against environmental impacts. There are three central problems with the premise of nutrient management planning as an environmental protection tool. The first relates specifically to the inability of a simple agronomic balance to account for the complexities of the nitrogen cycle. Unlike phosphorus, which can be fairly accurately partitioned between the soil and the crop only, nitrogen must be partitioned between the atmosphere, the soil, surface water, groundwater, and the crop. It can be transformed into different inorganic and organic forms, which is determined by variables such as temperature, pH, soil organic matter, groundwater oxygen concentration, and soil moisture.

The second problem relates to the presence of non-nutrient constituents. Those of primary concern are living microbes (bacteria, protozoa, viruses) and inorganic salts such as sodium and chloride. Uncontrolled loading of these constituents to either surface or groundwater represents a threat to drinking water, recreational water use, and aquatic habitat.

The third problem relates back to the difficulty in accounting for all the variables in the nutrient balance. This has translated into an uncertainly about nutrient availability and a lack of confidence in manure as a reliable fertilizer source. This lack of confidence has in turn resulted in the continued simultaneous application of nutrients from commercial fertilizer.

The use of NMAN as the core predictive tool in most municipal nutrient management by-laws falls short of offering a groundwater protection strategy for Ontario. The following two sections identify the gaps in both the approvals tool (NMAN) and the approvals framework (nutrient management by-laws) concerning groundwater protection.

### 3.4.1 NMAN

NMAN2001 has no predictive capability because it is not based on a mathematical model, but rather is an overly simplified mass balance primarily focussed on phosphorus. NMAN does not simulate the mathematical relationships that describe chemical and microbial partitioning between plant, soil, air, and water.

NMAN2001 is capable of handling the phosphorus cycle, and therefore provides an effective means of managing one of the threats to surface water. It does not, however, have the capability of determining acceptable application rates of nitrogen, or inorganic salts. NMAN2001 does not account for microorganisms in any way, which are lost in great numbers through tile drains (Fleming et al. 1999), and can be leached to groundwater (Joy 2000).

NMAN2001 does not consider any of the climate variables, except in a limited way with respect to estimating N losses during spreading. Goss (2001) reported that the key factors influencing ammonia losses from surface applied manure were wind speed, temperature, pH (manure and soil), dry matter content, and soil texture. These variables have not been adequately considered in the method of estimating ammonia losses by NMAN.

The most significant challenge for NMAN 2001 is to provide an accurate balance for nitrogen. Currently it is missing or providing an inadequate estimate of the following components: soil storage (initial conditions), atmospheric deposition, denitrification, leaching, and subsurface run-off. A recent study found that up to 50% of the ammonia that is initially volatilized is re-deposited on the lands within 50 km of the source (Fern 1998). Atmospheric nitrogen deposition must be considered in areas of high livestock density, and perhaps everywhere. When manure is applied on land with tile drains running with subsurface drainage water, an environmentally significant fraction of the manure constituents are lost through the tile drains (Lammers-Help, 2000). This component must also be considered.

In a multi-year simulation, the calculation of soil phosphorous and potassium levels have been based on the initial soil test value, as opposed to the previous year's simulated value. Soil depletion or excesses are not carried forward, so in effect, each year in a simulation goes back to the baseline soil test value. It is important to be able to simulate 10 and 25-year effects of current practices as agriculture is a long-term land use, and the 1-year prediction is of little value for environmental protection.

The above discussion illustrates several uncertainties in NMAN predictions. This factor has lead other jurisdictions to state up front that the results of a simple balance between the nitrogen, phosphorus, and potassium content in the manure and the quantity of these nutrients used by crops cannot be used to calculate crop fertility needs. The following description of another advisory system, MANURE MASTER, comes from the USDA, Natural Resource Conservation Service:

> *MANURE MASTER calculates a balance between the nitrogen, phosphorus, and potassium content in the manure and the quantity of these nutrients used by crops. Regardless of the balance you calculate with this program, continue to use university extension soil test and nutrient application recommendations or the expertise of professional nutrient management specialists to determine application rates of nitrogen, phosphorus, and potassium.*

The backbone of a regulatory regime created to protect public health should not be based on the current version of NMAN. As NMAN is modified to overcome these basic flaws, there needs to be rigorous method of ensuring that applicants no longer use old versions. Presently, municipal by-laws do not provide a mechanism to ensure that the latest version of NMAN is in use, nor that previously approved NMPs are updated. The distribution of NMAN needs to be licensed so that all users are approved to use only the current version. As NMAN is expanded to encompass groundwater concerns, its accuracy and precision should be evaluated through sensitivity analysis and field verification.

#### 3.4.1.1 Examples of Calculations Using NMAN.

Table 4 represents the quantity of nitrogen and phosphorus produced by one animal unit of combinations of livestock breeds under different management systems. The numbers were calculated using the NMAN advisory system. According to OMAFRA (1997), "The manure from one animal unit provides enough nitrogen to fertilize one acre of corn". The animal unit system has been the cornerstone of animal caps and density thresholds. It has also been proposed to be the method by which on-farm corrective or preventative measures should be progressively triggered. The animal unit conversion factor was designed to be able to compare different livestock systems based on the environmental risk from the quantity of nutrients produced.

The discrepancy in these results suggests that there is either a flaw in the conversion factors used by NMAN to calculate the N and P produced by livestock, or that the number of individual animals required to establish one animal unit in Ontario is incorrect. Since the livestock unit is the basis for many calculations and restrictions on farming operations, this could represent a serious flaw in the nutrient management framework.

For example, one can readily see from this table that using NMAN in combination with the animal unit system approved for use in Ontario is overly restrictive for mature beef cows and swine feeders, but perhaps excessively lax for sows and poultry pullets. It raises serious questions of both fairness and accuracy. This discrepancy must be corrected before any more by-laws or regulations are promulgated.

**TABLE 4: Nitrogen and Phosphorus Generated by One Livestock Unit**

| Manure Type | Animals per Livestock Unit | Manure Produced [$m^3$/day] | Nitrogen Production [kg per L.U. per year] | Phosphorous Production [kg per L.U. per year] |
|---|---|---|---|---|
| Sow + Litter | 5 | 0.11 | 73 | 33 |
| Swine - Weaner | 20 | 0.06 | 40 | 18 |
| Swine - Feeder | 4 | 0.03 | 28 | 15 |
| Beef - Mature | 1 | 0.03 | 25 | 14 |
| Beef - Feeder | 2 | 0.04 | 33 | 19 |
| Dairy - Mature | 1 | 0.08 | 57 | 24 |
| Dairy - Heifer | 2 | 0.06 | 54 | 28 |
| Poultry - Layer | 125 | 0.02 | 40 | 21 |
| Poultry - Broiler | 200 | 0.02 | 44 | 30 |
| Poultry - Pullet | 500 | 0.04 | 82 | 51 |

How the numbers were produced:

1. Selected manure type according to MSTOR choices
2. Animals/LU was obtained from MDSII
3. MSTOR output manure produced per day
4. Go back to NMAN, make sure that the manure produced per year was comparable with the manure/day number then go to Field Output to generate N and P numbers

A second example of the use of NMAN is a generalized case based on a farm in Adelaide Township that has been used as a research site examining the effects of farm practices on groundwater nitrate concentrations. Using general site characteristics, NMAN default values, and a range of synthetic fertilizer application rates appropriate for a corn crop (OMAFRA, 1992), nitrogen balance values were generated using NMAN2001. Table 5 shows that NMAN does not flag nitrogen input as excessive until the surplus is greater than 84 kg/ha. At the recommended application rate of 150 kg/ha to corn the excessive nitrogen is 59 kg/ha and no flag is raised. Groundwater nitrate concentrations have been measured at this site and attributed to synthetic fertilizer applied to the corn crop. These concentrations average 19 mg/L with maximum values of 70 mg/L (Ryan and Stokman, 2000). This example demonstrates that at application rates considered acceptable using NMAN groundwater nitrate concentrations significantly exceed drinking water limits.

**TABLE 5: Excessive Nitrogen Estimated by NMAN2001 based on Crop Recommendations**

| Nitrogen Application [kg/ha] | Nitrogen Credit (Previous Year Soybean Crop) [kg/ha] | Crop Removal [kg/ha] | Excess Nitrogen [kg/ha] |
|---|---|---|---|
| 125 | 15 | 106 | +34 |
| 150 | 15 | 106 | +59 |
| 175 | 15 | 106 | +84 |
| 200 | 15 | 106 | +109 (NMAN Flag) |

### 3.4.2 Nutrient Management By-laws

Municipal nutrient management by-laws have been implemented in counties with high livestock densities with the intention of protecting the environment. They have been hampered, however, by a lack of proper implementation tools from the Provincial government and opposition from farm federations and OMAFRA. There has also been a heavy reliance on the NMAN advisory system to determine environmental thresholds. This follows a basic misunderstanding of its limitations. These by-laws only apply to new or expanding operations, so they have no jurisdiction over the 60,000 farms that currently operate in Ontario.

The heavy reliance on NMAN has been at the expense of other critical components of a sound environmental protection strategy, some of which were included in OFEC's original Nutrient Management Planning Strategy. One of the most significant problems with current by-laws is the absence of any method of promoting cross-compliance with the BMPs that are so central to NMAN's relevance. BMPs are not addressed by the 60 odd by-laws that are currently on the books (FitzGibbon and Thacker, 2001).

For example, for the NMP to be even partially effective at protecting water resources, the following BMPs must be practiced:

1. Spread manure in the spring or as near plant emergence as possible (Goss et al. 2001).
2. Do not spread manure in the fall when nutrient losses can be most significant (Goss et al. 2001).
3. Test manure

The 4 testing labs in this province have reported that a very small percentage of farmers actually test their manure for nutrient content. Increasingly, however, fertilizer and feed companies are providing this as a value-added service along with completion of a NMP.

Nutrient Management By-laws do not provide for site verification of any of the information provided in the NMP. Under the current regime, OMAFRA reviewers do not visit the proposed facility and associated lands, and do not verify in the field any of the information provided. Previously, the Certificate of Compliance involved a site visit and the preparation of a site plan by the OMAFRA Engineer. There is also no method to track applications to avoid multiple registration.

The most significant items requiring either on-site or remote verification are the presence and location of field tiles and outlet drains, location of used and abandoned wells, surface slope, condition of watercourses, soil type, and subsurface geology.

It is not sufficient for the applicant to identify only the nearest well. A radius around the new or expanded facility including the radius of manure spreading should be established. All wells located within the prescribed radius should be identified, inspected, and sampled for bacteria, nitrate, and chloride, as a minimum. The radius should be based on local hydrogeology. This type of background work establishes the state of the local groundwater resources prior to a new development.

NM by-laws do not make adequate provisions for abandoned wells. They should stipulate that a licensed contractor must decommission abandoned wells on all properties registered in the NMP and that a Water Well Record must be filed with the MOE. Presently, applicants simply indicate that no wells are known or that known wells will be closed. This response is inadequate. There are a variety of tools, remote and on-site, available to locate unused wells, including geophysical methods. If unused wells have been located, they should be decommissioned and inspected prior to issuance of a building permit.

The present by-laws in Ontario do not require the applicant to provide any background data concerning local water quality, nor monitor water quality at any point in the future. In an environment where following the NMP is wholly voluntary, the absence of water quality monitoring data is a fundamental flaw. In the event of a spill or a leak, no one will be able to prove the origin of the contamination. Without background data, it is impossible to determine future impacts of current practices.

Although tens of municipalities have implemented nutrient management by-laws, most have failed to implement several important components of OFEC’s Strategy including: mandatory calibration of manure spreaders, mandatory manure testing, identification and minimization of environmental risk, third party review, six year record keeping, and an annual plan review. In a recent review of 54 nutrient management by-laws in Ontario (FitzGibbon and Thacker, 2001), almost 80% were found to have no requirement for land ownership, and almost 50% were found to have no requirement for the NMP to be reviewed on any basis whatsoever. Ten percent of the by-laws required no third party approval, while 70% do not require the NMP to be prepared by a consultant and 85% do not stipulate a maximum haul distance.

# 4.0 ROLES AND RESPONSIBILITIES IN REGULATORY FRAMEWORK

The potentially deleterious effect of agriculture on the environment has been demonstrated at Walkerton and in other jurisdictions (Carlson et al. 1990). Burton and Ryan (2000) conclude from their literature review that all wells installed in unconfined aquifers in agricultural settings had elevated nitrate concentrations. Previous sections demonstrate that existing guidelines and regulations do not provide adequate protection of water resources. A more robust regulatory regime must be developed.

The case for broad water resources protection has three compelling arguments. First, treatment costs almost always outweigh prevention costs (Agriculture Canada, 1993). Second, our scientific methods of sampling, analysis, and risk assessment have seldom kept pace with the manufacture and distribution of complex chemical and biological species. The successful removal of a known contaminant does not mean that impacted water is necessarily safe for drinking. Finally, groundwater and surface water have been shown to be interconnected. Protecting all water resources, therefore, is essential.

There is general agreement that a major policy shift is required to manage risks to both human health and the environment from farm wastes. The provincial government recently introduced the Nutrient Management Act, 2001 to provide a mechanism to fill the regulatory void. In the time that the Act has been in development, as many as fifty local municipalities have been forced to fill the regulatory void by creating by-laws to manage the disposal of manure on farms. The difficulty in doing this at the local level, and the opposition from the province, have lead some municipalities to impose moratoria on the construction of new large facilities, until safe guidelines and implementation procedures can be determined.

This section of the report puts forth a strategy to enable the provincial government to better protect groundwater by evaluating existing and proposed land uses within a water resources focussed model. It proposes tasks that must be undertaken to provide a regulatory environment that proactively protects highly vulnerable aquifers and avoids land uses that have a high potential to adversely impact groundwater. Delineation of vulnerable aquifers allows a system for prioritizing existing operations in areas of greatest need.

This framework requires that background work be undertaken to assess groundwater resources so that efforts can be focussed in areas that are more susceptible to impacts from development activities. It requires better data collection and record keeping so regulators have the appropriate tools to approve new or expanding operations. This framework requires a greater level of site investigation before new or expanding operations so that the potential impacts are evaluated up-front and if mitigating measures cannot be devised then the development can be rejected. A qualified professional should certify this investigation and assessment. Higher minimum standards for farming practices that have the potential to degrade groundwater should be clearly stated, and demanded of new operations and encouraged in existing ones.

Exemptions from this approval process would be available for new operations that are sufficiently small that they are unlikely to cause an impact and are in areas that are not considered to be susceptible to groundwater contamination.  Farms with the potential to have very large impacts may be prohibited in highly sensitive areas.

The proposed regulatory framework would have to be implemented on three levels.

1. First, the provincial government needs to develop strong legislation to protect groundwater and surface water resources, and allow more local control of water resources.  The new Nutrient Management Act can be used to establish regulations that will advance the framework that is proposed.  Minimum standards for some key agricultural operations need to be developed.  Some local jurisdictions may go beyond minimum standards to protect local resources.  The province also needs to reestablish a strong research focus that will help to answer some of the questions that are outstanding with respect to the impact of agricultural operations on water resources.

2. Secondly, regional assessment of water resources must be undertaken, perhaps by Conservation Authorities or the provincial government, Several crucial exercises must be conducted including: groundwater vulnerability mapping, definition of well-head recharge areas, ambient groundwater monitoring, surface water monitoring, and ultimately developing regional watershed models.  A subset of these assessments has been undertaken in thirty-three different locations of the province as part of the Provincial Water Protection Fund.  Some regional municipalities such as Waterloo and Halton have pioneered these assessments in Ontario.  An aquifer vulnerability assessment would allow regulatory agencies to better evaluate if a proposal is likely to adversely impact water resources or not.

3. Thirdly, on the site or farm scale more detailed information needs to be collected to actually estimate if an impact from the operation will occur.  The types of studies that could become part of an application for new or expanded structures include hydrogeological investigation, solute transport modeling, groundwater and surface water monitoring and the generation of an environmental management system.  More detailed site assessment will allow approval agencies to grant approvals with greater assurance that environmental protection has been addressed.  These more detailed site investigations should also serve to convince rural residents that their water resources would not be impacted.

For many of these tasks, there are tools available that make implementation much simpler and more reliable than in the past.  Computer modeling and Geographic Information Systems (GIS) systems are two tools that have undergone such incredible advancement in the past decade that they are now available as tools to a wide variety of users.

# 5.0 PROPOSED FRAMEWORK

## 5.1 Regulation

New provincial regulation should strive toward a higher standard of farm practice in some areas. Although flexibility must be incorporated so that the standards are applicable over a variety of operations and landscapes, it is appropriate to restrict practices that are known to adversely impact water resources or to require practices that will provide increased groundwater protection. Examples of recommended minimum standards are as follows:

- 365 days of manure storage should be required so that manure can be spread when the plant uptake of nutrients can be maximized. Spreading of manure during winter months should be prohibited.

- 100% of the land base over which manure is being spread should have written agreements authorizing the spreading. These agreements should clearly state that the lands in question are accessible for manure spreading and that they are included in only one nutrient management plan.

- A minimum amount of the land base used for manure spreading must be owned or long term control must be in the hands of the manure generator. The reliance on 100% of annual leases could easily result in an inadequate spreading base in a given season.

- All fuels and pesticides should be stored according to the BMP.

- Liquid manure should not be spread on tile drained fields when the tiles are running and in areas of sensitive surface water features. Data shows that under certain conditions manure can be detected in tile drains within two hours of application (Evans and Owens, 1972, Dean and Foran, 1990), providing a short circuiting of bacteria to surface water.

- Applicants for new or expanded facilities should be required to supply a detailed plan to re-route field tiles around the proposed structures. Location and layout of drainage tiles, of outlet drains and of buried or open municipal drains must be identified and a clear protocol for observation of flow prior to, during, and after manure application must be developed.

- On-site monitoring for storage system leakage should be conducted. In some cases, they could require that the applicant construct a perimeter drain around the barn and the storage, and install an observation well at the outlet. The observation well could be monitored for electrical conductivity with a hand held device. In other situations (where water tables are lower), groundwater monitoring wells could be used to detect groundwater impacts.

- A methodology for obtaining soil samples, including the requirement for an independent party to obtain them and that an accredited lab analyze them should be developed.

- Sufficient minimum construction standards to ensure water-tightness of manure storage structures should be developed. Concrete floors and walls can only be rendered watertight through the use of polymer liners, membranes, waterproof coatings, or pre-stressed engineered installation methods.

- Auditing is the cornerstone of voluntary regulations. Without auditing, compliance can reasonably be expected to be poor or non-existent.

- Similar to pesticide application, controls must be put in place regarding the timing of manure application with respect to precipitation, temperature, humidity, and wind speed. If voluntary guidelines can not be complied within the near future, municipalities should consider licensing manure applicators.

- Upper limits for manure application rates should be developed. Such limits may be necessary in order to protect water resources. They might need to consider run-off via tile drains, waste strength, soil type, surface slope, previous soil moisture, the depth to the first occurrence of groundwater, as well as local and regional groundwater recharge conditions.

- Manure generators or handlers should be required to submit a methodology for manure transfer, spreading and spreader calibration. The plan must include details of road crossings. Minimum standards for construction of piping under roads should be established. The applicant should keep spreader calibration records for a minimum number of years.

- Nutrient management by-laws need to provide for a mechanism to establish a database to track land lease agreements. The likelihood of double designation of parcels of lands increases with increasing facility density and multi-jurisdictional applications.

A review of the best management practices or the Environmental Farm Plan could be used as a guide for developing a set of minimum standards.

The provincial government should either develop, or facilitate the development of source water characterization and prioritization programs so that regulating agencies have necessary information to make the appropriate decisions. The recommended analysis is described below; much of the required data is available as published or provincially held data. Some of this work has already been conducted in parts of the province as part of the Provincial Water Protection Fund program or by area municipalities.

In addition to the requirement for regulating agencies to collect key data, regulations should also lay out the key components necessary for a land use application to be considered. This should contain, in addition to the proposed requirement of a NMP under the Agricultural Operations Act, the requirement for a hydrogeologic study of the subject farm including a site impact assessment.

Regardless of which jurisdictions are going to assess and approve applications for new operations, the legislation should empower those jurisdictions to make their own local standards provided that the provincial minimum standards are adhered to. All data held by the provincial government should also be made available to these jurisdictions to enable them to develop the most appropriate local standards possible.

### 5.2 Research

Without introducing discharge-controlled waste treatment, or Certificates of Approval for farm generated wastes, we are dependent on natural processes to transform waste products. Natural systems have been much more difficult to study in the lab and in the field, compared to engineered systems, such as sewage digesters. The variability in natural systems makes it difficult to predict the transformation products and pathways, and therefore, to predict the environmental impact.

It is important to strengthen research efforts in addressing the issue of agricultural impacts on water resources. OMAFRA provides significant research funds to the University of Guelph to help address scientific questions. Research funding must be strengthened in this time of changing regulation so that much-needed answers become available. Some outstanding questions include:

Transport of manure derived bacteria into the groundwater system,

- What geologic deposits can be considered “safe”?
- What is the bacterial content and variability of manure?
- What farm practices minimize the transport of manure from the ground to groundwater or tile drains?

The nitrogen cycle,

- When is the nitrogen in manure available for plant uptake?
- Is there any way of holding fall applied nitrogen in the soil zone so that it is still available for plant uptake in the spring?
- What are the effects of varying nitrogen contributions on yields?
- Is nitrogen leaching greater or lesser in a livestock system, as compared to straight synthetic fertilizer application?

Treatment of Manure,

- There are several technologies available to treat manure, however each methodology is relatively expensive to implement on a farm scale. More research is required to develop techniques that are more cost effective.

### 5.2.1 Sentinel Farms

There is a need to perform on-going field-scale research. Such research would serve two goals:

1. To improve our predictive ability (e.g., at a given manure application rate, what will the concentration of nitrate in groundwater be in 20 years time?)

2. To provide an early warning system if the regulatory framework fails to adequately protect the environment and human health (e.g., are bacteria migrating to the groundwater?)

A network of Sentinel Farms could fulfill the two goals above. It would consist of a small number of farms (20 to 50 across the province) representing a wide range of landscapes, where monitoring would be carried out on a much more detailed scale than would normally be practical. The high quality of data would support more accurate computer simulations, which in turn would be calibrated or verified by the on-going monitoring. Such farms would carry out normal farm practices (as opposed to innovative practices) and endeavor to meet, but not necessarily exceed, the regulatory status quo.

Regulatory monitoring will never adequately satisfy scientific demands (e.g., accuracy, reproducibility, and statistical significance). A network of sentinel farms, if managed properly, could justify less rigorous standards for routine monitoring of individual farms (so long as auditing is in place).

## 5.3 Groundwater Mapping and Monitoring

The following represents a list of information that would provide decision makers with the tools necessary to estimate the potential for water quality impacts from a specific development application. Some of this information will also serve to monitor changes to farming practices and estimate if these changes have produced an environmental benefit. These tasks could be performed by the provincial government or by conservation authorities or municipalities. If undertaken by conservation authorities or municipalities, the province would have to make the appropriate data available and possibly assist by laying out some standards to ensure that tasks conducted in different areas are comparable.

### 5.3.1 Aquifer Vulnerability Mapping

In the absence of on-site or communal waste treatment systems designed to meet engineered specifications and performance criteria (discharge limits), we rely on the landscape and natural processes to degrade and assimilate manure constituents and by-products.

In order to maintain a balance between what we produce and what the ecosystem can assimilate, at the very minimum, we should permit land-use activities according to a pre-determined inherent vulnerability of the landscape. An understanding of surface and ground water vulnerability to contaminants provides a scientific basis for assessing future land-use proposals (Fernandez et al. 1993).

A watershed vulnerability assessment recognizes that all physical settings are not created equally. Many biological, physical, and chemical factors interact to determine vulnerability (Meij and Abdalla 1990).

Theoretically, groundwater vulnerability addresses both the quality and quantity of groundwater resources; however, much of the impetus towards aquifer vulnerability mapping is the concern surrounding groundwater contamination. The natural ability of the subsurface to attenuate contaminants is variable and very difficult to quantify. The geologic properties that govern this ability are contaminant specific as the chemical and biophysical properties that act to attenuate contaminants are contaminant specific. Contaminant specific techniques, however, are not practical for contamination prevention and aquifer protection planning (Vrba and Zaporozec, 1994). The more common approach to aquifer vulnerability mapping is to estimate the intrinsic vulnerability or the capability of the land to attenuate contaminants in general. By using this general screen, aquifer vulnerability assessments generally combine several components: characteristics of the soil, unsaturated zone, aquifer materials and depth to groundwater, the direction and velocity of groundwater flow, and the amount of recharge.

Advanced methods for assessing aquifer vulnerability have been developed and implemented over the past 20 years or more. Most of this work began in Europe in the 1970s. In 1977, groundwater vulnerability maps were produced at various scales for the entire country of Germany. The Netherlands, Sweden, the Czech Republic, and the United Kingdom were also mapped in the 1980s (Vrba and Zaporozec, 1994).

The DRASTIC method for aquifer vulnerability was developed in the late 1980s to achieve some level of consistency between individual State efforts in the United States. DRASTIC has been used for groundwater vulnerability mapping in Texas, Ohio and Nova Scotia (Agriculture Canada, 1993). Other methods of groundwater vulnerability mapping have been undertaken in several states including Rhode Island, Massachusetts, Wisconsin, Nebraska, Delaware and South Dakota.

Ontario also began efforts to map aquifer vulnerability in the 1980s with the generation of 29 Aquifer Susceptibility to Contamination Maps. These maps were fairly simple in comparison to the European models, however, they provided some much needed information regarding Ontario’s groundwater resources. The MOE ceased these efforts in the late 1980s and in the past 5 years or so, aquifer vulnerability has been developed primarily by municipalities, who require this information to apply wellhead protection techniques and land use planning.

The availability of important site characteristics (Table 6) in digital format on a regional scale becomes the stumbling block in developing aquifer vulnerability assessments in most locations.

Often general characteristics of the soil, unsaturated zone and aquifer zones are used to estimate the characteristics listed above. Vrba and Zaporozec (1994) note, however, that:

> *The soil has a specific position among the groundwater vulnerability attributes because the soil itself is very vulnerable. The soil's function as a natural protective filter in the retardation and degradation of contaminants can be damaged relatively easy. The damage may lead to the loss of its control over groundwater quality. Therefore, the soil properties assessment should always take into consideration whether the soil in the area under study is in natural conditions or under stress from agricultural activities, acid depositions etc.*

**TABLE 6: Important Factors in Developing a Groundwater Vulnerability Assessment (Adapted from Vrba and Zaporozec, 1994)**

| FACTOR | CHARACTERISTICS |
|---|---|
| Soil | Texture, structure, thickness, organic matter, clay content, permeability |
| Unsaturated Zone | Thickness, lithology, travel time of water |
| Aquifer | Lithology, thickness, effective porosity, hydraulic conductivity, groundwater flow direction, age and residence time of water |
| Recharge | Net annual recharge, annual precipitation |
| Topography | Slope variability of land |
| Unit underlying aquifer | Permeability, structure, potential recharge and discharge |
| Surface water contact | Gaining or loosing stream, evaluation of bank infiltration, salt water interface in coastal areas |
| Land use | Natural, man-made, population density |

Digitally formatted data layer coverage exists for much of the province, however several different parties including the MNR, MOE, MNDM, OMAFRA and Agriculture Canada hold these layers. A long-term goal of the Ontario Government is to create a central data warehouse (Land Information Ontario Warehouse). Accessibility to these data layers, for generating aquifer classification maps and other studies, is currently on a request basis to the appropriate holding party.

Each of the available characteristics could be mapped using a Geographic Information System (GIS). A GIS consists of layers of data, geographically referenced, including but not limited to roads, infrastructure, well records, surface hydrology, soil classification, land-use, and water quality monitoring data. Several GIS systems have been developed and represent industry standards including ArcInfo and ArcView, Map Info and an AutoCAD/Intergraph system and others. Many layers of data can be easily retrieved, linked, layered and viewed using GIS software, making this a standard tool for most regulating bodies. In order to manipulate the data for specific requirements, however, a trained operator is generally required.

The Grand River Conservation Authority (GRCA) has used a GIS to map groundwater aquifers and recharge areas, and uses GIS technology to maintain an integrated, watershed based tool for resource management. The GRCA's GIS system is also used to monitor changes in watershed parameters by combining soil and geologic data with land use data and monitoring the impact of changing land uses on runoff for flood concerns and on water levels for water supply management (Conservation Ontario, 2001).

Various groundwater vulnerability mapping methods have been developed by, or are under contract, for different government agencies for use in their own country, province or state. Several of these methods have been reviewed and are discussed below.

#### 5.3.1.1 Ontario MOE - "Susceptibility of Groundwater to Contamination" Map Series

This map series were designed to assist in evaluating the susceptibility of groundwater to potential sources of contamination. The information sources used to compile these maps include:

- **MOE** - Water Well Record Database (Select records)
- **Dept of Mines** - Bedrock Topography Series
- **OGS** - Quaternary Geology Series
- **Ont Div of Mines** - Paleozoic Geology Series
- **MOE** - Drainage Basin Series
- National Topographic System Series

The well records were used as selected cross sections. A note on the map indicates that these maps are only a cursory step towards dealing with groundwater contamination and that the MOE's groundwater evaluator or a hydrogeologist should be consulted to interpret the map where site-specific developments or land-use planning decisions are being considered.

#### 5.3.1.2 Drastic Method

The DRASTIC method is the most widely used method of indexing aquifer vulnerability in Canada and the US. It was developed in the US during the mid-1980s by the National Water Well Association, in conjunction with the US Environmental Protection Agency. DRASTIC evaluates pollution potential based on the following seven hydrogeologic factors: **[D]**epth to the water table, **[R]**echarge of the aquifer, **[A]**quifer media, **[S]**oil media, **[T]**opography, **[I]**mpact to the vadose zone, **[C]**onductivity.

Each of these factors has an assigned weighting factor, between 1-5, based on its relative significance in affecting the pollution potential. Within each of these factors, a rating value, typically between 1-10, is assigned. The DRASTIC index is the summation of the products of these ratings and weighting factors.

$$\text{DRASTIC INDEX} = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w$$
$$\text{where } r = \text{rating (1-10)} \ \& \ w = \text{weighting (1-5)}$$

The higher the DRASTIC index the greater the relative pollution potential. The DRASTIC index falls into one of four ranges of values, which stipulate four categories Low, Moderate, High, and Very High.

Comments have been made that while trying to accommodate a large array of parameters, there is considerable overlap or redundancy in the parameters.

#### 5.3.1.3 Aquifer Vulnerability Index Method (AVI)

The AVI method was developed in Saskatchewan. It requires fewer input parameters, is simpler to use than DRASTIC, and removes some of the redundancy in the DRASTIC parameters (Stempvoort et al. 1992). The AVI method considers the thickness of each sedimentary layer above the uppermost, saturated aquifer surface, and the estimated hydraulic conductivity of each of these layers. These two parameters are used to calculate a hydraulic resistance for all layers. This is a theoretical factor used to describe the resistance of a geologic unit to vertical flow and represents the ability of the geologic unit to prevent migration of contaminants from the surface to the aquifer. Although the hydraulic resistance is in units of distance / time, it cannot be considered a travel time for water or contaminants because other factors, such as hydraulic gradient, diffusion, and sorption are not considered. Although the AVI method only addresses two parameters, it is considered to account for geology more thoroughly than other methods.

The AVI method was developed for the prairie environment and the author states that topography was not considered because of the generally uniform flat or undulating nature of the prairies. Use of this method in Ontario may require the addition of a topography factor.

The AVI method can be performed for each well driller's water well record in a database and an iso-resistance map can be generated. Prior to plotting these hydraulic resistance values, their log values must be taken, for a more appropriate range of values in the profile.

#### 5.3.1.4 Simplified DRASTIC Methods Including the Roeper Method

Other simplified DRASTIC methods have been developed for specific regions in Canada (Table 7). These simplified versions often rely on the thickness of the "protective clay or till overburden" above the uppermost major aquifer in the profile. The Roeper method is an example of a simplified

DRASTIC method, which was developed in the 1990s for Regina, Saskatchewan. Instead of considering seven factors as the DRASTIC index does, the Roeper method considers only the unsaturated zone thickness. The thickness factor is not considered on a continuous sliding range, but as three distinct ranges, 1-5m, 5-10m, and >10m.

The following table references some of the methods developed and the parameters that were addressed in each of these methodologies.

**TABLE 7: Comparison of Aquifer Vulnerability Methods (Stempvoort et al. 1993)**

| **PARAMETER** | **Soil or surf. Geol.** | **Unsaturated thickness** | **Hyd. Cond.** | **Recharge rate** | **Depth to water table** | **Water use** | **Land use** | **Aquifer media** | **topography** |
|---|---|---|---|---|---|---|---|---|---|
| MOE | Y | N | I | I | N | I | N | N | I |
| McCormack | Y | N | I | I | N | N | N | N | I |
| McRae | Y | N | I | I | Y | N | N | N | Y |
| Turner | Y | N | I | I | N | Y | Y | N | N |
| Roeper | I | Y | I | I | N | N | N | N | N |
| MNR Manitoba | Y | Y | I | I | N | N | N | N | N |
| DRASTIC Aller | Y | Y | I | Y | Y | N | N | Y | Y |
| AVI Stempvoort | I | Y | Y | I | I | N | N | N | N |

Y - parameter used
N - parameter not used
I - parameter considered indirectly and/or related directly to other parameters

### 5.3.1.5 Aquifer Classification System for Groundwater in British Columbia

The BC government developed its own method of aquifer vulnerability mapping, because none of the systems they reviewed seemed adaptable to their objectives and unique data.

The BC classification and ranking values are determined for aquifers as a whole, and not for parts of aquifers. The aquifer classification system has two components:

1. a classification component to categorize aquifers based on their current level of development (use), and vulnerability to contamination

2. a ranking component to indicate the relative importance of an aquifer

#### 5.3.1.6 Summary of Aquifer Vulnerability Tools

Comparisons of both AVI and DRASTIC to actual water quality data showed both methods highlighted wells that are already contaminated as “vulnerable” wells (Wei, 2001). A study of 169 water supply wells in the Fraser Valley showed that individual wells could be rated for aquifer vulnerability, although AVI was found to be less accurate on individual wells because of the reliance on local stratigraphy. Both methods could be used on clusters of wells to accurately represent vulnerable areas.

Wei (2001) warns that neither AVI nor DRASTIC appear to be particularly suited to fractured rock aquifers. Garret (1991) also cautions against the use of these methods in fractured rock environments.

Thirty-three groundwater assessment studies were undertaken in different parts of Ontario in the past several years partially funded by the Water Protection Fund of the MOE. These studies encompass a variety of geologic and hydrogeologic environments in the province. Most of these studies conducted aquifer vulnerability assessments of some description. At least one of these studies conducted a DRASTIC assessment; others used AVI and some simply assessed vulnerability based on the estimated thickness of fine-grained deposits, similar to the Roeper method. The MOE is presently compiling the results of these assessments in an attempt to put forth a standardized method for aquifer vulnerability assessments in Ontario. This information is presently unavailable for this review. Because the data available in the province is not consistent throughout, it is possible that different methods should be used in different parts of the province. The USEPA also recognizes that "there is no single approach for identifying systems at risk" (Federal Register, 2000).

Studies exist for each of these discussed methodologies, which have been implemented using a GIS. The use of a spatial-referenced data system allows for ease of input into a database management system and a computer modeling application. The benefit of incorporating all available background data into a GIS is that as new information is received the analysis can be redone relatively simply.

The proposed framework would require that aquifers in all parts of the province be assessed by one of the methods described above as high, medium or low susceptibility to contamination. Fractured rock aquifers with inadequate overburden cover to prevent exposure to contaminants would have to be treated as a special case, and unless the rock can be shown to be competent and of low bulk permeability, it must be considered highly vulnerable. Regulators would then be able to prioritize applications or existing land uses, focussing abatement, remediation and research on the more vulnerable areas. Possible scenarios for incorporating different susceptibilities to contamination are discussed in Section 6 Implementation of a New Regulatory Framework.

### 5.3.2 Defining Well-Head Recharge Areas

Infiltrating precipitation enters the groundwater system and ultimately discharges to a surface water body, a well, or contributes to a regional groundwater flow system. The recharge area for a particular well is the area over which infiltrating waters are expected to reach the well. These are the source areas for either wells or surface water bodies. It follows that the land use in recharge areas is of key importance, as only contaminants released in these areas should reach the water supply wells. Individual wells may have very local recharge areas or distant recharge areas depending on their depth and the local geology.

Mapping of wellhead recharge areas has been undertaken by various jurisdictions over the past several years. Methods have ranged from "bulls-eye" type concentric circles drawn around wells with arbitrary diameters, or the amount of water that would be pumped within a specific time frame, to complex particle tracking models that incorporate detailed geologic, hydrologic and hydrogeologic parameters. Many jurisdictions began with the simple approach and have moved toward greater refinement in the depiction of recharge areas. Factors such as funding, data availability, complexity of the geological system, vulnerability of the aquifer, use of final product and operator expertise must be considered when choosing the method of estimating wellhead recharge areas (British Columbia Ministry of the Environment et al. 2000).

The Wellhead Protection Program under the Safe Drinking Water Act in the United States was established in 1986. In 1987, the USEPA established guidelines for the delineation of Wellhead Protection Areas. There were five types of delineation criteria: 1. Distance, 2. Drawdown, 3. Time of Travel, 4. Flow Boundaries, and 5. Assimilative Capacity (Rifai et al. 1993). The WHPA uses an integrated semi-analytical flow model (Blandford and Huyakorn, 1990). This model estimates travel time and flow boundaries. This program is linked with a GIS interface and is used in the city of Houston, Texas to show wellhead protection areas (Rifai et al. 1993).

In order to develop planning scale capture zones for area water supply wells, the RMOW developed a state-of-the-art three-dimensional model of the aquifer systems utilized for water supply. This modeling effort resulted in the delineation of three-dimensional capture zones (Martin and Frind, 1998).

Halton Region used the United States Geological Survey (USGS) model, MODFLOW. This model is a three-dimensional finite difference model developed and verified by the USGS. The model is commonly used for capture zone analysis in the U.S. and Canada. MODPATH, another USGS model, can be added to MODFLOW. It is a particle tracking model that can be used to generate the path that a particle would have taken from recharge to entering the well (Regional Municipality of Halton, 1997)

The Strathroy-Caradoc Groundwater Management Study, one of the water protection fund studies, used existing well records and available groundwater and surface water monitoring points to develop a groundwater flow model. MODFLOW was also used to generate the 2, 5, 10 and steady state capture zones for the municipal wells and the groundwater flow in the entire area. Land use restrictions were then recommended based on these capture zones. MODFLOW has also been used to model regional groundwater flow for the Mill Creek and Blair-Bechtel watersheds and is also being used as part of the Grand River modeling effort (Conservation Ontario, 2001) and the Guelph aquifer system (Gartner Lee, 1999).

Despite more complex modeling required in some areas, the use of MODFLOW to predict regional groundwater flow and wellhead recharge areas appears to be an acceptable standard. Like all modeling efforts, good quality data must be used as input, and the output must be verified using both field data and the conceptual model of geology and hydrogeology in the area. The location of the recharge areas combined with the vulnerability of aquifers to contamination can be used together to highlight the areas of particular concern with respect to potentially contaminating activities.

It must be recognized that municipal wellhead recharge areas do not incorporate source water for rural domestic wells or surface water bodies. Therefore, regional protection of water resources is still necessary above and beyond municipal protection areas. Identification and protection of important recharge areas in the province might prevent future tragedies similar to Walkerton. These areas must be protected from a range of high-risk land uses, including some agricultural practices. As with all human engineered and operated systems, we must accept that there will always be a certain failure rate at water treatment plants. Source protection, therefore, is essential.

### 5.3.3 Regional Groundwater and Surface Water Monitoring Protocol

The Ministry of the Environment has recognized the role of long term, ambient groundwater quality monitoring in managing growth and development in Ontario. To this end they have designed a network of provincial groundwater monitors, and allocated funding for Conservation Authorities to collect and manage local data. Well locations were initially chosen by a modified aquifer vulnerability assessment. Monitoring will include water levels and groundwater quality. The range of chemical parameters to be tested will depend on the land use in the vicinity of the particular well. Although this represents a significant step in prioritizing protection of groundwater resources, this monitoring network is regional in nature and focuses on ambient water quality. It should not be seen as a replacement for local monitoring of significant resources or of impacts of specific land uses on water resources.

Local monitoring may target specific aquifer units in specific areas, or specific land uses. Local sampling may be short term, ceasing when the desired information has been accumulated (Hirsch, 1988).

The regional requirements for surface and groundwater monitoring need to be assessed as part of a new regulatory framework. Local regulating bodies may want to ensure that they have monitoring points in all vulnerable aquifers. Surface water monitoring stations would need to be set up in key locations, as would groundwater monitoring. Watershed modeling efforts may point out key areas where quality and quantity measurements are important. Some benefit will be derived from new province-wide initiatives, however, without a renewed and updated effort in local or targeted monitoring, it will never be possible to know what the impact of agriculture really is on surface water or groundwater

The provincial government has developed standards for data collection and management in addition to a sampling protocol. Adoption of these methods will ensure that the monitoring data will be of sufficient quality and in a form that can be incorporated into a central system. All new systems need to generate data that is high quality and statistically significant. The current pass/fail system of monitoring bacteria, for example, was never designed for statistical interpretation. To that end, both sampling and analytical protocols must be adhered to.

### 5.3.4 Watershed Models

The ultimate tool that could be developed to assist in tracking the environmental health of an area is the Watershed Model. This model would incorporate the other assessments described above and utilize those data to estimate impacts of certain activities on water quality and quantity. Groundwater and surface water monitoring could be used to check the accuracy of the model and ensure that the model is truly representing regional conditions.

One of the most valuable components of an aquifer model is the cumulative modeling of water quality impacts. Neither cumulative water quality nor water quantity impacts are currently assessed on a watershed basis. Although the MOE Permit To Take Water program assesses an application based on the potential to impact local groundwater resources, cumulative impacts of all local water takings are not assessed. The evaluation consists of a one-time pump test in isolation from other takings.

Efforts towards watershed modeling have been conducted by several conservation authorities, most notably the Grand River Conservation Authority (GRCA). Extensive modeling of both the river and groundwater environments has been undertaken by the GRCA (Conservation Ontario, 2001). Conservation Ontario's submission to the Walkerton Inquiry describes the models that are presently used by conservation authorities to model the surface water and groundwater aspects of the watershed.

At present, the ability to merge groundwater and surface water models is elusive, however, a regional scale groundwater model and separate surface water model may be sufficient until new regional models move beyond the research phase.

### 5.4 Site Assessment of Potential Water Quality Impacts

If the province and regional authorities had more information readily available to assess a given application, approvals would have a much greater potential to protect water resources. However, it is still necessary for farmers interested in expanding their operations to collect on-site data that reflect the potential for the operation to impact water resources. The present use of nutrient management planning is only one component in a list of several items that should to be assessed.

It is necessary to empower regional agencies with the ability to control nutrient and water allocation. Impacts from over application of nutrients or over use of water are greatest on a local context; although linked through the Great Lakes may have a provincial significance.

#### 5.4.1 On-farm Hydrogeological Investigation

The preparation of a hydrogeological investigation at an existing or proposed farm operation would go a long way in estimating if that operation has the potential to impact water resources. Site specific hydrogeological information can help to evaluate if contaminants applied on the ground surface have a high potential to reach the water table. Such investigations are standard practice in applications for large or multiple septic systems or industrial operations that are considered a risk to water resources.

In Ontario, an application for sewage works such as a sewage lagoon is regulated by the OWRA. The proponent must provide:

- A discussion of the assimilative capacity of the receiving environment (groundwater, surface water, vegetation etc.)
- A description of the redundancies, including contingency plans
- Raw sewage characteristics
- Sewage flow metering, sewage sampling and site monitoring program (groundwater, surface water, etc.)
- Discussion of the sewage works with respect to surrounding land use
- Maintenance protocols

Once the proposal for a large sewage works is submitted to the Ministry of the Environment, the design of the system must undergo a technical review, to ensure the conformance of the design with sound engineering principals and the adequacy of controls and contingencies provided to facilitate the proper operation of works.

Large septic systems designed for greater than 10,000 litres per day or more than five residences must use Guideline B-7 under OWRA to show that groundwater will not be impacted. The purpose of the Guideline is to maintain reasonable use of an aquifer by maintaining minimal impact to the aquifer by subsurface disposal. The proponent must estimate concentrations of a specific compound in the receiving water and show that there is sufficient dilution available in the aquifer to reduce concentrations to acceptable levels. The Ministry of the Environment or Municipal agencies may request that a monitoring program confirm the estimated concentrations in the aquifer.

The application of biosolids to lands is controlled by Regulation 347 under the Environmental Protection Act and must comply with the Ministry of the Environment Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land. A Certificate of Approval for a Waste Disposal Site (Organic Soil Conditioning) must be obtained before biosolids can be applied to agricultural land. The application for the Certificate of Approval must include the following:

- Site assessment including separation distances, site-specific information and to ensure that all pertinent criteria are applied in the site assessment.
- Maps or diagrams showing the location of the site, the relevant boundaries and geological features and where waste should not applied. Bedrock outcrops, drainage tiles, surface waterways, wells within 500 m, buildings within 1000m etc.
- A waste analysis report, for the biosolids that are to be applied to the land, of all pertinent parameters outlined in Ontario Regulation 347.
- Soil analysis report that should include a description of sampling locations and the results of the pH and sodium bicarbonate extractable phosphorous analyses.
- Geology investigation including soil types and overburden types, an overburden thickness of at least 1.5m, and the type of bedrock.
- Crops to be planted on the field.
- Notification to adjacent land owners

In 1995, the MOE published "MOE Hydrogeological Technical Information Requirements for Land Development Applications". This document outlines the information that must be collected to support applications for:

- *a development requiring a ground water supply, either individual, communal or municipal*
- *a development serviced by a sewage systems requiring subsurface disposal of sewage effluent via leaching beds for individual, communal or municipal systems, or via surface disposal using spray irrigation from a sewage lagoon;*
- *proposed development sites having known or suspected soil and/or ground water contamination from either on-site or off-site sources; and*
- *proposed development sites that are located on hydrogeologically sensitive areas*

Municipalities responsible for approvals of land use applications have similar guideline documents to assist proponents in preparing an appropriate site investigation for review (Halton Regional Health Department, 1997, RMOW 1991, Township of Eramosa, 1994). A requirement of all applications is to show that the local groundwater will not be adversely impacted by the proposed development.

The development of a large livestock operation has the potential to cause greater groundwater impacts than some of the land use changes that are governed by these investigations. Evan and Myers (1990) incorporate a land use risk rating in their use of the DRASTIC methodology described above. Agricultural land ranks 9 out of 10 in terms of high risk along with auto junkyards and salvage operations. Landfill and industrial waste disposal sites rank 10.

Components of a hydrogeologic investigation for a new livestock operation might include:

- a site reconnaissance to estimate the locations of manure storage, pesticide storage, fields on which manure is applied, patterning of field tile drainage, location of tile outlets etc.
- an examination of local groundwater conditions using published data to estimate the depth to groundwater and direction of groundwater flow
- where appropriate, the installation of groundwater monitoring devices to determine the direction of groundwater flow, the groundwater gradient, the depth to water table and to sample the groundwater to determine the background chemical concentrations
- sample the materials in the unsaturated zone during drilling to estimate the permeability, the presence of secondary permeability such as fracturing and root holes
- sample groundwater to estimate background $NO_3$ and bacterial concentration
- sample the aquifer material to obtain an estimate of the hydraulic conductivity of the aquifer
- sample the water in receptor surface water bodies
- assemble precipitation data to estimate recharge
- use of published data and/or geophysical methods to locate abandoned wells and other subsurface anomalies
- compilation of off-site well records

Collected information can be used to make the following assessment

- correlation of stratigraphic units and water sample analysis
- the travel time of compounds in the unsaturated zone prior to reaching the water table
- the potential for bacterial to travel to the groundwater regime
- the speed of travel of compounds once in the aquifer
- the down-gradient users of water infiltrating on a particular farm
- the existing impacts from present farm uses or neighbouring farms
- the potential for tile drainage to impact surface water bodies

The hydrogeological assessment should also describe a monitoring plan and a contingency plan. If monitoring indicates that surface water or groundwater resources have been impacted and that manure spreading is the source of the problem, then manure spreading should be decreased or cease. If the manure storage facility is leaking it should be repaired. The operator must present a plan to show that if the operation does not perform as expected that there are measures that can be undertaken to prevent long term contributions to the environment.

The hydrogeological investigation recommended contains standard investigative techniques that are commonly used in hydrogeological investigations for many purposes. Qualified hydrogeological consultants could undertake an investigation of this scope for $5,000 to $10,000 depending on the site conditions. This seems to be a reasonable upfront cost for an operation constructing a new barn facility. The initial investigation should be updated annually for water quality monitoring analysis.

An assessment such as that outlined above would give regulating bodies a good idea if impacts could be expected. This type of investigation may also give local residents some estimate of the protection of their water supplies.

### 5.4.2 Groundwater and Surface Water Monitoring

Monitoring would be a necessary component of a site assessment to ensure that the operation is not adversely impacting the environment. A property boundary monitoring well could be sampled and nitrate and bacteria levels measured. After an appropriate length of time, if no impacts are measured the well could be decommissioned. If an operation is adjacent to a surface water body, surface water monitoring and tile water monitoring should also be undertaken. If impacts are noted in any of these areas, mitigation measures should be undertaken.

Monitoring data could be provided to the local regulatory body to demonstrate the performance of the operation and to the local conservation authority for inclusion into a Watershed Model.

### 5.4.3 Solute Transport Modeling

Predicting the proportion of chemicals applied to the ground surface that will infiltrate and ultimately reach the groundwater regime is very difficult. It has been tackled in many different ways. In Ontario, there is widespread use of NMAN, a program designed to balance the amount of total nutrients applied to the estimated nutrient uptake by the crop produced. In order to better predict the transport of surface applied compounds to the groundwater regime, several predictive models have been developed in recent years. Water balance models, designed to estimate infiltration (Gogolev and Ostrander 2000) can be coupled with models that simulate the transport of parameters like nitrate, bacteria, and chloride, to estimate the mass flux at the water table (Healy 1990). These tools are in wide usage in scientific and regulatory contexts throughout North America (Gogolev and Delaney 2000), but are not generally used to assess specific farm operations.

In the future, landowners may use models that simulate the weather on their farm for 5, 10, 20 or 100 years into the future. After providing input data concerning tile drains, soils, slope, crop type, and depth to groundwater, the model will calculate the predicted loading of key manure or fertilizer derived parameters to surface water and the groundwater. We recognize that these state of the art tools are not widely used today, however, they will ultimately be useful as an evaluation tool for individual farms.

There are several existing means of calculating and modeling contaminant transport in the subsurface. These are based on differential equations, which consider the various sources and sinks associated with a contaminant. Modeling of virus or bacterial transport is a different matter as it is constrained by a lack of quantitative information on virus interaction with soil and fluid media. The application BIOF&T 3-D claims to be able to model biodegradation, flow, and transport in the saturated and unsaturated zones. It is fairly sophisticated application that tends to be used for academic purposes. Currently there are no more simplified and robust models for pathogen transport in the unsaturated zone. However, there are some tools in use in other geographic areas or other disciplines that could be potentially modified for use in predicting pathogen transport on the farm scale.

### 5.4.3.1 Current Practice of Nutrient Management Planning

NMAN is the application currently being employed to estimate the amount of phosphorus and nitrogen that is used by the crops and therefore appropriate to apply to the ground in the form of manure and/or synthetic fertilizers. As discussed in a previous section of this report, this budget application has several limitations and shortcomings.

The farmer or often a representative from a feed or fertilizer company uses NMAN. It is user friendly and does not require an extensive list of input parameters:

1. GENERAL INFORMATION
   - County
   - Municipality
   - Lot & Concession

2. FIELD INFORMATION
   - Field Sketches (includes watercourses, catch basins, wells, tile outlets, field boundaries, homes and buildings in close proximity)
   - Crop Type
   - Yield
   - Previous Crop
   - Field Size
   - Soil Texture
   - Sodium Bicarbonate P Soil Test
   - Ammonium Acetate K Soil Test

3. MANURE INFORMATION
   - Description
   - Time of Application (Fall, Spring, or Summer)
   - Incorporated (1,3,5 days, Not Incorporated (Bare Soil, Residue), Injected, or Late Fall)
   - Nutrient Values for N, $P_2O_5$ and $K_2O$

As shown by this list, there are no data pertaining to water resources on this list. Therefore, although NMAN helps to predict the amount of synthetic fertilizer that needs to be added on a farm that spreads manure, it does not in any way address the potential for contaminants to reach the water table. In fact, NMAN uses the false assumption that there is no groundwater or tile water component to nitrogen partitioning.

#### 5.4.3.2 New Modeling Tools for Agricultural Abatement

The effectiveness of a predictive model depends not only on the number of processes it describes, but also on availability of input data. The information currently collected for use with NMAN, as well as the output data, provides a great starting point. This information could be built into an agriculture database to be used in conjunction with the model applications reviewed below.

Some of the alternative tools discussed below have been proven applicable in the past. In the paper "Nitrogen Modeling on a Regional Scale" (Rijtema and Kroes, 1991) processes which are involved in nitrogen modeling on a regional scale are discussed, and the performance of some models in relation to measured field data is analyzed. Rijtema concludes that for the regional European model used, simulated data can be considered as being sufficiently reliable, and differences in nitrogen discharge between different scenarios can be considered realistic and meaningful, giving a good basis for a national policy analysis.

A limited number of computer model applications were investigated for their applicability towards improving upon the functionality of NMAN. Expert opinions were solicited concerning the applicability of these alternatives. Those applications reviewed are structural models rather than budget models and are listed in Table 8.

**TABLE 8: Available Models for Estimating Infiltration and Solute Transport**

| MODEL / APPLICATION | PURPOSE | DESCRIPTION |
|---|---|---|
| **HELP** | Landfill Hydrology | A versatile US EPA model for predicting landfill hydrologic processes and testing of effectiveness of landfill design |
| **VS2DT** | Unsaturated Flow and Transport | A US Geological Survey model for describing the transport of contaminants with unsaturated water flow and its transformation in vadose zone |
| **ANIMO** | Fertilizer Application Process | A 2D transport model for describing the complete cycle of nitrogen, phosphorus and carbon transformation processes in the saturated zone |
| **LEACHM** | Contaminant Transport | A quasi 2D transport model for describing contaminant transport through a unit column of specified soil type |

These models are all one-dimensional or quasi two-dimensional, based on the solution of an analytical equation. It has been proven theoretically that in 95% of cases within the unsaturated zone (except for the narrow zones along the drains and surface water streams) major fluxes occur in vertical direction. Preliminary conceptualization of the modeled area is therefore required for one-dimensional models. Piece-wise polygons, each with its own set of parameters, would have to be setup and modeled independently. This conceptualization would be best dealt with using a GIS system. Table 9 compares these models based on some key parameters related to agricultural land use.

**TABLE 9: Model Comparisons**

| CONCERN | APPLICATION | | | | |
|---|---|---|---|---|---|
| | ***HELP***** | ***VS2DT***** | ***ANIMO*** | ***LEACHM*** | ***NMAN*** |
| **Crop Type** | Model accounts for veg. on top of landfill, not directly connected to a "crop type" db | NO | **YES***** | Has a crop growth sub-routine; D Coote's expressed lack of confidence in it | **YES** |
| **Geology** | **YES** | **YES** | **YES** | NO | NO |
| **Historical Climate Data** | **YES** | No; does have input for evapotranspiration parameters | Allows for the input of weather conditions | Requires daily weather data | NO |
| **Scale - Regional** | Would be difficult to simulate, only in the framework of an expert system | Would be difficult to simulate, only in the framework of an expert system | Would be difficult to simulate, only in the framework of an expert system | Would be difficult to simulate, only in the framework of an expert system | NO |
| **Scale - Site Specific** | **YES** | **YES** | **YES** | **YES** | **YES** |
| **Soil Chemistry** | NO | Simulates contaminant transport, not directly applicable to nitrogen and phosphate cycles | **YES;** Simulates the behavior of pesticides nitrogen, phosphate and organic carbon | **YES** | **YES** |
| **Soil Moisture** | **YES** | **YES** | **YES**** | **YES** | NO |
| **Soil Type** | **YES** | **YES** | **YES** | **YES** | NO |
| **Tile Drainage** | Could be simulated by installing horizontal drains / lateral drainage layer | NO | **YES**** | Could be simulated by truncating the soil layers at the depth of the tile | **YES** |
| **Till Effects** | NO | NO | **YES**** | NO | NO |
| **Topography / Runoff** | **YES** | **YES In conjunction with HELP** | **YES**** | No, however, if the iput of water exceeds infiltration, then the quantity not infiltrated is specified | NO |
| **Unsaturated Depth** | Appears to be the default, due to capability to specify a sat. layer, however further investigation required | **YES** | **YES**** | **YES** | NO |

* Included in the UnSat Suite Applications pacakge (WHI)

** ANIMO uses the results of a hydrological model as it boundary conditions; therefore only addressed if appropriate hydrological model is applied

*** If ANIMO is used with the Dutch model SWACROP, crop types and yield may be simulated

## 1. NMAN

NMAN is the current computer application used by farmers to determine fertilizer application rates to their fields. This application is a "budget" or "black box" model, which relates outputs to inputs with little approximation of physical and chemical processes occurring in the unsaturated zone. Budget models have only a limited range of applicability (Rijtema and Bolt, 1995). No known review of the NMAN application has been conducted to date, nor has a sensitivity, gap error analysis, or field test ever been reported in the literature. NMAN has not been tested at the bench or field scale. As discussed in section 3 of this report, using NMAN to calculate the N and P generated by one livestock unit in different systems produces extraordinarily variable results. Applying NMAN to farms under identical input parameters except variable surface soils produces identical nitrogen results.

## 2. HELP

HELP (Hydrologic Evaluation for Landfill Performance) is a water budget program designed by US EPA to predict runoff and leachate generation at landfill sites. The model uses soil data, slopes, precipitation, and subsurface drainage to predict runoff and infiltration. The HELP model has been extensively tested and is a USEPA standard.

- Surface ponding
- Run-off
- Infiltration
- Evapo-transpiration
- Vegetative growth
- Soil moisture storage
- Lateral subsurface drainage
- Unsaturated vertical drainage

HELP would provide the cornerstone to a suite of predictive models for agriculture by combining geologic, agronomic, and climate variables to produce a value for volume of water infiltration. All simulation of chemical transport would be based on this important variable.

## 3. VS2DT

VS2DT is a USGS model describing the transport and transformation of contaminants in the unsaturated zone. It is based on the solution of Richard's Equation and is considered an academic tool, partially due to it being difficult to use.

## 4. ANIMO

ANIMO simulates the behaviour of pesticides, nitrogen, phosphate and organic carbon in a soil-plant-water-system. It is DOS-based and a Windows interface does not currently exist.

An example of the use of ANIMO is found in *Regional Approaches to Water Pollution in the Environment* (Rijtema and Bolt, 1995). In this example, ANIMO calculates the processes in the unsaturated zone and the top layer of the saturated zone for the calculation of the local discharge of nutrients and pesticides to surface water by drainage systems. Measured vs. calculated nitrate-N concentration show good correlation between actual and simulated values (Rijtema and Kroes, 1991).

**5. LEACHM**

LEACHM is a process-based model for water and solute transport, solute transformation, and plant uptake in the unsaturated zone (Hutson and Wagenet, 1995b). LEACHM describes the complete nitrogen and carbon transformation process. Although it was designed to study processes, it has been used as a screening tool to develop soil nitrate leaching potential ratings from soil survey information and weather data (Agriculture and Agri-Food Canada, 1995). LEACHM was modified for inclusion in the expert system EXPRES to include daily meteorological data, estimate potential evaporation, include a snow accumulation and melting routine and estimate surface runoff and erosional losses of water (Crowe and Mutch, 1994).

LEACHM has also been shown to provide good correlation between actual and simulated concentrations of nutrients and pesticides in drainage systems (Rijtema and Kroes, 1991).

#### 5.4.3.3 Expert System

Together a data collection/storage system, a GIS and a solute model would comprise an "expert system" that could be used to design or enforce sustainable agricultural practices.

To build an expert system, soil and agronomic databases would need to be created and used as input for the computer models. Calibrated models produce forecasts used for making strategic long-term decisions. These models should be calibrated with the observed data and corrected, as new data becomes available. These data should also be used for immediate decision making in emergency cases. Including the database development, an expert system for a farm scale operation could be developed in 12 to 18 months.

An expert system would be too demanding for an untrained individual to use. Even with development of a simplistic interface, the end user would need a general understanding of computer modeling. Therefore, the use of the expert system should be limited to sites or regions of concern, where there are too many variable or complex parameters or to work on the sentinel farm research sites. Conservation Authorities, planners and consultants could utilize this expert system to determine if a farm activity would be safe in terms of N and P impacts to the groundwater.

From this review, a coupling of the HELP model with the ANIMO model is recommended as the best means of developing a predictive capability. These two applications would be incorporated in the aforementioned 12 to 18-month expert system development. Based on the developed agricultural database, the expert system would use the adapted HELP model to simulate the hydrologic balance for a farm and ANIMO could then be run, using the help output as input. ANIMO estimates the annual loading rates of nitrate or phosphate to groundwater.

# 6.0 IMPLEMENTATION OF A NEW REGULATORY FRAMEWORK

The roles and responsibilities to implement the proposed framework are described below.

## 6.1 Provincial Role

It is recommended that the province conducts or facilitates the following:

- Develop the appropriate regulations to establish minimum standards for farming practice
- Review and approve applications for complex or large operations
- Develop the appropriate regulations to empower either the conservation authorities or the municipalities to assess and approve applications for changes in land use based on environmental factors; and to police operations of a certain scale based on the new minimum standards
- Provide the necessary resources to allow either the conservation authorities or the municipalities to collect all data presently held by the province in a GIS system for quick recall of area characteristics
- Provide the necessary resources to use the data above to develop an aquifer vulnerability assessment for each regional area. Alternatively this work could be conducted by the province and subsequently given to the regional jurisdictions. A similar methodology is being conducted as part of the province wide groundwater-monitoring program.
- Assist farmers in implementing new minimum standards, BMPs and NMPs
- Provide funding to offset costs to farmers for changes to farm operations or reduced yields.

## 6.2 Regional or Provincial Government

It is recommended that those regional jurisdictions such as the Conservation Authorities or Municipalities conduct the following:

- With the assistance of the province develop aquifer vulnerability mapping, wellhead protection zones and watershed modeling
- Implement land use restrictions in sensitive areas
- With the assistance of new regulation undertake the approvals of all new livestock operations, level of approval would be based on the type of operation proposed and the vulnerability of the water resources in the area
- Provide enforcement of NMP and of any other conditions of approval such as monitoring

- Examine the specific land uses within the sensitive areas of their jurisdiction, consider alternative methods of reducing environmental impacts such as purchasing land, reimbursing farmers for reduced yields in exchange for reduced manure or nitrogen application
- Consider area wide manure treatment facility if land is very sensitive and there is interest in large scale farming
- Audit agricultural practices on all existing farms according to new provincial regulations such as time of manure spreading, rates of application, off-site migration of bacteria, etc.

### 6.3 Proponents of New or Expanded Farm Operations

It is recommended that the proponents of new operations conduct a hydrogeological investigation prior to application. The scope of the investigation would depend on the proposed operation and the sensitivity of the land. To facilitate approval of new facilities the following checklist must be completed and certified by a qualified professional.

1. the direction of groundwater flow has been estimated
2. the rate of groundwater flow has been estimated
3. there are no sensitive surface water courses within a 5 year flow from the manure storage and spreading area
4. there are no municipal water supply wells within 5 year flow from the manure storage and spreading area
5. there are no domestic water supply wells within 3 year flow from the manure storage and spreading area
6. all wells abandoned or otherwise contained within the MOE well records have been located using scientific means as required
7. all abandoned wells have been appropriately decommissioned or are not down-gradient of manure spreading
8. All tile drain outlets have been located
9. General tile drainage system layout is known
10. Tile drains interrupted by construction will be redirected based on engineered plan of drainage
11. A nutrient management plan has been prepared and sufficient land is available, written agreements are available for lands not under ownership, soil and manure analysis data from certified lab are available on request
12. Solute transport model has been used to estimate infiltration flux and concentrations
13. Solute concentrations at the property line are not estimated to exceed background nitrate concentration
14. Groundwater monitors have been placed at property boundary to provide data regarding groundwater impacts, initial concentrations are below Provincial Drinking Water Objectives
15. Monitoring wells have been located at the discharge points in the perimeter drainage systems designed for all storage structures
16. Establishment of full or partial EMS

The submission of a checklist like this one with a short report should enable municipalities to conduct approvals without requiring professional expertise except in the case of highly contentious sites. "Professional" means an individual possessing membership in a professional self-regulating association such as a P.Eng. or P.Geol.

### 6.4 Levels of Approval

The approval process could be dependent on the aquifer vulnerability assessment. Proposals in highly vulnerable areas would be considered quite differently than those in low vulnerability areas.

The following example of a graduated approval regime is proposed:

High Vulnerability and in Wellhead Protection Area or surface water recharge areas

- Moratorium on intensive livestock agriculture
- Exporting of manure to areas of less sensitivity
- Use of manure treatment technology

Medium Vulnerability and outside of Wellhead Protection Area or surface water recharge areas

- Completion of the checklist above (Section 6.3)
- Annual monitoring of groundwater quality
- Annual renewal of NMP

Low Vulnerability

- Completion of checklist above excluding items 12, 13, and 14

### 6.5 Programs To Improve Existing Water Quality

High Vulnerability or significantly Impacted Regions

- Attempt to purchase any lands that are likely to be causing groundwater impacts
- Reimburse farmers for reductions in crop yields due to reductions in fertilizer and pesticide use
- Reimburse costs to farmers to move manure and spread in less sensitive areas or to transport to an off-site treatment location.
- Assist farmers in constructing 365 day storage facilities so that the optimum use of nutrients by plant growth can be utilized
- Construct treatment units (Robertson units) at the tile drain outflow
- Establish manure treatment facilities.

Medium and Low Vulnerability

- Assist in the preparation of EFPs for each farm in area, help to highlight key areas of potential impact and methods for improvement
- Develop an EMS program for agricultural facilities based on the ISO 14000 standard

## 7.0 WELLHEAD PROTECTION

Groundwater has many functions in the natural environment, including providing baseflow to streams, rivers, and lakes, being a natural resource and a source of water for drinking, irrigation, livestock watering and manufacturing of goods. Groundwater as a resource should be protected by provincial legislation that makes a governing body responsible for and capable of assessing the risks to groundwater quality. That body requires the tools to monitor these risks and possibly take action to eliminate risks. The framework discussed in sections 5 and 6 highlights the necessary tools to provide a greater degree of certainty that proposed land use changes do not negatively impact groundwater resources. Wellhead protection can be looked at as another level of protection specifically aimed at drinking water quality. As mentioned above, preventing contamination of a drinking water supply is a much more economical way of ensuring water quality than mitigating the costs of a contaminated water supply, including treatment, compensation, etc. Krewski et al. (2001) conclude in their submission to this inquiry that *"The most effective approach for managing microbiological risks from drinking water is source water protection".*

Other jurisdictions have undertaken comprehensive wellhead protection measures. Several European countries have undertaken wellhead protection strategies years ago and have been leaders in developing restrictive land use planning to protect their aquifer quality. Germany developed a groundwater protection system integrating travel time and distance from a water well in the 1930s with “Guidelines For Protected Areas Used For The Production Of Drinking Water, Part I: Protected Areas For Groundwater" published in 1953 (Schleyer and Milde, 1989). Protection zones generally include three levels, protecting the wells from various types of contaminants depending on the travel time to reach the well.

The Wellhead Protection Program (WHP program) of the Safe Drinking Water Act in the United States requires every state to develop a groundwater protection plan for drinking water supplies. Presently 48 states and two territories have wellhead protection programs in effect (Federal Register, 2000)

Canada also has some good examples of wellhead protection plans. In New Brunswick, a three tiered system was put into legislation (Communications New Brunswick, 2000). The three zones represent different travel times in the aquifers. Zone A represents 100 to 250 days and land uses that contribute bacteria and viruses to the environment are prohibited. No livestock grazing, or manure spreading is permitted in this zone. The second zone represents a travel time of up to 5 years and land uses that could contribute petroleum products to the environment are prohibited. Zone C is up to 25 years of travel time and land uses that could contribute chlorinated hydrocarbons are prohibited within this zone.

The Province of British Columbia has recently passed a Drinking Water Protection Act that has provision to develop wellhead protection plans across the province (British Columbia Ministry of the Environment et al. 2001). Considerations are given to siting of new wells, restrictions of land use within the wellhead recharge areas of the existing wells, the appropriate abandonment of unused wells and the need for a single authority protecting the water supply rather than the many layered system that presently exists in some areas. .

In Ontario, several local jurisdictions have mapped wellhead recharge areas and have begun to develop restrictive land use requirements within those areas. RMOW undertook an extensive program to estimate the high-risk land uses that exist within their wellhead capture zones. Studies from other jurisdictions that highlighted the potential for industries to contaminate groundwater were customized for their particular industrial and commercial base. The result was a list of industries that would be prohibited from commencing operations in their wellhead protection areas. An "A", "B" and "C" list was developed with "A" industries being the most likely to impact groundwater quality. In general, "A" industries are land uses where wastes are in direct contact with the environment such as sewage lagoons, waste disposal sites and auto wrecking sites. "B" industries are those that use hazardous substances or have been found in other areas to have resulted in groundwater contamination. The "B" list includes, service stations, certain types of manufacturing, road salt storage facilities and other land uses. The "C" list includes paper and rubber products manufacturing, textile manufacturing, golf courses and other land uses (RMOW, 2000). Although this list represents industrial and commercial land uses, agricultural uses may eventually be included in the list. In fact, liquid manure storage systems could arguably be placed in the "A" category.

The Town of Caledon and the Township of Caradoc have land use restrictions built into their Official Plans so that the source areas for their wells are protected. In the Town of Caledon underground storage tanks, dry cleaners, large septic systems, automobile service stations and other land uses are not permitted within the 10 year well capture zone of their water supply wells (Town of Caledon, 2000). The Township of Caradoc prohibits communal sewage systems, storage of chemicals and gas stations within the capture zone of municipal wells. Some restrictions are also placed on agriculture.

The government of British Columbia has prepared a Wellhead protection toolkit which is a very informative step by step document for developing a wellhead protection plan. The recommended steps include:

- form a community planning team
- define the capture zone (recharge area) of the community well;
- map potential sources of pollution in the capture zone
- develop and implement protection measures to prevent pollution
- develop a contingency plan against any accidents

- monitor, evaluate and report on the plan annually

Each of these tasks is described in detail in a booklet to allow easy adoption in other areas. The USEPA also has generated various documents with instructions on developing and implementing a wellhead protection plan (USEPA, 1991a, 1993).

Wellhead protection is a two-fold process. New wells should not be sited in areas with potentially contaminating land uses; potentially contaminating land uses should not be permitted in the vicinity of existing or proposed wells. Unfortunately, incorporating these principles in a developed area with water supply wells in place, is a complicated, controversial and potentially expensive procedure. However, the tragedy in Walkerton demonstrates that difficult as it is, the benefits most certainly outweigh the costs.

Approvals for new operations is a relatively simple procedure and is outlined above; if the aquifer is vulnerable and the land use has the potential to contaminate water resources it should be prohibited or restricted. Restrictions should be flexible enough to allow the proponent of a new or expanded operation to prove that the operation will not impact water resources. A professional should conduct the investigation and certification process so that the governing body can rely with some certainty that the assessment is accurate. Auditing and monitoring would have to be incorporated to show that the assessment was accurate. The Town of Caledon has implemented this type of land use restriction in their jurisdiction.

The issue of existing operations is much more complicated. Education programs such as the EFP should be updates to include more groundwater protection measures and continue to be implemented. In highly vulnerable areas or in the inner wellhead protection zones, new owners should phase out prohibited land uses over time by preventing the continuation of prohibited operations. Reductions in land values should be borne by the society that benefits from the clean water, i.e. the taxpayer. Key lands should be purchased by the government and set aside as protected areas or be resold with restrictions placed on title. Incentive programs such as the Rural Water quality Program in the Waterloo area and a similar program in Wellington County provide partial funding to farmers to alter a farm operation. High priority in these programs is given to fencing animals from watercourses and creating buffer strips. Programs such as these could be more effective in protecting the environment by targeting specific operations. The EFP program could highlight these operations and farms with particularly bad operations could be approached to conduct works with the assistance of the incentive program. It remains, however, critical that minimum standards of operation be applied to the normal farm practice of handling manure on existing farms through overarching provincial regulation.

Methods exist to delineate and protect wellhead protection areas. These methods have been implemented in other parts of the world and in other jurisdictions in Canada and on a smaller scale in Ontario. Land use mapping highlighting the high-risk industries and land uses will assist in siting new wells in locations where minimal impacts are expected. Land use mapping in the capture zones of existing wells may aid in tracking down the source of contamination in the event that a well is impacted. Restrictive zoning for existing capture zones and capture zones for new wells would help to protect the water quality in those areas. Incentive programs of various types could assist existing operations in sensitive areas to improve operations.

## 8.0 SUMMARY OF RECOMMENDATIONS

A recent trend in the agriculture industry is towards large scale farming, where the quantity of animal manure generated compared to the farm's land base for spreading has increased to the point that lands other than the home farm are required to dispose of the manure. This type of farming carries an environmental risk that needs to be acknowledged in regulations governing farming. All farms, large and small pose some degree of risk to the health of the natural environment. However, in the event that a release occurs, large farms have a proportionally greater potential to create significant environmental damage. Unfortunately, existing regulations of farm practices;

- do not require rigorous site investigation prior to farm siting,
- do not require the use of BMPs in the farm operation
- do not prohibit manure spreading at times when risk to the environment is greatest
- do not require leak monitoring for large liquid manure storage facilities
- do not require monitoring of surface waters and groundwater that receive tile drainage or seepage from storage facilities
- and do not require contingency plans in the event of facility failure or unforeseen weather

As was so tragically demonstrated in Walkerton, bacteria and viruses are some of the most deadly of the many potential drinking water contaminants. Research has shown that pathogenic bacteria and viruses can travel significant distances in certain geological and hydrogeological conditions. The most sensitive hydrogeological environments are at surface or near surface fractured (or karstic) bedrock and at surface or near surface sand and gravel aquifers. Unfortunately, it is still difficult to accurately predict the fate and transport of bacteria and viruses in the environment. Therefore, extra precautions must be taken when releasing bacteria to the environment, particularly if that release is the widespread such as manure on farm fields.

Existing manure management guidelines do not adequately provide for groundwater protection. They are not groundwater focussed and in many cases do not recognize the potential for bacteriological contamination of groundwater.

As educational tools the Best Management Practices and Environmental Farm Plan should be revised to include groundwater as a major consideration. Emphasis should be placed on activities that are likely to have significant groundwater impacts. "Best" practices should be carefully chosen, highlighted and even if these practices are not within reach of many farmers today, they should be put forth as future goals so that we are not simply maintaining the practices that can result in environmental degradation. BMPs and the EFP should not be relied upon to ensure adequate farm practices.

Nutrient management plans should either be improved to include leaching to groundwater using a solute leaching model or should be used as one part of an entire site assessment. The existing nutrient management plans are designed to balance nutrients and are not designed to predict release of bacteria to the environment.

A new regulatory framework should be set up for approvals of new operations and for reducing the existing environmental impacts on sensitive land. Key components of a new regulatory framework should be:

1. Strong provincial legislation should be developed that includes regulations requiring a more extensive evaluation of an agricultural operation prior to approval:

    - An applicant should have to conduct a hydrogeological investigation to show that the spreading of large amounts of manure would not cause an adverse environmental impact.
    - Minimum farming standards should be in place so that regulating bodies and the public know the degree of environmental protection that is provided in the day to day farm operation.
    - Monitoring of groundwater and tile drainage to surface water should be required to show that certain operations are not adversely affecting water resources.
    - Legislation should ensure that local regulating bodies have the appropriate tools to be able to assess the vulnerability of the groundwater resources in the areas and therefore the potential for groundwater impacts.
    - This legislation would also need to ensure adequate qualification of individuals spreading, transporting and handling manure, record keeping, auditing and compliance in order to have a positive effect on the groundwater quality.

2. Aquifer vulnerability mapping should be conducted across the province so that certain areas can be prioritized in terms of the potential for groundwater impacts and therefore drinking water impacts:

    - The type of mapping may be employed regionally in recognition of the varied geological conditions in Ontario. Appropriate methods are available and have been tested, not only in Ontario but also in other provinces and many states in the U.S.A. The MOE is presently compiling results of thirty-three studies conducted in Ontario and will soon be in a position to put forth methods that worked well in different regions.

    - Aquifer vulnerability mapping would point out drinking water sources that are particularly sensitive to environmental degradation. These areas would need to be rigorously protected.

3. Wellhead recharge mapping should be conducted to delineate the land area where drinking water resources originate. Wellhead protection strategies should be implemented for all municipal water supplies. Recharge areas for drinking water wells should rigorously protected.

4. Province wide groundwater monitoring is necessary to determine the impacts of agricultural land uses and to track the changes in groundwater quality with changes in land use.

5. Watershed modelling could use all of the above information to track the environmental health of an entire watershed. This modelling could perhaps be used to delineate areas where no further degradation of water quality should take place and other areas where some capacity still exists to assimilate agriculturally derived pollutants such as bacteria and nitrates. Consideration should be given to creating a database that identifies the land base used for manure spreading as identified in Nutrient Management Plans. This will allow for appropriate watershed-based planning to ensure that nutrients are not being over-applied within the watershed.

6. Site assessments need to include hydrogeological parameters such as groundwater flow direction, groundwater flow rate, potential receptors, travel time to water table etc. More detailed site assessments would allow proponents to conduct a checklist type evaluation of their operation, allowing regulators to more appropriately assess potential impacts from a proposed operation.

Agricultural operations have been shown to adversely affect groundwater quality. However, agricultural operations are largely unregulated. Regulations need to be developed beginning with new, large operations that carry a relatively higher risk to water resources followed by existing operations that are in susceptible hydrogeological environments. Incentives must be made available to existing operations to ensure that changes being made for the greater environmental good do not seriously affect the farm economics.

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