Watershed-Based Source Protection Planning

Science-based Decision-making for Protecting Ontario's Drinking Water Resources:

A Threats Assessment Framework

Technical Experts Committee

Report to the Minister of the Environment

November, 2004

Protecting our environment. Ontario

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Printed on recycled paper

PIBs 4935e

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November 30, 2004

The Honorable Leona Dombrowsky,
Minister of the Environment

Dear Madam Minister:

On behalf of the Technical Experts Committee, we are pleased to submit this report for your consideration in developing drinking water source protection legislation for Ontario.

The Committee sincerely appreciated the opportunity to provide input into this important program. Individually, the Committee members brought their enthusiasm and technical expertise to the discussions, while collectively they collaborated and shared thoughts and approaches so that their recommendations would reflect as much as possible a balanced and objective perspective.

Within the time-frame allocated for this work, the Committee focused its efforts on two key topics: those areas where the highest risk was perceived to be present or anticipated, and the technical components of the threats assessment framework. The Committee identified several areas that warrant further effort and noted that these recommendations simply reflect a starting point for Source Protection; it is likely that 15 or 20 years and 3 or 4 cycles of plan development or updating will be needed for the program to reach maturity.

Over time, and with guidance from the Ministry of the Environment, program participants can share their knowledge and experience to develop a comprehensive source water protection program that is truly "world-class."

The Technical Experts Committee wishes to thank you for the opportunity to contribute to the launching of this remarkable endeavor.

Sincerely,

Jim Smith, Co-Chair
Chief Drinking Water Inspector and
Assistant Deputy Minister,
Drinking Water Management Division
Ontario Ministry of the Environment

Gayle Wood, Co-Chair
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Acknowledgements

The Technical Experts Committee found the opportunity to interact with peers of different disciplines very rewarding and fulfilling. For that opportunity, we are grateful to the Minister of the Environment.

TEC was very capably supported by the Threats Assessment Working Group (TAWG) whose membership is included in Appendix 1b. TAWG included staff from the Provincial Ministries of Agriculture and Food, Natural Resources, Environment, and the Municipal Affairs and Housing. TAWG also included members from Conservation Ontario, Ontario Federation of Agriculture, the Grand River Conservation Authority and Ducks Unlimited Canada. Ian Smith of the Ministry of the Environment chaired this group, and TEC members especially appreciate his contributions both via TAWG and directly to TEC meetings and deliberations.

TEC members also greatly appreciate the administrative support that Gina Casey of the Lake Simcoe Region Conservation Authority provided by arranging meetings and managing records of the committee. The committee members also appreciate the accessibility and openness of Nicola Crawhall, policy advisor to the Minister of the Environment. Nicola shared ideas openly with the Committee and provided valuable input.

Finally, we appreciate the patience and support of our various employers for allowing each of us the time to contribute to what is such an important initiative of the people of Ontario.

Message from the Technical Experts Committee

In this report, the Technical Experts Committee presents a comprehensive set of recommendations relating to the "threats assessment framework" envisioned in the provincial government's proposed source protection legislation. While the members achieved a consensus on most topics, differing views emerged in some areas. These differences were sometimes resolved through agreements on progressive implementation schedules or the use of a range of acceptable methodologies. The Committee agrees that the methods and approaches recommended in this report are comprehensive and current. Over time, incorporating new knowledge, better data, and evolving approaches is necessary and appropriate. The Committee suggests that a technical 'advisory committee' could help facilitate this task. On behalf of the Minister of the Environment, the advisory committee could either suggest new approaches or review alternative approaches suggested by local source protection planning committees or their staff. In addition, the Technical Experts Committee recommends that the provincial government undertake studies or projects to address gaps in certain areas. In these instances, the Committee did not have the time to acquire and synthesize the necessary information to offer specific recommendations.

The Committee devoted significant amounts of energy addressing issues relevant to groundwater sources, as opposed to surface water sources. This decision was primarily based on the inherent complexity of the issues associated with the high variability of the subsurface environment. As such, many of the recommendations within the report address groundwater issues. Despite this focus, it is definitely not the intent of the Committee to convey a message that groundwater sources in Ontario are unsafe. Communities are not to be discouraged from utilizing groundwater based drinking water supplies in favour of more distant surface water sources such as the Great Lakes. The recommendations in this report are intended to provide prudent best practices for ensuring the continuation of the high quality groundwater that Ontario resident's have come to enjoy. Groundwater is inherently much better protected than surface water, and for the most part, the groundwater used by Ontarians is typically an inexpensive source of high quality drinking water, offering advantages to communities in that it is generally found close to the area of demand, requiring fewer costly infrastructure expenditures.

The Committee cautions that the source protection plans that come out of the threats assessment framework will be only as reliable as the supporting information. Source protection planning will be truly effective only if local communities make use of all available information. The information that they develop, together with knowledge compiled by various organizations and different levels of government, must be freely and widely available. Communities that develop and implement source protection plans need to adopt the idea of "free and accessible information" as a guiding principle. Furthermore, the Ontario Ministry of the Environment, and indeed the Government of Ontario, must demonstrate the leadership required to ensure that source protection planning benefits from a continually open and transparent exchange of information.

Foreword

The Technical Experts Committee (TEC) was mandated to advise the Minister of the Environment on a "threats assessment framework" for watershed-based source protection in Ontario. The table below provides brief depiction of the structure of the Committee's report. The first column refers to the report's Figure 1.1, which is a schematic representation of the general process for source protection planning in Ontario. Most of the Committee's recommendations will have a significant impact the preparation of the Assessment Report. The Committee also made recommendations on risk management and, in particular, on the threats of provincial concern that should be included in the source protection plan. The second column relates the topic areas covered in the report to the Committee's Terms Of Reference. The report is largely structured according to the Terms of Reference. The third column provides the sections in the report where these topics are discussed.

Figure 1.1	Terms of Reference	Report Sections
Assessment Report – Watershed Characterization	Vulnerability Assessment Ecological Protection Provincial Water Quality Objectives (PWQO)	Section 2 – Guiding Principles Section 3 – Threats Inventory - Issues Identification, Water Budgets Section 4 - Vulnerability Analysis Section 7 – Ecological Protection and PWQO
Assessment Report – Issues/Threats Identification	Threats Inventory Sensitive Water Resources	Section 2 – Guiding Principles Section 3 – Threats Inventory and Issues Identification Section 5 – Risk Analysis, "Significant Direct Threat"
Assessment Report - Risk Assessment/Categorization	Risk Analysis and Risk Management	Section 2 – Guiding Principles Section 4 – Vulnerability Analysis – IPZ, WHPA, AV Section 5 – Risk Analysis Section 7 – Ecological Protection and PWQO
Source Protection Plan	Risk Analysis and Risk Management	Section 2 – Guiding Principles Section 5 – Risk Analysis Section 6 – Risk Management
Iterative Cycle	Data Requirements and Management	Section 2 – Guiding Principles Section 4 – Vulnerability Analysis – WHPA, AV Section 5 – Risk Analysis – Risk Assessment Section 6 – Risk Management Section 8 – Data Requirements and Management Section 9 – Research, Data and Information Needs

Executive Summary

Background and Introduction

The Technical Experts Committee (TEC) was mandated to advise the Minister of the Environment on a "threats assessment framework" for watershed-based source protection in Ontario. The Committee consisted of experts specializing in a range of areas, including biology, groundwater, microbiology, risk assessment and risk management, and environmental policy. Experts on the committee included members from academia, conservation authorities, conservation organizations, First Nations, the federal government, and municipal governments and departments.

In this report, the Committee provides advice in nine topic areas. A Terms of Reference prepared by the Ontario Ministry of the Environment (MOE) directed the Committee's deliberations. The Terms of Reference covered the key science elements central to the development of a risk-based framework for Source Protection. Four of the key areas of consideration for the committee included:

- threats inventory and issues identification
- vulnerability analysis
- identification of sensitive water resources
- risk analysis and management

The terms of reference also directed the Committee to address three complementary areas of discussion:

- water quality objectives
- protection of waters not used as a drinking water source
- the role of source protection for ecological protection

In response to additional requests from the Minister, the Committee also provided advice on:

- modifications to the Permit to Take Water program
- recommendations for priority actions for Source Protection for 2008

The Committee met monthly from January until November 2004. It created several sub-committees to address key areas of interest or discussion. The Committee benefited substantially from the technical expertise and experience provided by staff from several provincial ministries, as well as Conservation Ontario, Ontario Farm Association and Ducks Unlimited Canada.

This report includes a range of guiding principles. The Committee felt these guiding principles were important in providing overall direction in the development of source protection plans (SPPs). The core of the report consists of 125 specific recommendations relating to key topic areas noted in the Terms of Reference, as well as data and information management. In addition, the Committee agreed to make available the working papers it reviewed during its deliberations,

as well as some additional materials, to provide readers with context for the overall report. These are included as appendices to the main report.

Guiding Principles

The Technical Experts Committee discussed several guiding principles that should be considered in the development of source protection plans. The guiding principles cover a range of topics and how they apply to source protection planning. Topics include:

- free and open data and information sharing;
- multi-barrier approach;
- consideration of uncertainty;
- adoption of a watershed-based approach while addressing extra-watershed implications;
- continual improvement and ongoing plan renewal;
- application of sound science as the basis for risk assessment;
- the application of the precautionary principle;
- a need for ongoing research in support of source protection plans, including both applied research and opportunities for source protection planning committees to share "lessons learned"

Overview of the Source Protection Planning Process

It is essential for managers of source protection planning to understand how the Committee's recommendations will be applied to the science-based, decision-making element of the process.[1] A brief synopsis is presented below.

Protection of drinking water sources is the first step in a multi-barrier approach to ensuring safe drinking water. The goal of source protection is to provide an additional safeguard for human health by ensuring that current and future sources of drinking water in Ontario's lakes, rivers and groundwater are protected from potential contamination and depletion. Protecting the quality and quantity of drinking water sources will also help maintain and enhance the ecological, recreational, and commercial values of our water resources.

The source protection planning process is designed to enable a local Source Protection Planning Committee (SPPC) to evaluate the vulnerability of drinking water sources and the potential threats to these sources. Through a careful and iterative analysis, local committees will identify the risks of contamination or depletion to their drinking water sources and plan actions to reduce those risks and enhance the protection of drinking water sources. Each action in the final plan will specify who will be responsible, the timing and method for completion, and the means for monitoring and evaluating its effectiveness.

[1] The reader may wish to refer to the government's *White Paper on Watershed-based Source Protection Planning* (February, 2004) and the draft *Drinking Water Source Protection Act* for additional details on the proposed administrative structures to be put in place to enable conservation authorities, municipalities and interested stakeholders to carry-out the development of source protection plans.

The committee felt strongly that source protection planning should be viewed as an ongoing process: the plan is developed, actions are implemented, results are monitored, progress is reported, and then plans are updated. Source protection plans must be "living documents" that are used and updated.

Threats Assessment Framework

The Technical Experts Committee was convened specifically to provide advice on the science and technical issues that need to be considered for the development of source protection plans. The committee's discussions, per the terms of reference, focused on the elements of a science-based threats assessment framework. Figure 2 (Section 6) provides a graphical illustration of how the threats assessment framework was designed to function. This approach is based on the classical risk assessment paradigm, but was tailored to meet the specific needs and challenges of assessing a broad variety of risks to various types of drinking water sources. An explanation of how each step would be carried out, along with a summary of the committee's discussions and key recommendations for each step in the process, follows below.

Risk Identification

The first set of actions in the framework combine to form the "Risk Identification" stage. The first step, Watershed Characterization, includes completion of a watershed description, development of water budgets, and "protection area" delineations.

The *watershed description* is a compilation of available background information (e.g. physical characteristics, population distribution, land uses) to provide context for source protection planning. All drinking water sources, including private, communal and municipal, are highlighted so that stakeholders know where drinking water supplies are located in relation to various threats.

Water budgets compare all current and forecasted water uses and withdrawals to the total amount of water in the watershed, and are used to identify quantity sustainability issues in the watershed. The Committee agreed that source protection planning must address threats to not only quality, but to quantity as well, and that water budgets are a critical tool to enable SPPCs to understand and address quantity issues. The Committee supported a recommendation that, at a minimum, all municipalities should have a 25 year supply plan in place and all new plans should look to the 50 year planning horizon. From a technical standpoint, the Committee recommended that water budgets include both groundwater and surface water dynamics, since withdrawals from one invariably affect the other. Furthermore, the Committee felt it is essential to analyze water budgets developed through source protection with respect to the landscape - to gain insight on the types and magnitudes of hydrologic functions that are attributable to various natural features in the landscape. These analyses will help planners decide how much and what type of natural cover is required to sustain water quantity. The Committee agreed that a water budgeting process that includes documenting the pathways of water travel will help identify the aquifer recharge areas that need to be protected. The Committee further recommended that research be carried out to determine what reductions in aquifer recharge and discharge are sustainable over the long-term.

Protection area delineation uses scientific models and analysis to set out drinking water protection areas. The areas include 1) wellhead (groundwater) protection areas (WHPA), 2) intake (surface water) protection zones (IPZ), 3) other vulnerable areas (areas susceptible to groundwater contamination and major recharge areas), and 4) potential future drinking water supplies. Wellhead protection areas (WHPA) are defined by modeling to delineate the area contributing water to the well (capture zone) over a specified period. Intake protection zones (IPZ) for inland rivers and lakes will also be defined via modeling. Vulnerable areas in the landscape will be identified via hydrogeological models and Great Lakes drinking water intakes will be managed through the establishment of a 1 km radius zone. Future drinking water sources will be identified according to the 25 or 50 year water supply strategy. Each of these protection areas is established and identified in order to denote drinking water source areas that warrant an increased focus on threats identification, risk assessment and risk management activities.

Wellhead Protection Areas

The Committee examined options for the preferred technical basis for modeling WHPAs and vulnerable areas in the landscape, and endorsed a number of recommendations. The recommendations respecting WHPAs covered off preferred modeling approaches and the establishment of specialized risk management zones.

Key technical recommendations include endorsement of the "Time of Travel"[2] (TOT) approach for delineating WHPAs, the outer extent of which should be demarked by the 25 year TOT. The Committee recommended that the 5 year TOT zone should denote the area where significant effort should be invested in thoroughly assessing drinking water threats. In addition to the TOT delineation, the Committee recommended that a semi-quantitative approach, such as a "surface to well advection time" (SWAT)[3], be used to evaluate the vertical travel time of the water from the above ground surface to the aquifer. This measure can be used as a means of measuring the degree of protection afforded by the soil overburden above the aquifer. The Committee recognized that some modeling approaches require more data than may be readily available across Ontario, and therefore recommended that local SPPCs will need to decide which recommended modeling approaches can be best supported by existing data.

The Committee recognized that some threats to drinking water sources are likely to pose greater risks to consumers than other threats. Pathogens and dense non-aqueous phase liquids (DNAPLs)[4] were identified as two types of contaminants that are extremely problematic from a human health protection standpoint once they enter the aquifer. The Committee therefore recommended that special zones within the WHPAs be established to enable focused risk management efforts close to the wellhead. Specifically, the Committee recommended that two pathogen management zones be delineated, including a 100 m pathogen security area immediately surrounding a wellhead, and a 2 year pathogen management zone around a wellhead. The first zone represents an area in which the drinking water source would be

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[2] The "Time of Travel"is the time required for a particle of water to move in the saturated zone from a specific point to a groundwater source of drinking water."

[3] A SWAT is a measure of the time and the bulk transport (quantity) of water from the surface of the ground to the well intake.

[4] DNAPLs are chemicals, generally solvents, that are heavier that water.

considered highly vulnerable to pathogenic contamination. In the case of DNAPLs, the Committee recommended that a 5 year TOT zone be established to represent the area where DNAPLs would be subject to the most stringent risk management measures for those compounds.

Intake Protection Zones

The Committee recognized the need to create a protection zone for surface water sources that would be analogous to the wellhead protection areas created to protect groundwater. However, the Committee noted that the issues for surface waters are somewhat different in character from those facing groundwater. For rivers and inland lakes, the Committee felt the main role of a protection zone would be to respond to "spill" situations, where accidental events or storm events deliver spikes in contaminant concentrations to the intake. The Committee's recommendation for addressing these risks to drinking water sources was the establishment of an Intake Protection Zone modeled on a 2 hour minimum response time. The approach involves correlating the 2 hour response time to a zone on the landscape that traces water flow backwards from the intake, 2 hours upstream and overland. Land activities and uses within this zone would need to be evaluated for their potential to spill contaminants that would enter the source water, and practices would be subject to risk management requirements for spill prevention. For intakes on the Great Lakes, a fixed radius, 1 km protection zone around the intake is recommended, unless localized or historical impacts suggest that a larger zone is required.

Other Vulnerable Areas

Although many source protection efforts to date, both in Ontario and in other jurisdictions, have focused on protection at the municipal drinking water intake or wellhead, the Technical Experts Committee stressed the importance of designing source protection so that all sources of drinking water would be afforded some protection. In addition, the Committee recognized that a means of focusing source protection efforts in the broader landscape was also needed. For groundwater, the Committee felt it important to draw on existing work that has been done through the provincial groundwater studies. The Committee recommended that initially, "high aquifer vulnerability areas" be identified according to the current Intrinsic Susceptibility Index (ISI) or the Aquifer Vulnerability Index (ASI)[5]. In keeping with their recommendations for WHPA delineation, the Committee also recommended that as soon as feasible, surface to aquifer advection times (SAATs)[6] should be used to improve our understanding of the protection afforded by the vertical path through the ground to the aquifer. Furthermore, the Committee recommended that water quality data be collected from areas of high aquifer vulnerability, as these areas would be most prone to contamination issues initiating from the surface. As well, wherever possible, new municipal wells should not be located within the highly vulnerable areas. In the case of surface water, the Committee concluded that all surface waters are intrinsically vulnerable, and that current policies and regulations regarding their protection need to be applied

[5] The ISI and AVI are indices which are used to describe the effectiveness of the soil overburden in preventing surface contaminants from reaching the groundwater. The AVI analysis is conducted with respect to the aquifer used as source water, where as ISI focuses on shallow groundwater.

[6] SAATs are similar to SWATs, in that they are used to describe the vertical travel time, and the bulk flow of water from the surface of the ground to the aquifer.

to their fullest extent to ensure that these vulnerable areas receive treatment equitable to that provided for groundwater. The Committee agreed that new regulations and policies should be added as needed when existing policies are found to be inadequate.

The second element of the "Risk Identification" stage in the process involves *identification of threats to drinking water sources and identification of existing watershed issues* that may have an impact on drinking water quality. Issues that may pose risks to drinking water supplies, now or in the future, are identified through consultations with local stakeholders and collection of existing information about the water resource (e.g., water quality monitoring data). The identification of threats involves an examination of historical, current and future planned land use practices to identify those activities that could negatively impact drinking water.

The Committee focused considerable attention on how the identification of threats and issues could be facilitated and coordinated. The Committee decided that a useful approach would be to develop a provincial threats database that local SPPCs could use in identifying and evaluation potential threats to drinking water. The Committee felt that plans should evaluate these threats at an individual property level and geo-reference these threats in the landscape. The conceptual model envisioned by the Committee was a provincial database with several layers of information, including the capability to capture geo-spatial identification of threats, as well as provincially generated generic threats "profiles" which would include hazard information regarding the types of risk to drinking water that would be posed by various threats. The Committee made a number of recommendations regarding the maintenance of such a database, with the underlying concept being that both the province and local committees need to contribute updated information to the database so that advances in information can benefit all source protection areas in the province. To allow for local contributions to the provincial database, local committees would generate their own locally validated threats database to identify known threats in the watershed; this information would be in a format that would enable integration with the provincial database, and serve to update the provincial database on a periodic basis.

Given the significance of pathogenic contaminants, the Committee felt additional tools were necessary to identify and characterize these types of threats. The Committee recommended that all municipal source waters be microbiologically characterized, and that this characterization be based on a multi-indicator approach to be developed by the province. Additionally, the Committee recommended that microbiological raw water standards or objectives for all drinking water sources be developed based on the multi-indicator approach.

The Committee discussed and rejected the notion that threats in the provincial database could be "ranked" in a generic way that could be meaningfully applied across the whole province. The Committee agreed that a local assessment of a threat would be necessary to determine the risk posed by it – and therefore the same "threat" in the database could carry different levels of risk in different watersheds across the province. However, the Committee did recognize that there are certain threats that have been known to impact drinking water sources in more than one instance in Ontario and other jurisdictions. The Committee came to the agreement that these particular threats should be considered threats of provincial concern. The Committee's intent in identifying a list of provincial concerns was to recommend that in all vulnerable areas, these threats be subject to a mandatory assessment. In other words, local SPPCs must identify, characterize and assess the risk from these particular concerns in WHPAs, IPZs and other vulnerable areas. The figure below illustrates the concept that both a threat and a pathway must be present in to create a risk to drinking water sources. The list of threats of provincial concern is presented in the subsequent table. By undertaking an inventory of threats using the threats database, as well as identifying issues in the watershed, the Committee envisioned the development of an integrated threats and issues list that would include all the relevant threats to drinking water in the watershed. The items included on the integrated list would then be subject to the next step in the process: Risk Assessment.

Concepts of Threat, Pathways and Risk to drinking water sources

Threats

Activities, Land Uses, Conditions of the Landscape that *could* potentially pose a risk to drinking water

e.g. **Land Use/ Activity:**	Gas stations	Dry Cleaners	Manure Spreading
Threat:	- <u>potential</u>: leaky underground storage tanks	- <u>potential:</u> leaking solvent storage, spills	- manure contains pathogens and nutrient

+

Pathways

Set of physical conditions that allow the **threat** (if present) to travel to the **drinking water source**

e.g. **Pathway type:**	Improperly constructed wells	Karst Topography	Surface water

- presence of **pathways** to the drinking water source provide mean that of contaminants are introduced, they can get to the drinking water source

=

RISK

If a threat AND a pathway to the drinking water source are present, there is a risk

- The size of the risk depends on the type of threat, and the *likelihood* the threat will move through a pathway to the drinking water source, and the number of people that use the drinking water source

Threats of Provincial Concern

Activities	Primary Issue
Human-made Pathways to the Aquifer Activities/structures that penetrate the water table and/or aquifer. These include: • Existing wells (water, gas, oil) • Abandoned Wells • Pits , quarries, mines Other construction activities that provide short or long term direct access to an aquifer	"vulnerability" – direct pathways to current or future potential drinking water
Liquid Chemical Storage /Use Includes "commercial quantities"[7] of : • Fuels/ Hydrocarbons • DNAPLs[5] • Organic Solvents[8] • Pesticides (of concern to Drinking Water)	Chemical Contamination of Aquifers
Historical Commercial/ Industrial Sites of Concern • Includes historical land uses/ activities that have a high potential for contaminating drinking water sources[9]	Chemical Contamination of aquifers
Waste Storage and Disposal Activities Includes (specified quantities of): • Landfill sites • Organic Soil Conditioning sites (except for biosolids application sites – covered under another item) • Hazardous waste • Liquid industrial waste • Mine Tailings	Chemical Contamination of aquifers
Biosolids and Septage • Storage and land application of biosolids and septage	Pathogen Contamination of Aquifers, Nutrients
Manure • Storage and land application of manure	Pathogen Contamination of Aquifers, Nutrients
Sanitary Sewage and Septics Includes: • Sewer infrastructure (sewer mains & connections) • Sewage treatment plants effluent • Septic Systems • Sewage treatment plant by-passes • Combined Sewer overflows • Sanitary Sewer overflows	Pathogen Contamination of Aquifers, Nutrients
Road Salt/ De-icing Includes: • Uncontained storage, and application of road salt/ de-icing compounds • Salt-laden snow storage (snow dumps from plowing)	Chloride Contamination of Aquifers
Cemeteries • Burial grounds	Chemical Contamination of Aquifers
Stormwater Infiltration • Stormwater collection ponds in urban areas that are designed to allow	Chemical or Solute Contamination & Pathogen Contamination of Aquifers

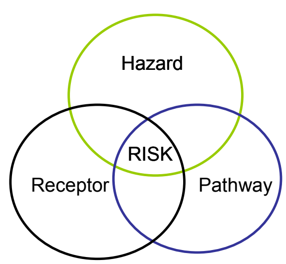
[7] Province to determine what the appropriate "trigger" quantity would be. Suggest considering thresholds or quantities referenced in existing legislation or accepted Environmental Management System schemes (responsible care, CSA, UL) for the purposes of risk management.
[8] As above
[9] Province to determine appropriate trigger contaminants
[5] Province to develop list of DNAPL materials

Activities	Primary Issue
stormwater to directly infiltrate into groundwater	
Water Treatment Plant Waste Water • Includes filter backwash discharges to surface water	Pathogen Contamination of Aquifers
Non-sustainable Withdrawals e.g. Situations where aquifers supplying municipal wells have levels which are steadily dropping over time, or where allocation of Surface Water supplies threatens quantity during low-flow conditions	Insufficient Quantity: resulting in reduced quality, reduced assimilative capacity, threat to sustainable supply

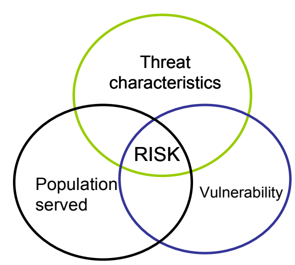
Risk Assessment

In the Risk Assessment step, the information gathered in the Risk Identification step regarding the vulnerability of the drinking water sources and the threats to the drinking water sources is considered and evaluated to determine the level of risk.

The Committee recognized that it would be unlikely that local source protection planning committees would be able to generate a strictly quantitative measure of risk posed by each threat, because the data required to generate such an estimate would be difficult to obtain. The Committee did recognize the need to have a consistent approach to assessing risks across the province and recommended that the *risk analysis* of risks from threats to drinking water should be assessed using a provincial semi-quantitative approach. The committee discussed a set of criteria that should be used as the basis for assessing risks to drinking water. Against these criteria, a systematic evaluation of the three components of the risk can be undertaken. The risk is comprised of: the hazard, or the characteristics of the threat; the exposure, or the pathway from the contaminant source to the drinking water; and the receptor, in this case the human population that would be consuming the water, as presented in the figure below.



Traditional Risk Paradigm



Source Protection Risk Paradigm

In order to facilitate risk management activities, the Committee recognized that it would be helpful to categorize risks. It was felt that three categories of risk, plus a fourth category for threats deemed to be of negligible risk, would create sufficient delineation for the range of risks expected to be found in a watershed. To this end, the Committee recommended that the semi-quantitative approach created by the province be developed in conjunction with benchmarks and guidance for local committees to use in determining how to categorize risks. The Committee also recommended that the tools and instruments identified by the Implementation Committee as appropriate for addressing risks to drinking water should be considered during the "calibration" of the risk categorization process.

The Committee was specifically requested to consider how to distinguish the most critical risks to drinking water from the rest. It recommended that the most serious risks to drinking water sources be deemed "Significant Risks", and:

> *A significant risk is one that has a high likelihood of:*
> - *rendering a current or future drinking water source impaired, unusable or unsustainable; or*
> - *compromising the effectiveness of a drinking water treatment process,*
>
> *resulting in adverse human health effects.*

Risk Management

The purpose of the *risk management* step in the process is to consider and evaluate the options available for reducing risks to an acceptable level. The Committee discussed risk management in general terms and with respect to the issues where it made specific recommendations.

In general, the Committee recommended an "outcome based" approach to setting risk management expectations. The Committee discussed at length how the appropriate level of risk reduction could be determined, and felt that the province needs to communicate its expectations on how much risk reduction would be enough. The Committee recognized that this determination would prove challenging, given the semi-quantitative nature of the risk assessment process. The semi-quantitative approach does not lend itself to the establishment of statistical benchmarks, as are seen in traditional risk assessment applications (for example, 1/1,000,000 acceptable risk level for additional lifetime risk of cancer for carcinogenic risks). The Committee recommended that an outcome based approach to setting provincial expectations be established, whereby the province would set generic targets and local SPPCs would develop options for meeting the targets. The Committee felt that in the majority of cases this would be the most appropriate means of encouraging development of innovative risk management approaches, and would enable local SPPCs to examine their suite of risks and develop risk management actions that would optimally address a range of risks.

With regard to significant risks, the Committee felt that the province should provide additional guidance on how these risks should be addressed, via the development of Beneficial Management Practices and new standards as appropriate. Furthermore, the Committee recommended that risk management activities for significant risks be initiated in a timely fashion. The committee specifically discussed the various ways in which risks from the threats of provincial concern could be addressed, and suggested that the province may wish to consider providing more prescriptive direction to local SPPCs on how to mitigate significant risks from these threats. In particular, the Committee recognized that it would be less difficult to prescribe the appropriate approaches for risk management of these activities with regard to future land use planning purposes than to impose drastic risk management measures (such as prohibition) on existing activities on the landscape. The Committee recommended that new activities that pose a threat to drinking water sources be directed to less vulnerable areas.

The Committee made a number of issue-specific recommendations regarding risk management approaches. Many of these focused on the management of risks from pathogen sources. Of particular note, the Committee recommended that all water sources intended for public consumption be treated for pathogens, where the treatment would be based on a characterization of the source water. The Committee recognized that complementary source protection measures should also be undertaken at the landscape level where local land uses/activities are known to contribute pathogen loads to the source waters. To address this problem, the Committee recommended that Beneficial Management Practices which include a variety of tools be implemented to reduce pathogen loadings to source waters. Additionally, the Committee felt it prudent that nutrient management plans and farm water protection plans be developed and implemented for all farms in vulnerable areas[10] as soon as feasible. The Committee also recommended that analogous "water protection plans" for commercial/industrial land use activities, located within vulnerable areas and identified as posing a risk to drinking water sources, be developed.

In recognition that source protection is a significant barrier in the multi-barrier approach for private drinking water sources, the Committee considered the role of source protection risk management activities in the protection of private wells and intakes in the province. The Committee recommended that the province develop a comprehensive program to address private water supplies; it was suggested that a primary focus of such a program should be the prevention of pathogen contamination of private wells and intakes.

With regard to the timing of implementation of the risk management actions, the Committee recognized that the provincial government will set out timelines under the source protection legislation and regulations. Notwithstanding the legislated timing requirements for general plan implementation, the Committee recommended that – in keeping with a precautionary approach – where local committees identify significant risks that have the potential to create a large impact, actions to mitigate the risks should be undertaken as quickly as possible. In other words, waiting for plan approval should not delay local due diligence in responding to known significant and potentially high impact risks.

Additional areas of recommendation

Permit to Take Water

The Minister of the Environment requested the Committee's advice on amending the permit to take water program. The Committee provided detailed advice on this topic. The Committee's letter to the Minister is included in the Appendices of this report. The Ministry of the Environment subsequently asked the Committee to review a proposal for lifting the (at the time) moratorium on permits to take water and the associated proposed changes to the program.

In their review of the proposal, the Committee noted that some original advice regarding permits to take water had not been incorporated. It is understood some of the fundamental changes suggested were outside the scope of the present activity, which was focused upon the lifting of the moratorium.

[10] Vulnerable areas include wellhead protection areas, intake protection areas and other designated vulnerable areas on the landscape.

With regard to the permit to take water program, the Committee has reiterated some of its original recommendations in this report, given their relevance to broader source protection planning issues. In particular, these recommendations call for local SPPCs to be recognized and given a role in reviewing or advising on requests for permits that may influence their source water, and secondly that the provincial government develop an overall "water strategy" to integrate this program with source protection and other existing policies or initiatives.

Provincial Water Quality Objectives (PWQOs) and Ecological Protection

The Technical Experts Committee examined the role of Provincial Water Quality Objectives (PWQOs) in source protection plans. In a related matter, the Committee reviewed the provision of ecological protection as a component of source protection plans.

The Committee agreed that PWQOs should be science-based and used as one benchmark against which water quality can be measured during the risk identification step. Rather than assessing how source waters measure up against all PWQOs, it was suggested that a suite of PWQOs which bear the most relevance to drinking water source quality be used as an index to measure quality. However, the Committee noted that because they are ecologically derived, it must be remembered that the PWQOs do not bear direct relevance to drinking water protection for human health.

The Committee discussed the importance of ecological protection under source protection planning. The Committee recommended that the provincial government encourage municipalities and conservation authorities to take action to ensure ecological sustainability with respect to source water, even where the water is not used as a source for drinking water.

In a related topic area, the Committee considered the role of natural features in the landscape, their contribution to protecting drinking water sources and how such features might be protected through source protection planning. Specifically, the Committee recommended that the role of wetlands and riparian zones be evaluated on a watershed basis, and that source protection plans endeavour to protect and restore these natural areas. The Committee also noted that artificial wetlands and buffer strips are important tools for reducing the vulnerability of source waters to the impacts of surface run-off from activities on the land.

Data Provision and Management

An overarching component of source protection planning is the collection, management, sharing and use of data. The Committee discussed in some detail the importance of good quality data in supporting all aspects of source protection planning, and made a number of substantive recommendations regarding the type of data that should be collected, how the data should be used, and who should manage the data.

A key recommendation was that the province update key data sets (as identified by the Committee) and ensure that the data are made available to local source protection planning committees at no cost. Updates to the data sets need to include corrections and improvements to cross-referencing of well records. The Committee felt that long-term funding to ensure maintenance of information and databases will be necessary to support planning over the long-term. The Committee's recommendations stress the need for an appropriately managed two-way flow of information and data: from the province to local committees, and from local committees to the province. The Committee realized that substantial efforts to develop data models and data management architecture will be required to facilitate these needs.

Priority Actions for 2008

The Minister of the Environment specifically requested that the Committee recommend which areas should be prioritized in source protection planning. In this report, the Committee recommends prioritizing large municipal wellhead protection areas/strategies for two reasons. Firstly, many of these areas were subject to previous studies under a variety of programs funded by the Ministry of the Environment, and therefore benefit from a sound scientific basis. Secondly, by virtue of their size, these municipal areas contain a large population that may be at risk. Additionally, the Committee recommended prioritizing surface water intake protection zones/strategies in inland areas (i.e. not serviced by the Great Lakes). The Committee also recommended prioritizing GUDI (Groundwater under the influence of surface water) sources due to the increased vulnerability of these supplies.

In this report, the Committee identified several key issues that will warrant action by the provincial government by 2008. Delivering on priority activities will require integrated data-systems, the development of a semi-quantitative risk assessment methodology, and training and mentoring on the modeling of various protection areas.

Recommendations

Multi-barrier approach

Guiding Principle 1: The multi-barrier approach, as defined by Justice O'Connor in the Walkerton Report, must form the basis for drinking water protection in Ontario.

Guiding Principle 2: Developers and implementers of source protection must balance the relative role of each barrier in the multi-barrier approach, both in the development of source protection approaches and in the ongoing improvement to the source protection initiatives.

Guiding Principle 3: Developers and implementers of source protection plans must recognize that the multi-barrier approach, and risk management, will significantly but not entirely reduce the risk of water contamination.

Planning for Source Protection

Guiding Principle 4: The provincial government should adopt an integrated and coordinated strategy for overall water protection and management across all provincial ministries and agencies.

Guiding Principle 5: Planning for the protection of drinking water in Ontario must be undertaken at the watershed level with appropriate mechanisms to facilitate management of groundwater-sheds.

Guiding Principle 6: The provincial government should ensure that the Provincial Policy Statements reflect the recommendations contained in this report, including those related to the primacy of safe drinking water legislation, protection of vulnerable areas, recognition of source protection plans, and contributions of natural areas and a healthy ecosystem to safe drinking water.

Guiding Principle 7: Source protection plans should specify measures to retain water on the land and to conserve water during human use.

Guiding Principle 8: Conservation programs that ensure efficient water use and retention of water on the landscape should be encouraged province-wide.

Guiding Principle 9: Source protection plans should specify ways to protect water for all uses, including recreational activities and environmental needs such as wildlife habitat.

Guiding Principle 10: Source protection plans must be developed to protect all water sources in the watershed, including the Great Lakes, surface and groundwater, and all public and private water sources.

Issues Approach to Source Protection Planning

Guiding Principle 11: Source protection plan preparation should be based on an issues identification and management approach that encompasses both past and present practices.

Guiding Principle 12: Risks to drinking water sources must include threats and issues associated with both water quality and quantity.

Protection of Human Health

Guiding Principle 13: Source protection plans must prioritize human uses of water, especially in areas where a risk might affect water used by large numbers of people or where a risk requires immediate attention.

Guiding Principle 14: Information on surface and well water quality should be provided to Medical Officers of Health, who are responsible for public health. These officers must also be involved in decisions on drinking water and distribution of related public outreach activities.

Guiding Principle 15: Drinking water source protection must take priority over the Nutrient Management Act, farm water protection plans, and any other provincial or municipal legislation, policies or regulations that impact drinking water.

Guiding Principle 16: Source protection plans should exercise the precautionary principle for pathogens, which are complex living organisms that may change over time and can be difficult to assess (both their presence and impacts).

Reliance on Sound Science and Data

Guiding Principle 17: Drinking water source protection must be subject to the principle of continuous improvement.

Guiding Principle 18: The provincial government must move quickly to develop reliable data systems, which are critical to the success of source protection planning.

Guiding Principle 19: Source protection committees should use existing data as a launching point for planning and acquiring new information.

Guiding Principle 20: All parties involved in source protection planning, including implementation and management, must openly share relevant information.

Error, Confidence and Caution

Guiding Principle 21: Source protection plans must be based on risk management, when risks can be estimated, and the precautionary principle when risks cannot be estimated.

Guiding Principle 22: Source protection plan implementation must be based as much as possible on existing policies, legislation, and regulations, particularly when data is insufficient.

Guiding Principle 23: Source protection planning committees should incorporate the 'uncertainty principle' into the source protection planning process, so that the resulting risk management activities are consistent with the level of certainty (acknowledging that certainty is largely a data-constrained principle).

Guiding Principle 24: Communities that draw their drinking water from the Great Lakes must participate in all source protection activities that influence their watershed.

Guiding Principle 25: Ontarians must understand that protecting the various components of the hydrologic cycle is necessary not only to safeguard water quality locally but also for downstream recipients in other major watersheds, such as the Great Lakes, St. Lawrence River and James Bay.

Guiding Principle 26: Source protection must address natural areas, since activities in these areas can significantly impact on drinking water quality.

Guiding Principle 27: The provincial government should continually protect and restore natural areas, both for drinking water quality and the intrinsic value of these areas.

Guiding Principle 28: Source protection planners must continually reduce current and future risks to source water through risk reduction activities and wise planning.

Guiding Principle 29: Source protection planners should categorize actions to reduce individual risks by efficacy, timeliness and proportionality.

Guiding Principle 30: The sustainability of water for drinking and other purposes requires its protection throughout the hydrologic cycle.

Threats Inventory and Issues Identification - Threats Identification

Recommendation 1: Source protection plans must include an inventory and assessment of threats caused by human activities that result in direct access to groundwater aquifers.

Recommendation 2: In wellhead protection areas, source protection planning committees should assess private wells and other potential conduits as threats and consider their impact on planning and risk management.

Recommendation 3: Source protection plans must include an assessment of potential threats on individual properties with a particular focus on vulnerable areas, and through the use of available data where possible.

Recommendation 4: Source protection planning committees should assess current and future quantity-related threats to drinking water sources and the implications of planned conservation activities.

Recommendation 5: Threats inventories must include past history and past land uses that might affect water supply quality and quantity.

Recommendation 6: The provincial government must develop and maintain a land use reference database that source protection committees can use to identify threats to drinking water. This database should be provincially held and continuously updated to reflect input from local committees as well as results from similar activities around the world.

Recommendation 7: The provincial government, in consultation with local planning agencies (municipalities, conservation authorities, etc.) should establish the data model for a local threats inventory database. It should be land-parcel based and provide a contiguous spatial fabric across the planning area. The land use reference database should be linked to the local threat inventory database through the land-parcel information.

Recommendation 8: The information in the provincial land-use reference database should include: Land use(s)-->land-based activities-->associated threats-->profile of threats. The profile should contain a list of specific contaminants or risks and associated properties and characteristics that can be used in the "issues identification" process at the local level.

Recommendation 9: The database structure and subsequent model should meet provincial needs for consistency of data acquisition and integration across the province and, at the same time, meet the data-access needs of local source planning protection committees.

Recommendation 10: The land-use reference database should allow integration of local and provincial information, so that source protection planning committees can develop as complete a list of potential threats as possible.

Recommendation 11: Source protection planning committees should develop their own local threats inventory database. The local database should integrate the provincial database and local data, and could be used periodically to update the provincial database.

Recommendation 12: The provincial government must commit to financially supporting, maintaining, continually improving and updating the databases, so that increasingly accurate and thorough information is available for future source protection planning.

Recommendation 13: The threats inventory databases should include three levels of hazard categories (high, medium, and low) that source protection planning committees can use to identify and classify known potential and suspected threats and potential hazards from suspected threats, and to link threat characteristics to a site. This hazard categorization would then be used to estimate the risk posed by the threat, when considered together with the vulnerability of the drinking water source.

Issues Identification

Recommendation 14: Source protection planning committees should use all available information, including consulting the public and reviewing available monitoring information, to catalogue known drinking water issues and threats.

Recommendation 15: The issues and threats should be cross-referenced based on common factors, such as quantity of withdrawal, type of contaminant, location, etc. so as to provide a comprehensive listing of "potential risks" that are to be subject to the risk analysis.

Recommendation 16: All municipal source waters should be characterized microbiologically according to guidance set out by the provincial government. Risk categories for each source should be determined by combining microbiological data and hydrologic and hydrogeologic information.

Recommendation 17: For surface waters, the information generated through characterization should be made available to water system purveyors downstream to help them make management decisions.

Recommendation 18: The provincial government should adopt a multi-indicator approach to establishing new and consistent microbiological raw water quality standards/objectives for all drinking water sources (rivers, lakes, reservoirs, and groundwater).

Water Budgets

Recommendation 19: As part of the source protection plans, a water budget should be progressively developed for the individual watersheds as a method of quantifying water storage volumes, fluxes, pathways, and water takings for the combined surface water and groundwater resources. The water budget can be used to assess whether existing and proposed withdrawals are a threat and/or potential cause of an issue.

Recommendation 20: Source protection plans must develop water budgets that reflect specific watershed needs, conditions and data availability and that improve in accuracy with successive plan developments. Information gaps should be also be addressed as plans are developed.

Recommendation 21: All municipalities should maintain a long-term (50 year) water supply strategy that sets out their water supply needs, including conservation plans, and they need planned sources for meeting their 25 year needs.

Recommendation 22: As part of the water budget process, significant data gaps will be identified that will need to be filled in order to progressively improve the water budget and steps will be taken to collect the required data as the source protection plan evolves over time.

Recommendation 23: As part of developing water budgets, vulnerable aquifers and aquifer recharge must be identified, in recognition of the importance of recharge in sustaining aquifers and also the connection between groundwater discharge and the maintenance of surface water. Source protection plans should protect the quality and quantity of these water supplies.

Recommendation 24: As part of preparing a water budget, source protection planning committees should evaluate what reductions in aquifer recharge and discharge are sustainable over the long term and establish baseline recharge rates for monitoring and future planning.

Recommendation 25: The tolerance of the ecosystem to changes in water flows and levels should be considered in assessing the sustainability of water supplies.

Significant Direct Threats

Recommendation 26: The term 'Significant Direct Threats' should be thought of as Significant Risks because the term risk implies both high threat and a likely pathway for the threat to reach the drinking water source.

Threats of Provincial Concern

Recommendation 27: A list of the threats of provincial concern should be adopted within the source protection planning framework.

Vulnerability Analysis

Recommendation 28: Vulnerable areas should be defined as the maximum extent of the zone described by a 25 year time of travel for wellhead protection areas, 2 hour travel time or pathogen response time (whichever is greater) for intake protection zones and zones of high or extremely high vulnerability for aquifer protection zones and major groundwater recharge areas.

Recommendation 29: Surface waters are intrinsically vulnerable by virtue of their proximity to landscape activities, and their use for waste assimilation and other industrial applications. Existing regulations, policies, and programs should be used to ensure that surface water protection is not sacrificed by efforts to protect other areas designated as vulnerable.

Surface Water Intake Protection Zones

Recommendation 30: The overall Intake Protection Zone for inland surface water intakes should be based on a minimum 2-hour response time. This area can be defined by converting the response time (e.g. 2 hours) to a capture area based on both overland run-off and channel flow components and appropriate storm events. This zone should be considered a vulnerable area and be managed to reduce risks from catastrophic threats such as spills.

Recommendation 31: The Ministry of the Environment, in consultation with the Ministry of Natural Resources, should designate an Intake Protection Zone (IPZ) based on a two-hour response time. They should also help local source protection planning committees to determine the appropriate response time in their respective IPZ, based on the two-hour minimum. The local IPZ should delineate a capture area based on both overland run-off and channel flow components under appropriate storm events (e.g. annual average flow rate in river, two-year storm event).

Recommendation 32: The guidance for the delineation of the Intake Protection Zone (IPZ) should incorporate the precautionary principle by requiring that the most protective zone be established depending on the local site characteristics. In particular, it should be recognized that low flow conditions produce a slower velocity and less dilution, while higher flows increase velocity and dilution.

Recommendation 33: The delineation of the Intake Protection Zone (IPZ) should take into account watershed characteristics that contribute the greatest risk, whether event-based (high or low flows), seasonal or continuous. The two-hour response time should then be applied to the event that contributes the greatest risk. If site specific information is unavailable, the annual average flow rate should be used. .

Recommendation 34: The catchment area should be the functional unit for the analysis of surface water "issues" such as pollutant loadings beyond the IPZ. Vulnerability mapping and threats identification should be undertaken to determine those locations within the catchment that do or may contribute to the "issues" so that the overall aggregate risk may be assessed and appropriate strategies implemented.

Recommendation 35: A pathogen risk zone (contiguous area of land and water immediately upstream or around a municipal surface water intake) needs to be delineated using a site-specific response time or two-hour travel time in which risk management should be undertaken for activities that pose a catastrophic pathogen threat.

Recommendation 36: All private drinking water supplies that come from surface water must be treated to eliminate pathogens. The level of treatment must be based on a source water quality evaluation.

Recommendation 37: The provincial government should develop guidelines for evaluating surface water sources of drinking water and for providing treatment of such sources, and should require education of private system operators to ensure private system quality, evaluation and treatment.

Recommendation 38: For intakes on large water bodies, such as the Great Lakes, the delineation of the IPZ shall be a 1 km radius around the intake structure unless issues are known or suspected, in which case a larger zone is to be delineated to encompass the physical location of known or suspected threats within the radius.

Recommendation 39: Based on research, issues analysis, and consultation, subsequent cycles of planning should replace the 1 km default with a science-based Intake Protection Zone.

Recommendation 40: The Ministry of the Environment, in consultation with the adjacent Provinces and the federal government, should develop a strategy for the source protection of the Great Lakes and its waters from transboundary threats that recognizes the interdependent, nested nature of Ontario's watersheds.

Recommendation 41: Quantitative mapping and hydrogeologic analysis must be undertaken to define the contributions of groundwater to the maintenance of the Great Lakes and surface waters so as to identify the recharge quality and quantity necessary for their long-term maintenance and/or restoration.

Recommendation 42: The benefits of watershed-base activities must be assessed and communicated not only to those who directly benefit (e.g. those in vulnerable areas) but to those downstream who are beneficiaries of these activities.

Recommendation 43: Source protection requirements should be reviewed periodically and if necessary amended to ensure an equitable distribution of the burden of source water protection. This measure applies particularly to practices and activities in communities served by the Great Lakes.

Wellhead Protection Areas

Recommendation 44: The preliminary delineation of the wellhead protection areas should be based on the classical "Time of Travel" (TOT) approach, either in two or three dimensions depending on the local availability of data.

Recommendation 45: The modeling approach selected must be reviewed and approved by a third party technical group, such as a Source Water Protection Technical Review Committee (SWPTRC), particularly the application of the vulnerability analysis.

Recommendation 46: Within the wellhead protection area, two pathogen management zones should be delineated, namely a 100 metre pathogen security area, and a 2 year TOT zone which should be considered the area of concern with respect to bacteriological/pathogenic contaminants.

Recommendation 47: New wells should be developed with a 100 m zone in which control will be gained so as to preclude pathogens.

Recommendation 48: Within the wellhead protection area, source protection planning committees should delineate and use a 5 year TOT capture zone which should be considered the area of highest vulnerability to Dense Non-Aqueous Phase Liquids (DNAPLs) impacts. The 5 year TOT should also be the zone where the risk assessment is more focused for all other (non-DNAPL or pathogen) threats from contaminant sources.

Recommendation 49: A 25-year Time of Travel should be defined to delineate a secondary wellhead protection area for less stringent risk management protocols.

Recommendation 50: The entire capture zone should be defined for long-term planning purposes, as well as to inventory existing uses and activities (particularly historic uses) that may pose a threat to the well.

Recommendation 51: The Time of Travel (TOT) assessment should include a quantitative evaluation of the level of confidence associated with the delineated TOT areas and an assessment of wellhead vulnerability.

Recommendation 52: The modeling and delineation of the wellhead protection area and its zones should be revisited every five years as part of a comprehensive review and/or when a substantial change in the capture zone is anticipated, or when additional new information is available to increase the level of confidence in the delineation and models.

Recommendation 53: A semi-quantitative approach (such as surface to ground water advection times) should be used to evaluate the degree of protection provided by the vertical travel path from ground surface, through the unsaturated zone and into the aquifer unit being assessed within the wellhead protection area (WHPA). This vertical travel path analysis when combined with the TOT value results in an estimation of surface to well advection time (SWAT).

Recommendation 54: SWAT should be categorized so as to support varying risk mitigation strategies in the areas of various vulnerability, such that 0 – 5 years represent high vulnerability, 5-25 year represents moderate vulnerability, and >25 years represents low vulnerability.

Recommendation 55: The recommended approaches to estimating SWAT values are subject to data availability, the level of understanding of the local system and knowledge of the threats in the wellhead protection area. Listed in increasing order of complexity and requiring progressively more information on the approaches are: an assumption of uniform high vulnerability everywhere, a simple indexing system, the calculation of average vertical advection time and fully thee-dimensional modeling. More advanced approaches should be used in subsequent revisions as data permits.

Recommendation 56: The application of wellhead vulnerability assessments to TOT zones should inform the risk analysis and be used to assist in prioritizing the risk management action plans to address threats. More restrictive/mandatory measures should be considered in highly vulnerable areas ranging down to less intrusive measures in less vulnerable areas. The wellhead vulnerability assessment should be used to direct future threats away from highly vulnerable areas.

Recommendation 57: Several pilot projects that demonstrate and evaluate the approaches recommended for delineating wellhead protection areas and assessing vulnerability within the wellhead protection areas should commence immediately and focus on areas where considerable work has already occurred through the Provincial Groundwater Studies.

Aquifer Vulnerability

Recommendation 58: At a minimum, the initial (not longer than SPP review) delineation of the aquifer vulnerability areas should be based on the current Intrinsic Susceptibility Index (ISI) or the Aquifer Vulnerability Index (AVI), as appropriate to local conditions and encompassing the information already contained in the Groundwater Studies.

Recommendation 59: AVI or ISI approaches should be used to identify aquifer vulnerability, where AVI or ISI scores of less than 30 should be used initially to delineate high aquifer vulnerability (HVA) areas. Moderate vulnerability should correspond to a score of between 30-80 and low greater than 80.

Recommendation 60: A quantitative approach, based on surface to aquifer advection times (SAAT), should undertaken by the first 5-year review to evaluate the degree of protection provided by the vertical travel path from ground surface, through the unsaturated zone to the top of the water table or aquifer unit being assessed.

Recommendation 61: Surface to aquifer advection time (SAAT) should be categorized and used in a similar fashion as for the delineation of WHPAs, to support varying risk mitigation strategies in the areas of various vulnerability, such that 0 – 5 years represent high vulnerability, 5-25 year represents moderate vulnerability, and >25 years represents low vulnerability.

Recommendation 62: Regional hydrogeologic and hydrologic data should be collected to support statistical and numerical modeling tools. These tools can be used to enhance quantitative assessment of aquifer vulnerability, particularly in areas modeled as highly vulnerable.

Recommendation 63: Water quality data should be collected from areas modeled as being of high vulnerability, because those areas should be the first to respond to insults from the surface. If the insult is measurable, the data will confirm the vulnerability.

Recommendation 64: Aquifer vulnerability information, including both quality and quantity concerns, should be used to determine the location of new municipal wells (with 100 metre pathogen zones in which control is gained) in order to avoid construction of new wells in highly vulnerable aquifers.

Recommendation 65: Construction of new private wells should be field verified and existing legislation (O. Reg 903 under the *Ontario Water Resources* Act) strictly enforced in highly vulnerably areas to ensure they do not become conduits of contamination for the aquifer.

Significant Recharge Areas

Recommendation 66: Significant recharge areas must be delineated through the source water plans and will be considered vulnerable from both a quality and quantity perspective. Source protection plans will consider these areas as: vulnerable to urbanization which can restrict recharge to subsurface aquifers; and vulnerable to cumulative contaminant loading impacts.

Risk Analysis - Risk Assessment

Recommendation 67: Risks from threats to drinking water quantity and quality should be assessed using a provincially consistent semi-quantitative approach.

Recommendation 68: Where threats of provincial concern are located within a vulnerable area (Wellhead Protection Area, Intake Protection Area or other designated vulnerable area), their level of risk must be assessed according to the semi-quantitative approach used to evaluate other threats in the watershed, and risk management actions must be identified in the Source Protection Plan.

Recommendation 69: The Implementation Committee that was established by the provincial government should identify a suite of tools to enable local committees to manage the risks identified through the assessment process.

Recommendation 70: The provincial government should consider the Implementation Committee's "suite of tools" when establishing and amending the semi-quantitative thresholds for the delineation of Significant Risks.

Risk Assessment – Considering Vulnerability

Risk Categorization

Recommendation 71: The assignment of risks into risk categories should be based on the risk analysis process.

Recommendation 72: The provincial government should develop a semi-quantitative risk assessment approach and provide guidelines to assist source protection planning committees in their interpretation of results from the assessment.

Risk Assessment - Identifying Significant Risks

Recommendation 73: A semi-quantitative analysis, considering uncertainty and the precautionary principle, should be used to determine the threats that pose a "Significant Risk" to a drinking water source, and these risks should be the subject of priority risk management activities.

Risk Management - Outcome-Based Approach

Recommendation 74: All "Significant Risks" should be prioritized and substantially reduced in a timely fashion through risk management activities.

Recommendation 75: The provincial government should develop an "outcome-based" approach to risk management. It should be based on targets and guidelines to be established by the local source protection planning committees. The approach should allow local development of options to meet the targets.

Risk Management Approaches

Recommendation 76: The provincial government should develop guidelines on how "Significant Risks" should be risk managed. The guidelines should draw on advice from the Implementation Committee, and the province should develop new Beneficial Management Practices and standards where required.

Pathogens

Recommendation 77: The provincial government should require that all drinking water sources be treated for pathogens, with the level of treatment based on the results of the source water risk assessment.

Assimilative Capacity, Cumulative Threats and Risk Management

Recommendation 78: Source protection plans should specify ways, in applicable watersheds, that Benenficial Management Practices can be used to reduce loading of pathogens (e.g. public education).

Recommendation 79: Approaches modeled after the USEPA program for total maximum daily load (TMDL) should be considered, with an aim to optimize the cost-benefit ratio when designing risk management strategies.

Recommendation 80: Managers and source protection planners must ensure that the risk analysis and characterization used in the development of risk management approaches includes consideration of cumulative threats and impacts on water quality and quantity from multiple point and non-point sources.

Uncertainty and Risk Management

Recommendation 81: Risk management will require statements of uncertainty, variability and accuracy in the analysis. These statements will be important especially where there is high uncertainty, since more and improved data and modeling will be required. Similarly, consequences should be included in the ranking process and risk assessment/management.

Ecological Protection - Provincial Water Quality Objectives

Recommendation 82: As source protection plans are prepared, the Provincial Water Quality Objectives (PWQO) should be used as the benchmarks for determining surface water quality and issues such as assimilative capacity and overall system health.

Recommendation 83: In source protection planning, watershed characterization should be based on the interpretation of a suite of Provincial Water Quality Objective parameters rather than a single isolated measure. The PWQO should be current and relevant, and may be used as benchmarks for public reporting on the progress of source protection implementation.

Recommendation 84: The provincial government should encourage and help municipalities and Conservation Authorities to facilitate actions that will ensure the ecological sustainability of source waters not used as a drinking water source.

Recommendation 85: Source protection planning committees, with the guidance of the provincial government, should evaluate the application of Provincial Water Quality Objectives with regard to amendments to Certificates of Approval for discharges to surface water.

Natural Areas

Recommendation 86: The provincial government should include the loss of wetlands and riparian zones in threats inventories and develop a process to protect and restore these natural areas in subsequent source protection planning cycles.

Recommendation 87: The initial water budgets developed under source protection planning should include an analysis that estimates the total area or percentage of landscape comprised of natural areas that perform a significant hydrological function.

Recommendation 88: Subsequent water budgets should include an analysis that estimates the total area of lands considered "significant" and ranks the significance of individual parcels of land and land-forms.

Recommendation 89: The provincial government should consider the use of guidelines on minimum levels of natural area cover in watersheds as one measure of watershed health.

Recommendation 90: Specifically within the Intake Protection Zone, artificial wetlands and/or buffer strips should be evaluated to determine their potential to reduce the vulnerability of the source water to degradation in quality or quantity and to improve water quality and quantity.

Recommendation 91: Initial source protection plans should describe the natural areas and their benefits to source water and ecological sustainability so that both source water quality and ecological sustainability can be enhanced via initial and future plans.

Data Requirements and Management

Recommendation 92: Source protection plans will require significant amounts of data. The provincial government must update key data sets and ensure that provincially held data are available to source protection planning committees at no cost and with no bureaucratic encumbrance.

Recommendation 93: The provincial government must correct, improve and cross reference well information and record databases and provide these databases to source protection planning committees and others involved in ground water study and management. These records are critical to drinking source protection.

Recommendation 94: Existing provincial data sets are critical to the success of source protection planning, and require improvement. These data sets must be accessible within the Ontario Land Information Warehouse (OLIW) by the end of 2005.

Recommendation 95: Adequate, long-term funding for maintaining information and databases is necessary to support long-term planning.

Recommendation 96: The provincial government should provide adequate training for those who generate well information and should ensure that records kept by well-drilling firms are consistent, accurate, and complete, given the tremendous significance of this data-set to source protection.

Recommendation 97: Data-set and database management must include reciprocal agreements that allow for the free flow of information to those involved in source protection planning.

Recommendation 98: In keeping with the principle of free and open data movement, a mechanism must be developed and enforced that will allow source protection planning committees, boards and researchers to exchange information and experiences related to source protection planning and implementation.

Recommendation 99: Methods of monitoring data quality must be developed so that quantitative statements can be made about the quality and level of confidence in data that are held in provincial and local databases.

Recommendation 100: The provincial government should identify the acceptable levels of scale and validation for the studies that are used to develop source protection plans. This guidance should promote consistency, and ensure that the appropriate level of detail and confidence is provided in the risk assessment. A mechanism that will incorporate cumulative effects into decisions regarding the appropriate scale is also necessary so that finer resolution investigations will occur where needed.

Recommendation 101: A provincially managed groundwater inventory should be developed and maintained in the fashion of the data protocols used in Ontario's oil and gas inventories, with this central database and mapping function being freely available for source protection planning and for persons wishing to withdraw water such as through the Permit to Take Water (PTTW).

Recommendation 102: As information is generated on the aquifers and important factors for the aquifers (well locations, geophysical information) it should be mandatory that this information be provided to the provincial inventory.

Recommendation 103: All provincial and local information used in Source Protection Planning should have accessible, authoritative versions.

Recommendation 104: Where possible, all provincial and local information used and generated in Source Protection Planning should be geo-referenced to provincial standards.

Recommendation 105: A provincial data coordination body should be established for source protection planning.

Recommendation 106: For each planning team that supports a local source protection planning committee, at least one member should be a GIS professional focused on data management.

Recommendation 107: All provincial and local information used for Source Protection Planning must have a full set of metadata defined and available. Data sets must take advantage of the Provincial government's OLII as much as possible.

Recommendation 108: The provincial government should review completed municipal groundwater studies for key hydrologic and hydrogeologic data (including locations of previously unknown wells) and data refinements to known wells should be reflected in the Water Well Information System (WWIS).

Recommendation 109: The provincial government should strategically expand the collection of relevant water monitoring data sets and make them accessible within the Ontario Land Information Warehouse (OLIW) by the end of 2005. Where comparable local data sets are held by local authorities, the provincial government should assist these groups to ensure the data have recognized standards and are accessible.

Recommendation 110: The provincial government must initiate the standardized collection of several new sets of provincial data and make these data sets accessible within the Ontario Land Information Warehouse (OLIW).

Recommendation 111: The provincial government should build a threats data model to cover continuous and catastrophic threats.

Research, Data and Information Needs

Recommendation 112: The provincial government should commit sustainable and long-term funding to address fundamental research, data, and information needs, with a focus on but not limited to:

- Methodologies to define vulnerability of groundwater at a regional scale including their relationship to recharge areas and means to assess cumulative impacts;
- In collaboration with the federal government, impacts of and strategies to address climate change;
- Methodologies to establish acceptable rates of aquifer recharge for long-term sustainability;
- Quantitative methods for the delineation of recharge areas;
- Markers for and characterization of landfill leachate/contaminants;
- New chemicals potentially threatening source water to support screening and early warning systems;
- Documenting the beneficial impacts of Best Practices;
- Listing of DNAPLs for assessment in wellhead protection areas;
- Models to link Great Lakes source water to (and to direct) upstream activities;
- Numeric methods for screening land-practices for potential issues, such as density of septics as an indicator of nutrient loadings;
- Benefits of protecting or restoring riparian zones and wetlands;
- Investigation of pathogen threats including viruses for their persistence in source water and implications for intake or wellhead zone delineations;
- Improved approaches to developing water budgets in different types of watersheds under variable development and use;
- Optimizing hydrologic data collection to ensure the correct type and scale of data are collected in the most efficient and cost-effective manner (current topic of research internationally);
- Developing methods for estimating risk to municipal groundwater supplies from historical or legacy land-use practices;
- Developing methods for early detection of significant risks to municipal groundwater supply systems, and ways of accommodating threats (new chemicals) as they become identified.

Permits to Take Water

Recommendation 113: The Permit to Take Water program should be re-oriented to be a component of a larger and more comprehensive government-wide initiative to manage and protect Ontario's water resources, such as through a Provincial Policy Statement for water.

Recommendation 114: The permit application, review and approval process should include a "science assessment" to increase the level of confidence that the taking qualifies as a sustainable use.

Recommendation 115: The provincial government should provide regional aquifer and/or surface water data to the applicant upon receipt of an "enquiry" for a Permit.

Recommendation 116: The provincial government should amend the Permit to Take Water (PTTW) legislation such that if a PTTW is proposed for a wellhead protection area or intake protection zone, the application process will recognize the presence of the zone and the onus will be placed on the applicant to consider/address the potential implications for the proposed withdrawal on that zone, rather than placing the burden on the existing source protection planning committee.

Recommendation 117: The practice of providing exemptions to permitting requirements should be reviewed in the context of source protection planning and consideration should be given for amending the OWRA through the Source Protection Planning Act.

Recommendation 118: A specific technical quantitative basis for assigning water allocation (to withdrawals) should be incorporated into the Permit to Take Water (PTTW) approvals process in such a way as to harmonize with other jurisdictions, providing a level playing field for major water-taking industries in Canada.

Recommendation 119: A scientific rationale for the protection of surface water ecological functions must be adopted for both the Permit to Take Water program and the identification of water quantity risks under Source Protection.

Recommendation 120: The rationale for granting a permit should be expanded to encompass not only the volume of water but other factors, such as consumption, export from the basin or aquifer to surface water, impacts on water quality, and societal benefits.

Recommendation 121: With the establishment of source protection planning boards, these bodies should be granted a formal role in partnership with the provincial government in the review and approval of Permits to Take Water.

Drinking Water Protection Actions by 2008

Recommendation 122: The provincial government should encourage the implementation of programs and activities in jurisdictions that have initiated source protection plans for wellhead protection areas through provincial groundwater studies money.

Recommendation 123: A comprehensive program to address private water supplies should be developed and implemented through the source protection planning committees, with a focus on preventing pathogen contamination of aquifers and private wells.

Recommendation 124: In conjunction with Medical Officers of Health, information relevant to private wells should be efficiently communicated to those who may benefit.

Recommendation 125: Risk management actions for high risk/high impact situations that are identified prior to formal plan approval should be implemented as quickly as is feasible. The approval process should not inhibit due diligence.

Recommendation 126: The provincial government should establish a comprehensive and publicly accessible groundwater aquifer data structure to accept 2008 submissions of data to support aquifer mapping.

Recommendation 127: The provincial government should develop a data structure and model that would allow data sharing to occur through distributed and disseminated databases held by various local source protection committees.

Recommendation 128: An assessment report for each source protection area in Ontario should be in progress by 2008.

SECTION 1: INTRODUCTION

Preamble

Ontario has an abundance of fresh water. This invaluable resource underpins the province's prosperity. The vast majority of Ontarians have the good fortune to live near a large and dependable water supply. However, not all of this water is readily potable. The provincial government and Ontario residents alike have a responsibility to protect and conserve the province's water, particularly drinking water sources.

In 2003, the Ontario Ministry of the Environment made a commitment to the long-term protection of Ontario's present and future drinking water sources. The Minister announced the government's intention to develop and introduce legislation and regulations stemming from the recommendations of Justice Dennis O'Connor in the *Part Two Report of the Walkerton Inquiry*.

At the time, the Minister created an Implementation Committee (IC) and a Technical Experts Committee (Appendix 1) to provide advice and guidance to the Minister as the legislation and regulations were developed. The Implementation Committee's role was to provide advice on approaches to achieve source water protection and funding mechanisms. The Technical Experts Committee's (TEC) role was to provide technical advice that would guide how plans were to be developed, what data might be needed, what standards might be required, and how threats and risks to drinking water were to be managed.

The Minister provided independent instructions to the two committees. While the committees mutually informed one another of their progress, the final reports were created independently by each committee. This report contains the summaries of TEC discussions and recommendations. The Committee supports Justice O'Connor's view that drinking water source protection is a key priority for Ontario. The Committee appreciates the opportunity to provide this report for the Minister's consideration.

Terms of Reference

The Committee was provided with specific initial Terms of Reference (TOR) intended to guide the scope of its discussions and recommendations. The Committee made some modifications to this initial TOR. It is contained in Appendix 2 and briefly summarized below. The Terms of Reference focused on four major areas specifically related to the "threats assessment framework for protecting drinking water sources":

1. **Threats Inventory**. The Committee was asked to develop a "threats" reference list and provide advice on how to categorize and rank threats in addition to providing a definition of 'significant direct threats' – a term used by Justice O'Connor.

2. **Vulnerability Assessment**. The Committee was asked to define "vulnerable areas" and recommend methods to define such areas, provide advice on the scale of assessments required, and also criteria for classification of the level of vulnerability.
3. **Sensitive Water Resources**. Sensitive water resources were identified by the Advisory Committee and Justice O'Connor for protection, and TEC was asked to provide advice on how to address cumulative impacts on such resources and to provide criteria for ranking risks to the resource.
4. **Risk Analysis and Risk Management.** The TOR requested an evaluation of existing risk management strategies and the best available science related to risk management. TEC was specifically asked to propose a methodology to match risk management with predicted risk, to define prescriptive risk management, and to provide advice on the development of prescriptive risk management approaches for sensitive water resources. It was also asked to provide advice on requirements for post risk management monitoring and review of Source Protection Plans (SPP) and threat assessments.

The TOR also required that the Committee provide advice on a number of areas indirectly related to drinking water protection, namely:

5. **Ecological protection.** The Advisory Committee had recommended that Source Protection include waters not used directly for drinking in order to provide ecological protection and/or protection of other significant characteristics such as heritage values, and also whether a threats assessment process (as noted above) should be used for such.
6. **Provincial Water Quality Objectives**. The Advisory Committee recommended these be incorporated into Source Protection and the TEC was asked for advice on their review and use in a manner similar to #5 above.
7. **Data requirements and management.** The Committee was asked to provide advice on uncertainty as it relates to the availability of data, how data should be managed, and the format for and methods of data analysis in planning including the threats assessment process. TEC was asked to provide advice on data requirements and their inclusion in technical guidance documents for both planners and plan reviewers. Additionally, the Committee was asked to provide advice on data implications for legislation and the process to be considered in updating the threats assessment analysis in source protection plans.

TEC activities and the report organization

The Committee met monthly from January to November 2004 to consider the technical details of drinking water source protection and to respond to the Minister of the Environment's request to the Committee and the TOR. This report is intended to provide technical advice to the Minister and the Ministry of the Environment that will help the Minister to prepare legislation and enable the Ministry to establish effective regulations. In addition, the TEC makes these recommendations so that the Source Protection Planning Boards and Committees will be able to develop and implement drinking water protection plans based on the best available scientific analysis to the benefit of Ontarians. In addition to the specific comments in this report, TEC strongly supports the government's efforts to provide a rational, strategic approach in providing a safe and dependable supply of drinking water for Ontario.

This report is organized sequentially in the same order that as Source Protection Planning Committee would follow in preparing a plan. The report includes numerous recommendations; while they are grouped under headings that correspond to this sequence, there is no priority to the order. The Committee agreed not to emphasize any particular recommendation(s), since all the recommendations are important for the provision of safe drinking water.

The Process to Develop Source Protection Plans (SPPs)

The Committee worked through early 2004 with the Threats Assessment Working Group (TAWG) to develop a functional “model” for the process that might be followed to develop source protection plans. In several instances, these discussions were incorporated into the Source Protection Plan (SPP) “working model” in the draft Source Protection Planning Act released by the Minister of the Environment (June 2004) for review. The Committee’s work also builds on the elements outlined in the White Paper on Watershed-based Source Protection Planning (February 2004).

The Committee framed its recommendations in part to correspond to the various stages in the source protection planning process. It begins with an initial assessment of the water resource, including: a characterization of the watershed, and a description of documented “issues” for source water and also threats that pose the potential to be risks, and finally a risk analysis that leads to a risk categorization/ranking.

Based on their assessment, source protection planners may then be requested to state the objectives of source protection risk management actions that could be implemented to achieve the objectives of the plan. As well, they may need to identify issues or risks not addressed specifically as part of source protection but which can be addressed through other planning processes, such as watershed or fisheries planning, species at risk recovery strategies, or heritage initiatives. The Minister of the Environment must review and approve these risk management activities. To be consistent with the guiding principle of continuous improvement, several “cycles” may be required to address all the risks. In this report, the Committee presents recommendations on continuous improvement and plan updating/review that are consistent with the objective of making “significant risks” to human health the first priority. Other, and less significant, risks can be addressed either through less “certain” implementation tools or through subsequent planning cycles.

Figure 1.1 (below) is a schematic representation created by TAWG of the general process for source protection planning in Ontario. Though the bulk of the Committee’s recommendations would impact the preparation of the Assessment Report, it also made recommendations on risk management and, in particular, on the threats of provincial concern that would be included in the source protection plan. This process should not be seen as “one-way,” but rather as a loop. Data-management and information sharing will be critical to ensuring that each loop builds on the previous Assessment Report, and on the outcomes of the plans as they are implemented.

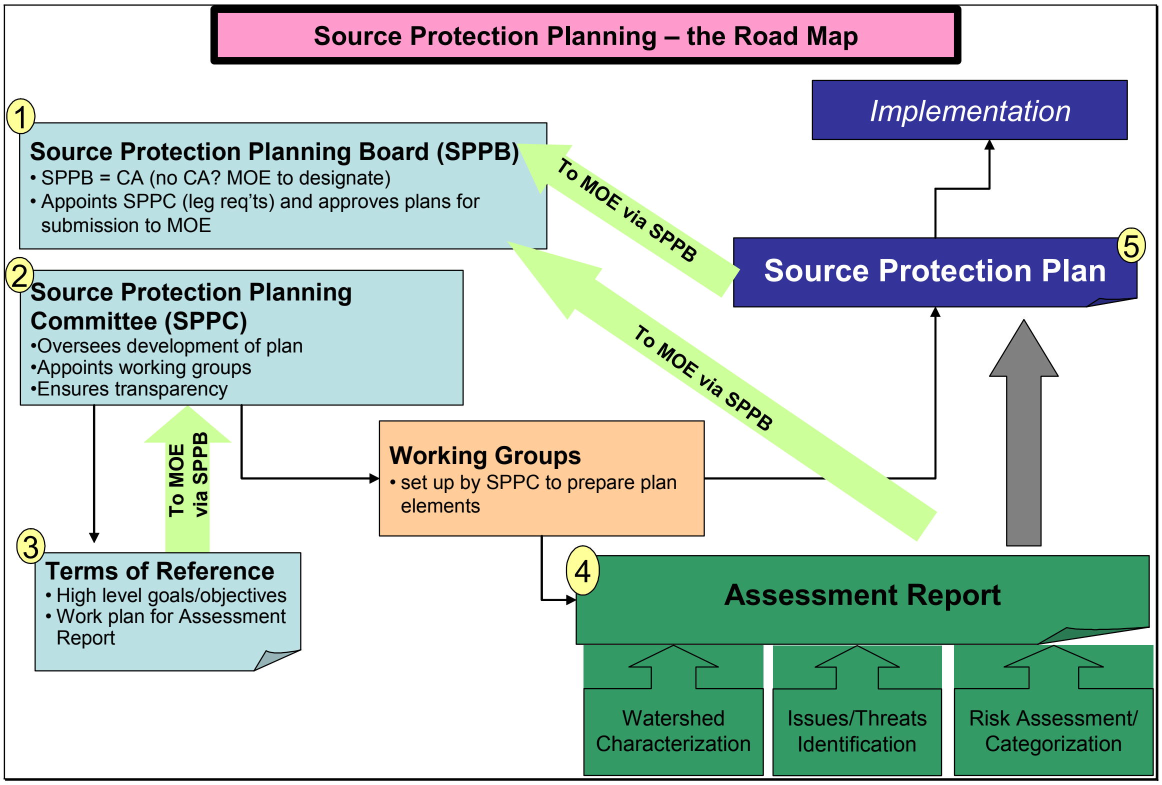


Figure 1.1: A generalized overview of the major steps towards the establishment of a Source Protection Plan

SECTION 2: SOURCE PROTECTION GUIDING PRINCIPLES

Source protection must be grounded in clear and strong guiding principles. The Technical Experts Committee developed guiding principles to frame its discussions. In many instances, these principles cannot themselves be "delivered." They must be considered within the overall context of this report, or addressed in the delivery of specific recommendations. An example of a principle adhered to throughout the report is the concept that uncertainty is real and should be documented whenever possible, so that risk management decisions take the level of uncertainty into account. In this report, the guiding principles are presented as an initial set of recommendations. Ideally, the balance of the recommendations will make the most sense by virtue of this order. The guiding principles should be used to direct the development and implementation of drinking water source protection plans; the regulations and/or guidance for developing the plans should incorporate these principles.

Multi-barrier approach

Guiding Principle 1: The multi-barrier approach, as defined by Justice O'Connor in the Walkerton Report, must form the basis for drinking water protection in Ontario.

The Committee developed the threats assessment framework on the understanding that source protection cannot be considered the only barrier in source protection. The Committee makes several recommendations that relate to subsequent barriers. In some cases, the source protection strategy must be linked to a subsequent barrier. In *Part Two Report of the Walkerton Inquiry*, Justice O'Connor writes that a healthy public water supply will be best ensured through the multiple-barrier approach. O'Connor observes that single barriers are never entirely effective and that a level of redundancy provided by multiple barriers will guard against the failure of any one barrier. Drinking water protection will be best achieved through a strategic selection of barriers.

Guiding Principle 2: Developers and implementers of source protection must balance the relative role of each barrier in the multi-barrier approach, both in the development of source protection approaches and in the ongoing improvement to the source protection initiatives.

Guiding Principle 3: Developers and implementers of source protection plans must recognize that the multi-barrier approach, and risk management, will significantly but not entirely reduce the risk of water contamination.

Inherent in the multi-barrier approach is a balance in emphasis between the various barriers. To protect the drinking water source, there is an implicit assumption that the barriers build on one another, and may carry relative weight. It is a challenging task to determine how much emphasis to place on the source protection barrier, particularly if additional barriers are already in place, or expected to be put in place. For example, protection strategies that benefit private water supplies, such as a collection of private wells near a crossroads in an urban area or small community, may be reliant upon source protection alone. By contrast, a small municipal well serving the same number of households may have testing and training requirements under the *Safe Drinking Water Act* to comply with, as well as source protection. Since people have greatly varying levels of tolerance, it is impossible to *entirely* eliminate the possibility that they could be negatively impacted by the chemical or biological insults that could exist in drinking water.

Planning for Source Protection

Guiding Principle 4: The provincial government should adopt an integrated and coordinated strategy for overall water protection and management across all provincial ministries and agencies.

Many of Ontario's provincial ministries and agencies make decisions that impact on water in different ways. In his report, Justice O'Connor writes that water policy and law in Ontario is complex and fragmented. Consequently, in reviewing policy objectives, it is essential that the province take steps to ensure its water protection and management decisions are integrated and coordinated.

Guiding Principle 5: Planning for the protection of drinking water in Ontario must be undertaken at the watershed level with appropriate mechanisms to facilitate management of groundwater-sheds.

Watersheds have formed the basis for water management activities since the implementation of the *Conservation Authorities Act* in 1946. In his report, O'Connor refers to watersheds as the ecologically practical unit for management water. A surface watershed is an area that is drained by an integrated system of lakes, rivers, creeks, and channels into a common water body. Though the term watershed is thought of as it relates to surface water, a close inter-relationship exists between surface water and groundwater. However, there may not be a complete overlap between surface watersheds and the groundwater-sheds. A groundwater-shed is the region found on the down-gradient side of a regional groundwater flow divide. While a 'watershed' may be delineated on the basis of surface water for planning and jurisdictional reasons, the associated groundwater must be included in the watershed plan so that both surface water and groundwater issues and interactions are considered when planning is undertaken.

Although the surface watershed should be the basis for source water protection planning, the Technical Experts Committee recognizes the fact that groundwater-sheds can extend far beyond surface watershed boundaries. Therefore, where applicable, a mechanism is required for cross-jurisdiction source water protection planning. The issue of source protection planning along shared surface waterways and cross-border groundwater-shed should also be considered. The watershed approach must form the basis for drinking water protection and planning in Ontario. Some areas within a watershed may be more significant than others as groundwater recharge areas or for provision of drinking water supplies. Nevertheless, planners must remember that all water in a watershed is connected. It may be necessary to prioritize key strategic areas, but planning and implementation must occur throughout the watershed so that all present and future supplies are protected.

Guiding Principle 6: The provincial government should ensure that the Provincial Policy Statement reflect the recommendations contained in this report, including those related to the primacy of safe drinking water legislation, protection of vulnerable areas, recognition of source protection plans, and contributions of natural areas and a healthy ecosystem to safe drinking water.

The Provincial Policy Statement (PPS) provides guidance to municipalities and others on matters of provincial interest. Municipalities look to the PPS for direction or support when developing new planning policy directions, and consider the PPS when responding to individual development applications. Anchoring source protection in the PPS will ensure that municipalities have the appropriate direction from the province to undertake source protection activities. It could also be used to: establish, in principal, primacy of source protection legislation; clarify where the PPS provides conflicting direction on matters of provincial interest; and ensure that natural areas and a healthy ecosystem are recognized and protected for their contributions to safe drinking water. Source protection should be incorporated into the PPS to provide municipalities with the necessary direction and support to initiate source protection planning and activities.

Guiding Principle 7: Source protection plans should specify measures to retain water on the land and to conserve water during human use.

As the human population rises, drinking water demands will increase in many parts of Ontario. This increasing demand can be addressed through a two-pronged approach. Firstly, conservation of water on the land can retain water in the watershed where it is available for surface water use or recharge to groundwater. Such conservation or preservation in the form of the retention and restoration of lakes, wetlands, etc. will serve to increase potential supplies for drinking in the inland areas of the province. Secondly, conservation of water use generally, through gains in water use efficiency, will reduce the overall demand and allow available supplies to go farther, with the added benefit of reducing the costs of management and treatment. Water conservation reduces demand and stress on the resource for future years. These two aspects of "water conservation" must be considered in the source protection plan.

Guiding Principle 8: Conservation programs that ensure efficient water use and retention of water on the landscape should be encouraged province-wide.

Conservation of water on the land allows for diversification of potential drinking water sources that reduce the possible exposure to risks that would result from a few sources. The conservation of future potential sources is a strategic action that will ensure Ontario does not foreclose on future drinking water sources. The conservation of water during human use is a similar strategic action. Conservation ensures that the costs of providing water are optimized and that pressure on the raw water resources is minimized.

Guiding Principle 9: Source protection plans should specify ways to protect water for all uses, including recreational activities and environmental needs such as wildlife habitat.

Justice O'Connor's report focused on the protection of drinking water and its sources. However, the Advisory Committee recommended a strong environmental focus. Environmental water needs should be defined as the regime of water flows, levels, and quality required to sustain a healthy ecosystem. This regime is based on hydrology, water quality, geomorphology, connectivity and biology. The Technical Experts Committee accepts the principle that all water in a watershed is linked and that each drop of water likely serves several users. Drinking water arises from the environment and all water quantity changes are reflected in changes in water levels and flows.

For many reasons, it is difficult to compartmentalize water resources into drinking and non-drinking sources. Firstly, users in a watershed effectively 'compete' for water. Therefore, a rational basis must exist for determining how the water is allocated. Only by considering drinking water sources in the light of such 'competing' uses can managers make decisions on the allocation of water uses. Secondly, the strategy of ensuring safe future drinking water sources requires taking actions with an incomplete knowledge of future water sources. Otherwise, actions taken today could foreclose future opportunities.

Given the inter-connectedness of the hydrologic cycle, protective actions for drinking water source protection planning need to work in concert with similar programs for other water uses. Managers responsible for implementing source protection plans should undertake actions that benefit ecological functions – where these actions do not unduly prioritize one particular set of implementation actions.

Guiding Principle 10: Source protection plans must be developed to protect all water sources in the watershed, including the Great Lakes, surface and groundwater, and all public and private water sources.

It may take some time to ensure all drinking water in Ontario is protected. Clearly, the detection and adequate management of serious imminent threats to public water sources must be prioritized. But it is also important to address all factors that threaten water sources within a reasonable time frame. Initial threat inventories must include imminent threats to drinking water. It will be important to develop source protection plans that address these imminent threats immediately, while addressing less critical threats in the development of future plans (as long as the provincial government and source protection planning boards commit to future work where necessary). This process of plan development and review should adhere to the principle of continuous improvement of plans.

There are many different public and private sources and mechanisms of extraction of drinking water in Ontario, including those that range from individual private wells to large municipal drinking water plants. Drinking water source protection planning should address all these sources in a manner consistent with the level of risk experienced by each category of use.

Although most Ontarians obtain their drinking water from one of the Great Lakes and the associated tributaries, inland water supplies must also be addressed. The actions taken initially to address inland drinking water supplies will in turn have downstream benefits for the Great Lakes. Meanwhile, the complexity around the Great Lakes may require a unique or perhaps "bi-national" strategy. While Great Lakes sources might seem to be at low risk to land-based activities, it is important to address any potential contamination by pathogens and chemicals of such a widely use water supply. The management of the Great Lakes as "source water" must be undertaken with the recognition that the overall risk is a function not only of the "stressor" but also the population served. Securing the water quality of the Great Lakes requires that managers undertake protection efforts that address the collective activities in the Great lakes basin and the shared boundary initiatives. These efforts must also account for activities in the United States.

Issues approach to Source Protection Planning

Guiding Principle 11: Source protection plan preparation should be based on an issues identification and management approach that encompasses both past and present practices.

The primary focus of developing a source water protection plan is to anticipate future and assess present threats and risks to drinking water. Managers will need to identify implementation actions that minimize or eliminate the possibility of these threats putting drinking water sources at risk. The Committee, along with TAWG, devoted much of its attention to considering the best approach for developing these plans. Ultimately, the Committee devised recommendations that respect the principle that all drinking water sources must be protected and the reality that water flows from place to place. In this regard, the best approach to detecting threats and risks, as well as quantity-related issues, is to seek out water quality and quantity issues in the entire watershed. Since these issues could be the result of present and/or historic land uses, both past and present activities need to be identified. In addition, more focused evaluations should occur in the direct vicinity of the intake pipe or well. This approach is a comprehensive and precautionary way to ensure drinking water protection, while recognizing that it may require a progressive approach to information collection and/or planning in order to eventually become fully developed.

Guiding Principle 12: Risks to drinking water sources must include threats and issues associated with both water quality and quantity.

During their initial meetings, the Committee was asked to provide advice on the Permit to Take Water program (PTTW) (Section 11). This topic stimulated a great deal of discussion about the fact that since water is so abundant in Ontario, water quantity is rarely addressed as potential threat to drinking water. The PTTW program does not currently consider source protection. But the subject of water quantity must be considered, both in terms of the quantity of water available in any one place, and its general availability across Ontario.

In a fashion akin to investment strategies, maximizing or optimizing the number and diversity of drinking water supply sources best protects water consumers. Where there are few sources, either because a source is no longer available or the quantity in any one source is reduced, each remaining (high quality and quantity) source takes on increasing strategic value. This value should be considered during threat and risk assessments, so that the risk is partially controlled by virtue of having a variety of investments (water supplies available for drinking) so that average exposure is lowered relative to having fewer investments or in this case reliance upon a single (perhaps vulnerable) water supply.

Protection of Human Health

Guiding Principle 13: Source protection plans must prioritize human uses of water, especially in areas where a risk might affect water used by large numbers of people or where a risk requires immediate attention.

The need for the Ontario government to ensure water safety for human use is clearly paramount. There are, however, contaminants that diminish the acceptability of drinking water by consumers on the basis of appearance, taste, odour, etc. Existing Ontario drinking water standards reflect the importance of these parameters to Ontarians. Such features may not pose immediate (catastrophic) or even continuous health risks. However, as Justice O'Connor points out, poor quality water that people find so unappealing as to make it unacceptable may lead them to seek other sources that have greater esthetic appeal, yet are unsafe.

Guiding Principle 14: Information on surface and well water quality should be provided to Medical Officers of Health, who are responsible for public health. These officers must also be involved in decisions on drinking water and distribution of related public outreach activities.

Several members of the Committee reflected upon historical work or activities that included the participation of local Medical Officers in the provision of advice on the safety of water. In this regard, it was agreed that the public health units should have a role in the development and implementation of safe drinking water sources, particularly given their role as recognized purveyors of quality information about implications of water quality for human health.

Guiding Principle 15: Drinking water source protection must take priority over the Nutrient Management Act, farm water protection plans, and any other provincial or municipal legislation, policies or regulations that impact drinking water.

The Committee recognizes that there are various types of "risks" to human health, with varying relative significance. This report contains many specific recommendations regarding pathogens, since pathogens constitute a major risk. Pathogens are complex living organisms that can be difficult to assess, both in terms of their presence and impact. Pathogens can cause catastrophic mortality and/or immediate sickness, whereas many other chemicals pose a risk that is of an ongoing nature. Both Justice O'Connor and the Nutrient Management Act (NMA) state that Nutrient Management Act regulations and planning must incorporate drinking water source protection regulations, legislation and plans, rather than the reverse. The Technical Experts Committee supports this view. The NMA is not designed to address pathogen threats, and therefore in many circumstances Nutrient Management Plans may not be adequate to protect against pathogen threats. In addition to the NMA, other policies, legislation, and regulations should be amended to reflect source protection planning.

Guiding Principle 16: Source protection plans should exercise the precautionary principle for pathogens, which are complex living organisms that may change over time and can be difficult to assess (both their presence and impacts).

Pathogens represent a threat that requires special attention. Though the knowledge of pathogen detection and movement is incomplete, it is known that each living organisms behaves differently. Approaches used historically to measure the presence of pathogens in drinking water sources are outdated, and should be revisited in the light of new and emerging pathogen sources. New approaches that err on the side of caution, with regard to identifying potential pathogens should be adopted.

Reliance on Sound Science and Data

Guiding Principle 17: Drinking water source protection must be subject to the principle of continuous improvement.

Guiding Principle 18: The provincial government must move quickly to develop reliable data systems, which are critical to the success of source protection planning.

Guiding Principle 19: Source protection committees should use existing data as a launching point for planning and acquiring new information.

Guiding Principle 20: All parties involved in source protection planning, including implementation and management, must openly share relevant information.

The provincial government – through ongoing source protection planning – should provide Ontarians with increasingly improved systems to protect drinking water sources. To achieve this goal, the government should ensure that high quality data, science, models, and planning processes are available, and must strive to ensure that these instruments are continually improved. It is essential that this commitment to continual improvement be a deliberate, planned effort that is incorporated into the source protection planning policy and process. In particular, data management and analysis is a key area where continual improvement can be undertaken.

The Committee has made specific data recommendations in this report. As a principle, it is important to note that providing advice today based on currently available information is constrained by a lack of integrated knowledge on the current threats or risks to drinking water supplies. This knowledge will ideally be available after the initial round of planning. In addition, the Committee felt constrained by the fact that a great deal of information that might have proven valuable was difficult to access and/or unsuited in its present form for discussions on source protection.

Error, confidence and caution

Guiding Principle 21: Source protection plans must be based on risk management, when risks can be estimated, and the precautionary principle when risks cannot be estimated.

Guiding Principle 22: Source protection plan implementation must be based as much as possible on existing policies, legislation, and regulations, particularly when data is insufficient.

Guiding Principle 23: Source protection planning committees should incorporate the 'uncertainty principle' into the source protection planning process, so that the resulting risk management activities are consistent with the level of certainty (acknowledging that certainty is largely a data-constrained principle).

Justice O'Connor suggests that 'scientific' risk management and the 'precautionary' approaches to risk management would be complementary. Where risks are clearly understood and can reasonably be established on scientific grounds, the risks should be managed on the basis of that science. Where they can not be scientifically assessed, the prudent course of action would be to use the precautionary principle. This principle states that where information is insufficient to use the rationalist (scientific) approach, the system should err consistently on the side of safety as it moved to manage risks. In essence, the absence of scientific certainty about a risk requires that precautionary measures be taken in the face of irreversible harm. In instances where risks cannot be adequately estimated, precautionary measures such as investments in risk mitigation, alternative technologies, and research are warranted. The Committee supports O'Connor's assessment; in order to effectively manage risks, actions should result in reductions in the threat, impact or pathway by which the threat might reach the water source. For source protection, planning and implementation may need to proceed while better information is being collected. In these cases, the provincial government should make a commitment to acquire such information and ensure that follow-up measures, such as monitoring or a reassessment of the risk, occur where appropriate.

Guiding Principle 24: Communities that draw their drinking water from the Great Lakes must participate in all source protection activities that influence their watershed.

Guiding Principle 25: Ontarians must understand that protecting the various components of the hydrologic cycle is necessary not only to safeguard water quality locally but also for downstream recipients in other major watersheds, such as the Great Lakes, St. Lawrence River and James Bay.

Guiding Principle 26: Source protection must address natural areas, since activities in these areas can significantly impact on drinking water quality.

Guiding Principle 27: The provincial government should continually protect and restore natural areas, both for drinking water quality and the intrinsic value of these areas.

Guiding Principle 28: Source protection planners must continually reduce current and future risks to source water through risk reduction activities and wise planning.

Guiding Principle 29: Source protection planners should categorize actions to reduce individual risks by efficacy, timeliness and proportionality.

Guiding Principle 30: The sustainability of water for drinking and other purposes requires its protection throughout the hydrologic cycle.

SECTION 3: THREATS INVENTORY AND ISSUES IDENTIFICATION

In the initial Terms of Reference for the Groundwater Studies (funded by the Ontario government), a major component of the anticipated work was a "threats inventory." In general, this task has been approached by evaluating what present land-practices (e.g. dry cleaners, heavy industry) are taking place, what chemicals they are using, and what the potential impact could be of a spill or accidental release.

The Technical Experts Committee (TEC) took a broader approach to "threats." Of particular note, the Committee wanted to include any human-caused activity that pierces the protection afforded to source water, either by overlying soils in the case of groundwater or intervening land (e.g. buffer strips, treatment structures) for surface water, as a potential threat. For example, the Committee wanted to ensure that any activities, either past or present, that have the capacity of creating a pathway that could permit contamination of a drinking water supply are identified as a threat. In the case of groundwater, abandoned wells are of particular concern because their condition and whereabouts are often unknown. However, these types of "enhanced pathways" would not have been included under the earlier Groundwater Studies threats inventory. The uncertain location and modification of land cover may make detection of threats such as abandoned wells difficult, and in many cases impossible. In such cases, other approaches might be necessary to discern the impacts of historic or present day activities that are exacerbated by abandoned wells. Incorporating the "issues approach" into the "threats identification and characterization" might be a method to document the threat posed by abandoned wells.

This section is organized into two initial parts: threats identification and issues identification. It also includes sections on significant risks and provincial concerns.

Threats identification

Recommendation 1: Source protection plans must include an inventory and assessment of threats caused by human activities that result in direct access to groundwater aquifers.

Recommendation 2: In wellhead protection areas, source protection planning committees should assess private wells and other potential conduits as threats and consider their impact on planning and risk management.

One of the Committee's initial tasks was to consider factors that might have a significant bearing on the delineation of wellhead protection areas (WHPA) (see Section 5: Vulnerability Assessment). The delineation of these areas relies on some assumptions about the homogeneity of the soils in the given area. The premise that the soils provide a barrier to the movement of chemicals or pathogens to the well intake assumes that no "permissive conduits" are present.

Examples of such permissive conduits would include poorly constructed or abandoned wells or fractures in overlying clay or rock. The presence of such conduits introduces considerable uncertainty in a groundwater scientist's ability to predict the movement of materials to a wellhead, and by extension the reliability of risk management activities to preclude risk and even real impacts. A reliance on models to calculate "vulnerability" assumes with some certainty that the pathway is clearly understood and intact. For this reason, "permissive conduits" are a major threat with regard to groundwater, and must be evaluated. The Committee characterized these permissive conduits as "anthropogenically-induced groundwater pathways", and identified several examples including sand and gravel pits, quarries, mines, oil and gas wells and construction projects.

Such conduits should be located; in terms of locating such conduits, local communities that rely on the integrity of the soils for the protection of their water should have the ability to provide for the proper decommissioning of abandoned wells or other conduits. For example, in the transfer of a deed of a property within a wellhead protection area, the property be evaluated to determine if it could serve as a conduit. Those responsible for the area would then be afforded the tools and ability to ensure such conduits are identified and rectified. In the interim, the inspection/enforcement of proper well design for existing wells should be strengthened, particularly in vulnerable areas. Incentives for proper decommissionings have a good history of success.

Recommendation 3: Source protection plans must identify potential threats on individual properties with a particular focus on vulnerable areas, and through the use of available data where possible.

The Committee discussed at length the "scale" of threats investigations, leading to the general agreement that the combination of the issues approach (reliant upon monitoring and consultation) and the potential threats arising from the analysis of property level lists (land use, practices, zoning) should result in a comprehensive list of known existing and future threats/issues in the given watershed. The probable outcome from this approach to developing a comprehensive list of potential risks will only be the known (threats) or detected (issues) potential risks because there is likely to be significant gaps in data.

Recommendation 4: Source protection planning committees should assess current and future quantity-related threats to drinking water sources and the implications of planned conservation activities.

The conservation of water on the land contributes to ensuring that the overall hydrologic cycle is maintained, thereby protecting the supply to meet current and future demands. The assessment of threats and issues related to water quantity should make use of the water budget information and be linked directly to the Permit to Take Water Program. Where water use issues involve drinking water supplies, the source protection planning committee should coordinate the development of a water conservation plan for the affected water users that will reconcile total water taking with the sustainability of the water resource. The conservation plan may recommend operational limits on water taking that can influence Permit to Take Water decisions.

The Technical Experts Committee recommends the development of a water conservation plan among water users so that the economic and social costs of reducing water use can be balanced among the affected water use sectors. A water conservation plan allows source protection planning committees to consider opportunities to enhance supply and reduce demand. Overall, the impacts on water quantity and the water budget process should be clearly linked to the goals and legislative mechanisms associated with the Permit to Take Water program. The two should be compatible and mutually supportive. Future potential high-volume extractions should be accounted for in the threats assessment.

Recommendation 5: Threats inventories must include past history and past land uses that might affect water supply quality and quantity.

Past land use practices have resulted in hazardous materials being released into the environment. These materials may take years to reach source waters. In combination with practices that have pierced the protective overburden above the groundwater aquifers, the time for these materials to reach the wellhead may be difficult to predict. Furthermore, such materials could find their way into the surface water and as such could be identified via the issues approach, demonstrating the linkage between groundwater and surface waters. Source protection planning committees must search out these past land uses and evaluate whether there may have been hazardous material released or abandoned and non-maintained exposure of aquifers and, where these occurrences exist, develop adequate monitoring and contingency plans to protect drinking water sources.

Recommendation 6: The provincial government must develop and maintain a land use reference database that source protection committees can use to identify threats to drinking water. This database should be provincially held and continuously updated to reflect input from local committees as well as results from similar activities around the world.

Recommendation 7: The provincial government, in consultation with local planning agencies (municipalities, conservation authorities, etc.) should establish the data model for a local threats inventory database. It should be land-parcel based and provide a contiguous spatial fabric across the planning area. The land use reference database should be linked to the local threat inventory database through the land-parcel information.

Recommendation 8: The information in the provincial land-use reference database should include: Land use(s)-->land-based activities-->associated threats-->profile of threats. The profile should contain a list of specific contaminants or risks and associated properties and characteristics that can be used in the “issues identification” process at the local level.

Recommendation 9: The database structure and subsequent model should meet provincial needs for consistency of data acquisition and integration across the province and, at the same time, meet the data access needs of local source planning protection committees.

Recommendation 10: The land-use reference database should allow integration of local and provincial information, so that source protection planning committees can develop as complete a list of potential threats as possible.

Recommendation 11: Source protection planning committees should develop their own local threats inventory database. The local database should integrate the provincial database and local data, and could be used periodically to update the provincial database.

Recommendation 12: The provincial government must commit to financially supporting, maintaining, continually improving and updating the databases, so that increasingly accurate and thorough information is available for future source protection planning.

The Technical Experts Committee established a sub-committee which, with support from the TAWG, debated in detail the analytical process that might be followed to establish the threats inventory. The sub-committee considered the fact that compiling the outcomes of a number of efforts to identify threats to drinking water within the context of wellhead protection activities both in Ontario and outside the province, resulted in a list of practices in excess of 350 in number. These activities could be organized by general activity, or by the nature of their threat (e.g. large-quantity withdrawals, loss of chemicals, chemicals used, or pathogen source). The sub-committee brought forward to the Committee the results of their discussions, summarized below, which have been endorsed by the full Committee. Appendix 3 contains the report of the sub-committee to the full Committee. It provides some additional information that may be relevant but which the Committee agreed to place in the Appendix as supporting information.

In all cases, the generation of data can be costly. But the costs of not having key data may prove more costly. Initially, managers should use data that are easily accessed from existing data sets. As data are needed and generated, these data sets should be upgraded and updated, in keeping with the principle of continuous improvement. A comprehensive threats inventory is an essential component of the development of watershed descriptions, and ultimately management plans. The Technical Experts Committee also recognized the need to comprehend the threats and the site-specific nature of those threats. However, a single, provincially held comprehensive list will be either impossible to assemble or prohibitively expensive to develop and maintain. Furthermore, while there may be provincial information available, significant amounts of local data will also need to be generated. The provincial government should ensure that data are efficiently acquired, especially from existing sources. As well, the government should establish and fully fund a data management system or database that will allow for the coherent integration, development, and management of provincially and locally derived data. The basis for the provincial segment of the database should be assembled using a list of possible land practices and the threats that might be associated with those activities.

Recommendation 13: The threats inventory databases should include three levels of hazard categories (high, medium, and low) that source protection planning committees can use to identify and classify known potential and suspected threats and potential hazards from suspected threats, and to link threat characteristics to a site. This hazard categorization would then be used to estimate the risk posed by the threat, when considered together with the vulnerability of the drinking water source.

While it is important to understand threats and risks at a watershed scale, it is also essential to identify and understand them at a local, site-specific land parcel level (to as cost effective an extent as possible). Since the implementation of risk management activities will occur at the land parcel level, it is important to understand risks and implications of management activities at this level. It is also important to make some ranking statement that allows prioritization of the threats for risk assessment. While the Committee declined to assign intrinsic levels of risk to each and every threat that might be identified through a provincial threats inventory (default) listing, the members did discuss whether the listing should be focused upon "high risk" land-practices. The Committee concluded that the list should instead be as comprehensive as possible. In keeping with the principle of continuous improvement, the list should be modified as source protection plans are revised and upgraded.

Issues identification

Recommendation 14: Source protection planning committees should use all available information, including consulting the public and reviewing available monitoring information, to catalogue known drinking water issues and threats.

Recommendation 15: The issues and threats should be cross-referenced based on common factors, such as quantity of withdrawal, type of contaminant, location, etc. so as to provide a comprehensive listing of "potential risks" that are to be subject to the risk analysis.

Existing knowledge and information in a watershed can be evaluated to yield information not only on important "threats" but also "issues." These threats and issues might be important because they reflect "on the ground" changes in water quality or quantity, or reflect the knowledge and expertise of the basin's citizens. The Technical Experts Committee proposed that the issues approach follow the following steps:

1. Characterize the watershed with detection of drinking water issues in mind as well as other water needs in the watershed
2. Identify all drinking water related issues, as well as other water use issues
3. Set goals and objectives based on the issues and priorities that result
4. Develop, implement and evaluate actions to alleviate the issues.

Information should be collected and processed so that source protection planning committees can identify all water issues (drinking water in particular) in a watershed and then decide whether and how to deal with them. An area of cross-over into the "threats identification" activity would be the use of surrogates as a means of identifying threats, such as the review of land uses and land covers by using remotely sensed information. Managers could refer to a provincially provided database to consider whether practices exist that might create source protection issues. As a major component of this approach, source protection planning committees should examine water quality and quantity information in the watershed and consult the local community. They should also consolidate existing publications and reports.

The intent of this background information and evaluation is to provide as comprehensive a list of potential drinking water issues in the watershed as is practically possible, given the data limitations. Source protection planning committees would consider the list, evaluate risks and priorities, and develop action plans to deal with the potential risks. Some issues might not be considered relevant, but these issues could be communicated to other planning groups for consideration and/or offered as information items for local stewardship initiatives. Details of the methodology and greater explanation of the approach is found in Appendix 3.

Recommendation 16: All municipal source waters should be characterized microbiologically according to guidance set out by the provincial government. Risk categories for each source should be determined by combining microbiological data and hydrologic and hydrogeologic information.

The threat identification process must prioritize potential pathogen sources to source waters. Each of these source water categories – municipal wells, rivers, lakes, etc. – has different physical characteristics and vulnerabilities to pathogen contamination. Furthermore, pathogens have different survival times and behave and travel differently in and out of these different types of source water. Information must be garnered for each source category individually in order to properly evaluate the risk associated with the source. Moreover, the microbiological risk assessment will allow for the identification of a primary risk category, whereby the assignment of a drinking water source into a particular category would determine the required actions to protect or improve source water quality. The development of adequate protective measures requires an understanding of these characteristics and knowledge of the intrinsic levels of pathogens that might be present. Such a characterization of the water source with respect to quality, treatment and vulnerability is consistent with Justice O'Connor's Recommendation 30 in *Part Two Report of the Walkerton Inquiry*: "All raw water intended for drinking water should be subject to a characterization of each parameter that could indicate a public health risk. The results, regardless of the type of source, should be taken into account in designing and approving any treatment system" (O'Connor 185).

Recommendation 17: For surface waters, the information generated through characterization should be made available to water system purveyors downstream to help them make management decisions.

In some surface water systems, source water may only require a few hours to travel downstream to the next intake. As such, the knowledge collected on the *entire* system may need to be evaluated in order to better understand the source, fate, survival and potential infectivity of pathogens.

Recommendation 18: The provincial government should adopt a multi-indicator approach to establishing new and consistent microbiological raw water quality standards/objectives for all drinking water sources (rivers, lakes, reservoirs, and groundwater).

Due to variations in transport, survival and response to environmental stress, the use of a single faecal indicator bacterium as an index of risk to human health may significantly over or under estimate risks from pathogens. Proposed indicators include:*E. coli, enterococci*, *coliphage*, and *Cryptosporidium.*

The establishment of raw water standards/objectives will set achievable, protective targets and ranges for all drinking water sources. These protective targets and ranges will provide an additional barrier to protecting drinking water in the event of a failure at the drinking water plant. These targets will also identify appropriate management strategies to reduce the loading of pathogens to the water. By striving to achieve these standards/objectives, the overall water quality for other uses (e.g. recreational) should improve.

Water budgets

Recommendation 19: As part of the source protection plans, a water budget should be progressively developed for the individual watersheds as a method of quantifying water storage volumes, fluxes, pathways, and water takings for the combined surface water and groundwater resources. The water budget can be used to assess whether existing and proposed withdrawals are a threat and/or potential cause of an issue.

The water budget framework and approach is essential to the source protection planning process. It provides a logical methodology for evaluating threats and issues related to water quantity, which can include over exploitation of the resource and associated impacts on surface water and natural landscape features.

In making its recommendations, TEC has taken the view that protecting the sustainability of water resources that may be the source for drinking water requires landscape level consideration of the hydrologic cycle and the cumulative impacts of human activities on this cycle. The water cycle or "hydrologic cycle" is dynamic. The proportion and method by which water runs off the land into streams, evapotranspires, recharges groundwater aquifers, or discharges from groundwater to surface water depends on many factors. These factors include geology, soil characteristics, land cover, drainage, and where and how humans take water for water supply purposes. Source protection planning must address threats to not only quality, but to quantity as well. The water budget framework provides a scientific basis to enable source protection planning committees to understand and address quantity-specific issues.

Water budgets compare all current and forecasted water uses and withdrawals to the total amount of water in the watershed. They may also provide quantitative information on the water flux within the major components of the hydrologic cycle, including groundwater recharge and discharge, fluctuations in storage volumes, and variations in surface water flow. The information derived from the water budget estimations can be used to identify quantity sustainability issues in the watershed, facilitate calculations of regional contaminant mass loadings from non-point sources, assist in identifying and characterizing hydrologically sensitive components of the watershed, and assist in the long-term conjunctive management of the surface and groundwater resources.

Water budgets should include both groundwater and surface water dynamics, since withdrawals from one invariably affect the other. Furthermore, it is essential to analyze water budgets developed through source protection with respect to the landscape - to gain insight on the types and magnitudes of hydrologic functions that are attributable to various natural features in the landscape. These analyses will help planners decide how much and what type of natural cover is required to sustain water quantity.

A water budget should ultimately include:

- quantification of the components of the water balance equation (precipitation, evapotranspiration, groundwater inflow and outflow, surface water outflow, change in storage, water withdrawals and water returns)
- characterization of the storage and flow of water on and beneath the surface, using hydrologic and groundwater models
- identification of key hydrologic processes (e.g. major recharge & discharge areas)
- quantification and projection of water uses and needs.

Recommendation 20: Source protection plans must develop water budgets that reflect specific watershed needs, conditions and data availability and that improve in accuracy with successive plan developments. Information gaps should also be addressed as plans are developed.

Water budgets should be developed on a watershed-specific basis, recognizing that the threats and issues related to water resource management will vary greatly, as will the existing physical understanding of the different watersheds and the availability of data. Although the water budget should form a fundamental component of the source protection plan, it will likely require continual development as the nature of the watershed characteristics and threats become clearer and additional data are made available. As the water budget evolves, gaps in required data will become apparent and steps can be taken to establish the required monitoring networks that will provide the most pertinent data. These networks and related data will vary from one watershed to another.

In southern Ontario and areas of northern Ontario under Conservation Authority jurisdiction, source protection plans may ultimately include water budgets at two levels of scale and detail:

- For the entire watershed area: a watershed level water budget, based on available data and hydrologic modeling, that identifies areas with potential water uses issues resulting from cumulative water takings.

- In the areas where potential water issues have been identified: a more detailed water budget that is based on refined information and hydrologic/groundwater modeling.

In northern Ontario, only ‘simple’ water budgets may be appropriate given that the withdrawals in any one place may be quite limited and consumption often negligible. In the parts of northern Ontario outside of Conservation Authority jurisdiction, a simple water budget should be completed to determine whether sufficient water use exists to warrant further research.

Recommendation 21: All municipalities should maintain a long-term (50 year) water supply strategy that sets out their water supply needs, including conservation plans, and the planned sources for meeting their needs.

Recommendation 22: As part of the water budget process, significant data gaps will be identified that will need to be filled in order to progressively improve the water budget and steps will be taken to collect the required data as the source protection plan evolves over time.

Planning to meet future drinking water needs should be an integral part of the municipal land use planning and growth management process. Large parts of Ontario are growing and changing rapidly. The provincial government regularly provides municipalities with 25-year population projections. Municipalities are required, under the *Planning Act*, to provide for growth through their land use planning processes. All municipalities should maintain a long-term water supply strategy that sets out their water supply needs, including conservation plans, and the planned sources for meeting those needs. In particular, those municipalities that do not have water supply capacity to meet their 25-year needs – or a water supply strategy that shows how their 25-year needs will be met – should prepare a long-term water supply plan as part of developing a source protection plan. Municipalities preparing a new long-range water supply strategy or updating their plan should look to the 50-year planning horizon.

In order to protect the quantity of future municipal water supplies, the future municipal water supplies identified in the long-term water supply strategy should be considered when Permits to Take Water for other new or expanding uses are considered. Similarly, municipalities should consider the availability of water when development applications for water-intensive land uses are considered. Integration of these two decision making processes should be considered as part of the overall water management program in Ontario.

Future drinking water wells and intakes identified in the municipal long-term water supply strategy should be protected, from a quality perspective, in the same way that current water supplies are protected. Where it is too costly or too early to pinpoint future municipal wells and intakes, it will be necessary to rely on protection afforded to vulnerable areas; future water supplies that are vulnerable can be prioritized when determining risk management actions to be undertaken in vulnerable areas (see Table 6.2 in Section 6 – Risk Management).

Recommendation 23: As part of developing water budgets, vulnerable aquifers and aquifer recharge must be identified, in recognition of the importance of recharge in sustaining aquifers and also the connection between groundwater discharge and the maintenance of surface water. Source protection plans should protect the quality and quantity of these water supplies.

Recommendation 24: As part of preparing a water budget, source protection planning committees should evaluate what reductions in aquifer recharge and discharge are sustainable over the long term and establish baseline recharge rates for monitoring and future planning.

Water quantity protection involves managing water withdrawals and maintaining the recharge that replenishes groundwater and sustains groundwater discharge to surface water. Land uses and activities that reduce infiltration may, cumulatively, pose significant long-term risks to drinking water supplies by reducing recharge to groundwater aquifers and reducing groundwater discharge to surface water. Examples of threats that reduce recharge potential include:

- Activities which increase surface runoff, resulting in a loss of recharge potential at source, including paving, grading to remove surface depressions, and improving surface drainage (e.g. storm sewer systems, tile drainage and municipal drains), and
- Activities which speed up the flow of surface water, resulting in a loss of recharge potential, including the loss of wetlands and loss of riparian vegetation along streams.

Similarly, all land uses and activities that interfere along the recharge pathway to a drinking water supply aquifer are threats to water quantity, and cumulatively may be significant long-term risks to drinking water supplies. The major recharge contribution areas and pathways should be identified and steps taken to manage the risks. The Technical Experts Committee discussed the advisability of protecting particularly those areas where very large amounts of water are infiltrated, while protecting 80% of the potential recharge overall. There was concern, however, that in areas that are already impacted, protection of 80% of the recharge potential may not be enough to sustain the resource. The Committee suggests that a water budgeting process that includes documenting the pathways of water travel should be adopted, in order to identify the aquifer recharge areas that need to be protected. Furthermore, work should be carried out to determine what reductions in aquifer recharge and discharge are sustainable over the long-term. The quality of water infiltrated in major recharge areas is also a concern, due to the potential long-term water quality impairment of aquifers.

Recommendation 25: The tolerance of the ecosystem to changes in water flows and levels should be considered in assessing the sustainability of water supplies.

In determining whether water is being over-used, or the sustainability of future supplies jeopardized, it is necessary to determine how much water must remain in the environment. Changes in groundwater, whether from withdrawals or interference with the recharge processes, are ultimately reflected in groundwater discharge to surface water features and cumulatively affect surface water flows and levels. The regime of water flows and levels that is required to sustain a healthy ecosystem should be determined based on hydrology, water quality, geomorphology, connectivity and biology.

Significant direct threats

Recommendation 26: The term ‘Significant Direct Threats’ should be thought of as Significant Risks because the term risk implies both high threat and a likely pathway for the threat to reach the drinking water source.

Effective source protection planning will require a consistent and rational “lexicon”. The Technical Experts Committee reviewed Justice O’Connor’s use of the term ‘Significant Direct Threat,’ and concluded that this term refers to land-use activities that pose a risk to human health via water use, and where the threat will likely reach the drinking water source. While it is important to focus attention on these activities, it is equally important to recognize that threats are simply the presence of activities or materials that cause concern. Threats only become a risk when there is a hazard associated with the threat and a reasonable probability that the threat will reach the drinking water source, and result in potential for human exposure. It important to focus attention on activities that are risky by virtue of inherent hazards and probable pathways, especially where those risks are significant or imminent enough to be worrisome. Threats are of lesser concern until a pathway that might cause delivery of the threat is created, discovered or perceived. Source protection planning committees must carefully examine and consider all potential pathways for each threat detected in the landscape.

Threats of Provincial Concern

Recommendation 27: A list of threats of provincial concern should be adopted within the source protection planning framework.

The Committee discussed at length a TAWG proposal that the various land-practices identified through the threats inventory be “ranked” for their potential risk. The Committee chose not to make this proposal a general principle. Throughout the province, the watershed characterization, issues identification process, and threats inventory are all tools and methods for identifying threats to drinking water. There are certain threats to drinking water quality which, if present in a vulnerable area, may pose a higher probability of risk to human health or to the sustainable use of the drinking water supply and which likely warrant a consistent approach to risk management if found to be a risk by the local committee. The Committee helped provincial staff identify these threats, which were compiled in a list of the threats of provincial concern (Table 3.1).

As a starting point for the list, the Committee considered the recommendations of Justice O’Connor and the Advisory Committee on Watershed-based Source Protection Planning. In reviewing a list proposed by TAWG, the Committee considered whether:

- the particular threat would result in contamination or loss of use of drinking water in Ontario or in another jurisdiction
- the threat had been identified as a high risk to drinking water in one or more of the provincial ground water studies
- the threat would be reasonably prevalent in watersheds across Ontario.

The Committee discussed the implications of having such a list and how this list might be used. The purpose of the list is to ensure that in the areas most vulnerable to contamination - where impact on human health or the sustainability of the supply is a greater risk - well-documented risks to drinking water sources are identified, assessed and properly managed. The Committee concurred that, within identified vulnerable areas, items on the list should be subject to provincial requirements to consistently identify, assess and manage the associated risks. The Committee felt that no practice listed in Table 3.1 should be subject to risk management activities without the appropriate analysis of potential pathways (as would be determined during the vulnerability assessment). The provincial list can be used to guide the local threats assessment process. However, it is not intended to limit the local assessment of activities.

Table 3.1: List of land use activities that threaten drinking water sources and are sufficiently serious to be of provincial concern.

Activities	Primary Issue
Human-made Pathways to the aquifer Activities/structures that penetrate the water table and/or aquifer. These include: • Existing wells (water, gas, oil) • Abandoned Wells • Pits , quarries, mines Other construction activities that provide short or long term direct access to an aquifer	"vulnerability" – direct pathways to current or future potential drinking water
Liquid Chemical Storage /Use Includes "commercial quantities"[11] of : • Fuels/ Hydrocarbons • DNAPLs[5] • Organic Solvents[12] • Pesticides (of concern to Drinking Water) • Fertilizers Proposed that only quantities above a certain threshold would be captured	Chemical contamination of aquifers, Nutrients
Historical Commercial/ Industrial Sites of Concern Includes historical land uses/ activities that have a high potential for contaminating drinking water sources[13]	Chemical Contamination of aquifers
Waste Storage and Disposal Activities Includes (specified quantities of): • Landfill sites • Organic Soil Conditioning sites (except for biosolids application sites – covered under another item) • Hazardous waste • Liquid industrial waste • Mine Tailings	Chemical Contamination of aquifers
Biosolids and Septage • Storage and land application of biosolids and septage	Pathogen Contamination of aquifers, Nutrients
Manure • Storage and land application of manure	Pathogen Contamination of aquifers, Nutrients
Sanitary Sewage and Septics Includes: • Sewer infrastructure (sewer mains & connections) • Sewage treatment plants effluent • Septic Systems • Sewage treatment plant by-passes • Combined Sewer overflows • Sanitary Sewer overflows	Pathogen Contamination of aquifers, Nutrients
Road Salt/ De-icing Includes: • Uncontained storage, and application of road salt/ de-icing compounds. • Salt-laden snow storage (snow dumps from plowing)	Chloride Contamination of aquifers

[11] Province to determine what the appropriate "trigger" quantity would be. Suggest considering quantities referenced in existing legislation or accepted Environmental Management System schemes (responsible care, CSA, UL) for the purposes of risk management.
[12] As above
[13] Province to determine appropriate trigger contaminants
[5] Province to develop list of DNAPL materials

Activities	Primary Issue
Cemeteries • Includes Burial grounds	Chemical Contamination of aquifers
Stormwater Infiltration • Stormwater collection ponds in urban areas that are designed to allow stormwater to directly infiltrate into groundwater	Chemical/ solute contamination & Pathogen Contamination of aquifers
Water Treatment Plant Waste Water • Includes filter backwash discharges to surface water	Pathogen contamination of aquifers
Non-sustainable Withdrawals • eg. Situations where aquifers supplying municipal wells have levels which are steadily dropping over time, or where allocation of Surface Water supplies threatens quantity during low-flow conditions	Insufficient quantity resulting in reduced quality, reduced assimilative capacity, threat to sustainable supply

SECTION 4: VULNERABILITY ANALYSIS

Recommendation 28: Vulnerable areas should be defined as the maximum extent of the zone described by a 25 year time of travel for wellhead protection areas, 2 hour travel time or pathogen response time (whichever is greater) for intake protection zones and zones of high or extremely high vulnerability for aquifer protection zones and major groundwater recharge areas.

After the threats inventory and issues identification, a vulnerability analysis would be the next step in developing a source protection plan. The vulnerability analysis could be rendered moot if the issues approach, through monitoring, identifies issues directly in drinking water. But even in such a case, the vulnerability analysis may prove useful in determining the implications for other water supplies. For example, monitoring of private wells within a wellhead protection area might identify a plume of chemical solvent moving toward a municipal well-head. The vulnerability analysis would be used to evaluate the likelihood of the plume reaching the municipal intake. The Technical Expert Committee's discussions around vulnerability have an additional implication in that the delineation of "vulnerable areas" will likely have implications for other program areas, such as the requirement that farms located in vulnerable areas produce Farm Water Protection Plans. The Committee discussed the potential types of delineated areas and how they might be defined, keeping in mind the need to adhere to the precautionary principle.

Recommendation 29: Surface waters are intrinsically vulnerable by virtue of their proximity to landscape activities, and their use for waste assimilation and other industrial applications. Existing regulations, policies, and programs should be used to ensure that surface water protection is not sacrificed by efforts to protect other areas designated as vulnerable.

The Technical Experts Committee addressed the concept of "sensitivity" and its application in the threats assessment process. By applying the issues approach, source protection planning committees can monitor water bodies and determine quickly whether they are sensitive and/or impacted. It is therefore more appropriate to consider the sensitivity of a water body during the development of the approaches for risk management. It is appropriate to include assimilation studies among the tools and instruments that might be advisable if a threat, combined with vulnerability, identified a risk. For example, when calculating the mass flux of a contaminant, such as road salt, from several sources to a wellhead, the assimilation study could help determine whether a 50% reduction, or 90% reduction, in salt use is required. A second example would include the relative rates of recharge, discharge, storage and withdrawals in evaluating the extent of reductions in withdrawal rates where a water shortage was noted; water bodies with high sensitivity (low renewal rates) would require more rapid and deeper cuts in water allocations. Furthermore, the Committee recommends that sensitive water bodies be considered in the final risk ranking, possibly through the addition of a "modifying factor" for the intrinsic sensitivity of the water body in calculating the final risk ranking.

The Committee established a sub-committee that grappled with the technical and analytical challenges of defining vulnerable groundwater resources. TAWG staff undertook a number of analyses of potential surface water vulnerabilities, presenting them to the Committee for consideration. The detailed reports presented to the Committee by the vulnerability sub-committee are included as Appendix 4 and Appendix 5.

Surface water intake protection zones

Recommendation 30: The overall Intake Protection Zone for inland surface water intakes should be based on a minimum 2-hour response time. This area can be defined by converting the response time (e.g. 2 hours) to a capture area based on both overland run-off and channel flow components and appropriate storm events. This zone should be considered a vulnerable area and be managed to reduce risks from catastrophic threats such as spills.

Recommendation 31: The Ministry of the Environment, in consultation with the Ministry of Natural Resources, should designate an Intake Protection Zone (IPZ) based on a two-hour response time. They should also help local source protection planning committees to determine the appropriate response time in their respective IPZ, based on the two-hour minimum. The local IPZ should delineate a capture area based on both overland run-off and channel flow components under appropriate storm events (e.g. annual average flow rate in river, two-year storm event).

Recommendation 32: The guidance for the delineation of the Intake Protection Zone (IPZ) should incorporate the precautionary principle by requiring that the most protective zone be established depending on the local site characteristics. In particular, it should be recognized that low flow conditions produce a slower velocity and less dilution, while higher flows increase velocity and dilution.

Recommendation 33: The delineation of the Intake Protection Zone (IPZ) should take into account watershed characteristics that contribute the greatest risk, whether event-based (high or low flows), seasonal or continuous. The two-hour response time should then be applied to the event that contributes the greatest risk. If site specific information is unavailable, the annual average flow rate should be used. .

Recommendation 34: The catchment area should be the functional unit for the analysis of surface water “issues” such as pollutant loadings beyond the IPZ. Vulnerability mapping and threats identification should be undertaken to determine those locations within the catchment that do or may contribute to the “issues” so that the overall aggregate risk may be assessed and appropriate strategies implemented.

Drinking water intakes draw water from all lands and tributaries that are upstream of the intake structure. As such, the watershed and sub-watershed boundaries were considered appropriate management units to define the catchment area of a drinking water intake for small river and inland lake systems. However, experience has shown that surface water supplies can be more vulnerable to contaminant inputs that originate from the areas immediately upstream of the intake. Similarly, water supplies in the Intake Protection Zone (IPZ) and catchment area can be sensitive to land use activities that influence runoff and infiltration, thereby affecting supply quantity. The IPZ was considered vulnerable for several reasons:

1. It is the area in closest proximity to the drinking water intake and as such offers limited response time in the event of an unexpected contaminant discharge;
2. By definition the IPZ will be situated immediately upstream of a drinking water intake, and as such the ability of the receiving stream to assimilate and dilute contaminant inputs is significantly reduced, thereby imposing a higher level of risk and financial burden at the water treatment system;
3. Municipal drinking water intakes are normally located next to the urban centres they service or downstream of a neighbouring urban area. Urban areas have a thoroughly documented history of being significant contaminant sources. Examples include viruses, bacteria and pathogens associated with untreated urban run-off and combined sewer overflows, pesticide residues, metals, suspended solids, salts and nutrients in run-off, numerous point-source discharges, and historic contaminated sites.

The surface water approach for small river and inland lake systems can therefore be structured into separate management zones. The first area, the Intake Protection Zone (IPZ), is considered the primary zone and is immediately upstream of a drinking water intake. This area can be defined either by applying a set distance upstream of the intake (on land and in the water) or by using a response time (e.g. two hours) approach to delineating a capture area based on both overland run-off and channel flow components. Once defined, this IPZ would be recognized as a high vulnerability area.

Beyond the primary IPZ, the catchment area can be used to define the secondary management area. In most situations, the upstream watershed will be used to define the remaining catchment area. Vulnerability mapping and the threats analysis should be undertaken to determine those locations within the catchment area that represent potential risks, so that a strategy for reducing the overall aggregate risk may be implemented. In systems with multiple surface water intakes and potentially multiple source protection planning committee, it will be necessary to take a coordinated approach to assess watershed loadings and cumulative impacts.

The source protection planning committees should define an area within the Intake Protection Zone where land use activities may increase the rate of surface run-off. The committees should undertake an intensive threat assessment that focuses on activities such as pipes, drains and other activities – including threats of provincial concern – that result in run-off. This run-off could threaten the quality of surface drinking water.

Recommendation 35: A pathogen risk zone (contiguous area of land and water immediately upstream or around a municipal surface water intake) needs to be delineated using a site-specific response time or two-hour travel time in which risk management should be undertaken for activities that pose a catastrophic pathogen threat.

The US EPA reported that between 1971 and 1996, there were a total of 643 waterborne disease outbreaks infecting nearly 600,000 people; one incident in Milwaukee, which relied on a surface water source, affected 400,000 people. Severe storms, spills or failures that result in a release of pathogens are catastrophic threats to the intake and require a reactive approach. The pathogen risk zone is the area in which, if a release occurs, sufficient time exists for the drinking water plant operator to turn off the intake.

Recommendation 36: All private drinking water supplies that come from surface water must be treated to eliminate pathogens. The level of treatment must be based on a source water quality evaluation.

Recommendation 37: The provincial government should develop guidelines for evaluating surface water sources of drinking water and for providing treatment of such sources, and should require education of private system operators to ensure private system quality, evaluation and treatment.

Surface water drinking sources are distinctly different from groundwater drinking sources and require additional consideration. Groundwater is filtered by the sub-surface materials, and this natural filtration is considered in provincial treatment requirements, whereas surface water does not have the benefit of natural filtration. Managers should take the precautionary approach for surface water drinking sources, and should undertaken a minimum level of treatment for this water. Furthermore, a source water quality evaluation should be used to determine if the current treatment is sufficient, or what additional treatment may be deemed necessary to minimize the pathogen risk.

As well, the provincial government should prepare guidelines to assist source protection planning committees in performing the assessment, and in making decisions on risk management in the watershed. Such guidelines from the government will help to ensure a consistent approach across the province. Experience has shown that surface water supplies can be more vulnerable to contaminant inputs that originate from the areas immediately upstream of the intake. Source protection planning committees should consider risk management in the watershed area upstream of the intake as an approach to reduce pathogen loadings. Risk management activities to reduce the loadings of pathogens are consistent with the precautionary approach.

Recommendation 38: For intakes on large water bodies, such as the Great Lakes, the delineation of the IPZ shall be a 1 km radius around the intake structure unless issues are known or suspected, in which case a larger zone is to be delineated to encompass the physical location of known or suspected threats within the radius.

Recommendation 39: Based on research, issues analysis, and consultation, subsequent cycles of planning should replace the 1 km default with a science-based Intake Protection Zone.

Recommendation 40: The Ministry of the Environment, in consultation with the adjacent Provinces and the federal government, should develop a strategy for the source protection of the Great Lakes and its waters from transboundary threats that recognizes the interdependent, nested nature of Ontario’s watersheds.

Recommendation 41: Quantitative mapping and hydrogeologic analysis must be undertaken to define the contributions of groundwater to the maintenance of the Great Lakes and surface waters so as to identify the recharge quality and quantity necessary for their long-term maintenance and/or restoration.

Recommendation 42: The benefits of watershed-base activities must be assessed and communicated not only to those who directly benefit (e.g. those in vulnerable areas) but to those downstream who are beneficiaries of these activities.

Recommendation 43: Source protection requirements should be reviewed periodically and if necessary amended to ensure an equitable distribution of the burden of source water protection. This measure applies particularly to practices and activities in communities served by the Great Lakes.

The drinking water for 80% of Ontario's population is derived from the Great Lakes and associated tributaries. The Technical Experts Committee did not have sufficient time to consider this factor in detail. In many cases, the drinking water intakes servicing the communities along these systems are located a considerable distance from shore, and in deep, cold, thermally stratified hypolimnetic waters. These types of intakes are not as susceptible to local or near-field sources of contamination, and in many cases the predominant influence on the quality of the raw water is from inputs made from the tributary watersheds located a considerable distance upstream. By managing the tributary watersheds and reducing the risks through source water protection, drinking water intakes located in large water bodies will in turn be protected.

The provincial government should apply source protection strategies to all tributary watersheds of the Great Lakes. This measure will ensure the integrity and sustainability of the Great Lakes as a drinking water source. It will also reduce the risk to the drinking water intakes located in the Great Lakes and the interconnecting rivers. Additionally, municipalities drawing their drinking water directly from the Great Lakes or other large water bodies will be required to implement source protection measures to minimize the risk of water quality impacts from local threats, and to protect source water for downstream users. Every Great Lake intake jurisdiction needs to work with their adjacent or upstream watershed municipalities to evaluate threats and issues to their source water.

Wellhead protection areas

Recommendation 44: The preliminary delineation of the wellhead protection areas should be based on the classical "Time of Travel" (TOT) approach, either in two or three dimensions depending on the local availability of data.

Recommendation 45: The modeling approach selected must be reviewed and approved by a third party technical group, such as a Source Water Protection Technical Review Committee (SWPTRC), particularly the application of the vulnerability analysis.

The Vulnerability sub-committee undertook the task of developing a practical approach for evaluating the vulnerability of a groundwater receptor, specifically a water well, to contamination from a potential surface source(s). Building on the work of the Pathogen sub-committee, the Threats sub-committee and TAWG, the Vulnerability sub-committee considered vulnerability in the context of the identified threats of provincial concern. The sub-committee provided guidance (Appendix 5) regarding the application of a wellhead vulnerability assessment to these threats, in order to help define appropriate risk management measures for future and existing (including historic) land uses and activities.

The primary application of the vulnerability assessment involves three main components:

a) delineation of surface areas around wells (Wellhead Protection Areas or WHPA) where new land-use activities should be controlled or restricted to minimize potential impacts to groundwater quality and where current and past land use activities should be investigated to assess the potential threat that they pose to the receptor.

b) perform a semi-quantitative evaluation of vulnerability of the land area within the WHPA with respect to contamination of the well, in order to assess the level of risk associated with various land uses within the WHPA.

c) prepare a threat (risk) prioritization within the WHPA, based primarily on the vulnerability evaluation ((a) and (b) above), where specific proactive or reactive initiatives should occur as defined within protocols established for risk management (some guidance provided).

In Ontario, Time of Travel (TOT) is a well established, and fairly well accepted method for modeling wellhead protection areas. The approach and methodologies required to determine the TOTs are extensively documented. This approach is also a well established international method. The TOTs provide a conservative approach for decision-making. They minimize the potential impacts of the uncertainty inherent in surface and subsurface conditions and the potential of these conditions being insufficiently accounted for in the quantitative assessment.

Indeed, the Vulnerability sub-committee felt it appropriate for source protection planning committees to be encouraged or required to adopt more quantitative modeling of Wellhead protection areas. Numerical modeling is highly recommended, despite the fact that it requires a high quantity of quality data and expertise in order to reasonably represent field conditions. It offers the advantage that it can be continually improved as new data become available. The development of a numerical model is advantageous in that it promotes the continual acquisition of good quality data. It also provides the source protection planning committee with a management tool that will be continually improved, and that will ideally evolve into an effective tool used to inform other water-related decisions. The use of numerical models will also encourage consistency across the province.

Recommendation 46: Within the wellhead protection area, two pathogen management zones should be delineated, namely a 100 metre pathogen security area, and a 2 year TOT zone which should be considered the area of concern with respect to bacteriological/pathogenic contaminants.

Recommendation 47: New wells should be developed with a 100 m zone in which control will be gained so as to preclude pathogens.

Recommendation 48: Within the wellhead protection area, source protection planning committees should delineate and use a 5 year TOT capture zone which should be considered the area of highest vulnerability to Dense Non-Aqueous Phase Liquids (DNAPLs) impacts. The 5 year TOT should also be the zone where the risk assessment is more focused for all other (non-DNAPL or pathogen) threats from contaminant sources.

Recommendation 49: A 25-year Time of Travel should be defined to delineate a secondary wellhead protection area for less stringent risk management protocols.

Recommendation 50: The entire capture zone should be defined for long-term planning purposes, as well as to inventory existing uses and activities (particularly historic uses) that may pose a threat to the well.

Within the proposed approach, specific TOTs are prescribed for risk management purposes as outlined below. For each TOT, the Vulnerability sub-committee (Appendix 5) provides guidance regarding additional risk assessment and risk management measures. While the guidance is offered primarily in the context of the threats of provincial concern, such measures can also be applied in the context of locally-identified threats.

The results of a study of groundwater quality of about 1,300 wells in Ontario showed that about 35% of rural wells contained indicators of faecal contamination above drinking water standards. More than half of the waterborne disease outbreaks in the U.S. between 1971 and 1996 were associated with groundwater sources. Of these, 25% were attributable to specific viral or bacterial pathogens.

The two-year TOT zone for pathogen management is based on an extensive review of scientific literature on pathogen survival and transport. An inventory of pathogen sources in the pathogen protection zone must be compiled by the source protection planning committee as part of the threats inventory, since any source within this zone has the potential to adversely affect the water source. The inventory will include pathogen sources such as those on the threats of provincial concern list as well as private wells (conduits) in the protection zone. The wellhead operator should mitigate existing pathogen sources within this radius, particularly where risk assessment indicates a significant risk.

Pathogen sources resulting from human activity should not be permitted within a 100 metre zone surrounding a new wellhead. This security/prohibition zone is identified to recognize the inherent uncertainty in the subsurface zone that is expected to provide some mitigation to pathogen transport. Thus, over short distances, it is difficult to provide a detailed enough characterization to the hydrogeological setting to assess the potential risk of pathogen travel. A 100 metre pathogen security zone is consistent with practices in other jurisdictions and is consistent with other provincial legislation.

Recommendation 51: The Time of Travel (TOT) assessment should include a quantitative evaluation of the level of confidence associated with the delineated TOT areas and an assessment of wellhead vulnerability.

Recommendation 52: The modeling and delineation of the wellhead protection area and its zones should be revisited every five years as part of a comprehensive review and/or when a substantial change in the capture zone is anticipated, or when additional new information is available to increase the level of confidence in the delineation and models.

An evaluation of the level of confidence is an extremely important consideration in delineating the zones on the ground, particularly as the location of the "line" on the ground may substantially influence risk assessment and management. This evaluation may influence the final delineation of the TOT area and should be taken into consideration when developing risk mitigation strategies for these areas. A lower level of confidence in the TOT should also serve as the trigger for the collection of additional data and upgrading the model at the 5-year review interval. As confidence in the modeling rises, appropriate adjustments to the risk mitigation strategy for a WHPA can be made.

Recommendation 53: A semi-quantitative approach (such as surface to ground water advection times) should be used to evaluate the degree of protection provided by the vertical travel path from ground surface, through the unsaturated zone and into the aquifer unit being assessed within the wellhead protection area (WHPA). This vertical travel path analysis when combined with the TOT value results in an estimation of surface to well advection time (SWAT).

Recommendation 54: SWAT should be categorized so as to support varying risk mitigation strategies in the areas of various vulnerability, such that 0 – 5 years represent high vulnerability, 5-25 year represents moderate vulnerability, and >25 years represents low vulnerability.

Recommendation 55: The recommended approaches to estimating SWAT values are subject to data availability, the level of understanding of the local system and knowledge of the threats in the wellhead protection area. Listed in increasing order of complexity and requiring progressively more information on the approaches are: an assumption of uniform high vulnerability everywhere, a simple indexing system, the calculation of average vertical advection time and fully thee-dimensional modeling. More advanced approaches should be used in subsequent revisions as data permits.

Recommendation 56: The application of wellhead vulnerability assessments to TOT zones should inform the risk analysis and be used to assist in prioritizing the risk management action plans to address threats. More restrictive/mandatory measures should be considered in highly vulnerable areas ranging down to less intrusive measures in less vulnerable areas. The wellhead vulnerability assessment should be used to direct future threats away from highly vulnerable areas.

The classical TOT areas provide a conservative approach to delineating source protection areas for wells. This may be sufficient for smaller rural supplies with relatively small capture zones, particularly if there are no Threats of Provincial Concern present and the municipality is prepared to manage or prevent new threats. In other cases, the WHPA TOT areas can be further investigated through a wellhead vulnerability assessment, taking into consideration the entire pathway from release at ground surface to arrival at the well. The recommended approaches range from simple indexing systems to fully three-dimensional modeling, as follows:

i. simple indexing system based on surficial soils, basic hydrogeologic conceptual model and depth to target aquifer;
ii. calculation of average vertical advection times from ground surface to top of aquifer unit or particle depth from the TOT model using estimated or known vertical hydraulic gradients and average porosities; and
iii. fully three-dimensional modeling allowing for reverse-travelling particles to migrate to the ground surface thus providing an estimation of the Surface to Well Advection Times (SWAT – See Appendix 5)

The addition of a wellhead vulnerability assessment will not change the extent of the classically modeled TOT, though it does enhance the level of understanding of vertical travel within each TOT. Source protection planning committees can use this assessment in the risk assessment process for source protection. In particular, the committees will have an improved ability to evaluate a proposed new land-use activity within wellhead protection areas, since they'll have a more complete understanding of the level of vulnerability associated with the specific location in question. They will also have an improved ability to prioritize the level of threat and subsequently the action requirements associated with existing and past land use practices within the wellhead protection areas

Recommendation 57: Several pilot projects that demonstrate and evaluate the approaches recommended for delineating wellhead protection areas and assessing vulnerability within the wellhead protection areas should commence immediately and focus on areas where considerable work has already occurred through the Provincial Groundwater Studies.

Pilot projects that can establish protocols to define variations in wellhead vulnerability based on, for instance, vertical travel time, would be extremely valuable in testing the approaches and demonstrating their applicability in real-world conditions. The pilot projects can provide guidance on data collection and in further defining data needs or improvements to existing data sets. The projects will also demonstrate and report on the reliability and validity of each approach, and illustrate how the results can ultimately be used. Finally, these pilot projects can be used for education and training for source protection planning committees. Building on the steps of delineating and assessing the vulnerability of wellhead protection areas, the Technical Experts Committee further suggests that more localized criteria be used to prioritize additional analysis or risk mitigation. Such criteria could include:

- the importance of the well to the supply in terms of volume, quality or longevity (i.e. how long the well is anticipated to be on-line)
- whether the well is showing any early signs of contamination, which should be developed through application of the issues approach
- whether the source was found to be a GUDI well
- the level of uncertainty associated with the modeling or vulnerability assessment, or
- other criteria important to the community, including but not limited to the availability of alternative supplies.

Through this prioritization, municipalities and source protection planning committees can determine where to target resources: should they do more analysis, or undertake risk mitigation and management. These priorities should be re-evaluated during the development of the planning framework.

Aquifer vulnerability

Recommendation 58: At a minimum, the initial (not longer than SPP review) delineation of the aquifer vulnerability areas should be based on the current Intrinsic Susceptibility Index (ISI) or the Aquifer Vulnerability Index (AVI), as appropriate to local conditions and encompassing the information already contained in the Groundwater Studies.

Recommendation 59: AVI or ISI approaches should be used to identify aquifer vulnerability, where AVI or ISI scores of less than 30 should be used initially to delineate high aquifer vulnerability (HVA) areas. Moderate vulnerability should correspond to a score of between 30-80 and low greater than 80.

The objective of delineating aquifer vulnerability areas is to address groundwater source protection in areas that are not delineated as municipal wellhead protection areas (WHPAs). These areas are predominantly in rural settings. These delineations are also intended to recognize different uses of water in a regional setting, including shallow and deep private wells and ecological resources and recharge/discharge areas. Such delineations also serve as the basis for protection efforts for these resources.

In developing an approach to assessing aquifer vulnerability, the Vulnerability sub-committee considered the following applications for the information developed through the aquifer vulnerability assessment:

- Delineate high vulnerability areas (HVAs);
- Provide spatial information on regional groundwater recharge and discharge;
- Indicate areas sensitive to cumulative contaminant loadings, water takings, or change in recharge rates;

- Assist in evaluating potential impacts of industrial mineral extraction operations (quarries and aggregate pits);
- Provide information to assist in evaluating water-taking permits;
- Implement specific land-use management actions.

According to the sub-committee, assessments of aquifer vulnerability have been undertaken on an international scale over the past decade, using a wide variety of approaches. It is important to note that the Ministry of the Environment (MOE) selected the Intrinsic Susceptibility Index (ISI) approach for the funded regional groundwater studies, which will provide the basis for much of the work to be undertaken by source protection planning committees over the next few years. There has been a steady development of methodologies for aquifer vulnerability assessments at the regional scale, primarily with respect to increasing the physical basis for the analysis and enhancing the quantitative nature of the evaluation. The more advanced methods require progressively more data and understanding of the physical conditions. A range of tools is required to conduct aquifer vulnerability assessments across Ontario that are applicable to local data availabilities. These assessments are subject to periodic updates as new data become available.

A primary goal of the aquifer vulnerability process will be to encourage the adoption of the most quantitative level of analysis possible within local data constraints. This measure will ensure that the most complete information set possible is derived from the analysis to assist, for instance, in estimates of local and cumulative contamination impacts and recharge magnitudes. The overall approach adopted in developing recommendations for a regional aquifer vulnerability assessment is to capitalize on the information that has already been collected throughout the province. This information has been collected through the regional groundwater studies.

In developing aquifer vulnerability maps, it is important to note that the ISI/AVI maps are regionally-derived products based largely on water well records. Using these maps for taking specific prescriptive management actions must be considered carefully. For instance, ISI/AVI mapping is suitable for prohibiting certain higher risk land uses, such as those that involve hazardous chemicals (e.g., landfills). But the risk assessment process, carried out during the preparation of source water protection plans, should consider the limited precision of regionally-derived maps as risks are evaluated and ranked within a study area.

Recommendation 60: A quantitative approach, based on surface to aquifer advection times (SAAT), should undertaken by the first 5-year review to evaluate the degree of protection provided by the vertical travel path from ground surface, through the unsaturated zone to the top of the water table or aquifer unit being assessed.

Recommendation 61: Surface to aquifer advection time (SAAT) should be categorized and used in a similar fashion as for the delineation of WHPAs, to support varying risk mitigation strategies in the areas of various vulnerability, such that 0 – 5 years represent high vulnerability, 5-25 year represents moderate vulnerability, and >25 years represents low vulnerability.

An abundance of information has been compiled from the application of the ISI and AVI methods. This information can be used to target areas of high aquifer vulnerability. However, a more advanced approach to aquifer vulnerability – Surface to Aquifer Advective Travel Time (SAAT) – should be used to more accurately define high vulnerability areas (HVAs). Detailed explanations of the SAAT method are provided in Appendix 4b. Advection time mapping is appropriate for imposing additional requirements, such as the preparation of farm water protection plans or contaminant management plans for threats of provincial concern located in high vulnerability areas. Highly vulnerable areas provide source water to regional aquifers and private wells. They should be protected to preserve surface water quantities, and should be protected from pathogens and from dense non-aqueous phase liquids (DNAPLs). In general, these high vulnerability areas should be treated in a similar fashion to the 5 to 25 year wellhead protection areas.

Recommendation 62: Regional hydrogeologic and hydrologic data should be collected to support statistical and numerical modeling tools. These tools can be used to enhance quantitative assessment of aquifer vulnerability, particularly in areas modeled as highly vulnerable.

Recommendation 63: Water quality data should be collected from areas modeled as being of high vulnerability, because those areas should be the first to respond to insults from the surface. If the insult is measurable, the data will confirm the vulnerability.

Municipalities or source protection planning committees will be faced with the prospect of managing areas of modeled high vulnerability. In these cases, they may wish to collect and utilize high-quality regional groundwater quality data to define quantitative estimates of vulnerability in these areas. Probability estimates can be made that relate the occurrence of measured water quality constituents in groundwater to explanatory variables such as intrinsic aquifer properties. This statistical method uses available aquifer properties to describe the relative ease with which constituents migrate to the aquifer/well, using a built-in correlation between vulnerability level and observed contamination patterns. This method predicts water quality as a probability that can produce a quantitative risk assessment (e.g. likelihood of exceeding a nitrate threshold concentration in groundwater at well ‘x’ compared to the likelihood of exceeding the whole study area).

Recommendation 64: Aquifer vulnerability information, including both quality and quantity concerns, should be used to determine the location of new municipal wells (with 100 metre pathogen zones in which control is gained) in order to avoid construction of new wells in highly vulnerable aquifers.

Recommendation 65: Construction of new private wells should be field verified and existing legislation (O.Reg 903 under the *Ontario Water Resources Act*) strictly enforced in highly vulnerably areas to ensure they do not become conduits of contamination for the aquifer.

A major component of source protection for future generations will be the protection of future source water supplies not yet in use. A second component will be to construct wells in locations that are not vulnerable to land-based practices. Existing municipal wells in highly vulnerably areas, and even those not in highly vulnerable areas, require considerable maintenance costs. Under the provincial Safe Drinking Water Regulation 170, wells that are constructed in highly vulnerable areas (e.g., where groundwater sources are under the direct influence of surface water) typically require high levels of treatment (i.e., chemically-assisted filtration). This treatment has significant capital and long-term operation and maintenance costs. In some cases in Ontario, operators have abandoned some small communal water supply systems because of the costs associated with upgrading these systems.

Municipal wells constructed in highly vulnerable aquifers would also have broader social and economic costs. For instance, land use activities (e.g., privately serviced development, municipal sewers, animal agricultural operations) located in highly vulnerable aquifers would likely have to meet additional requirements in order to remain and operate within the immediate vicinity of these wells. Therefore, the construction of new municipal wells should be discouraged in highly vulnerable aquifers.

Significant Recharge Areas

Recommendation 66: Significant recharge areas must be delineated through the source water plans and will be considered vulnerable from both a quality and quantity perspective. Source protection plans will consider these areas as: vulnerable to urbanization which can restrict recharge to subsurface aquifers; and vulnerable to cumulative contaminant loading impacts.

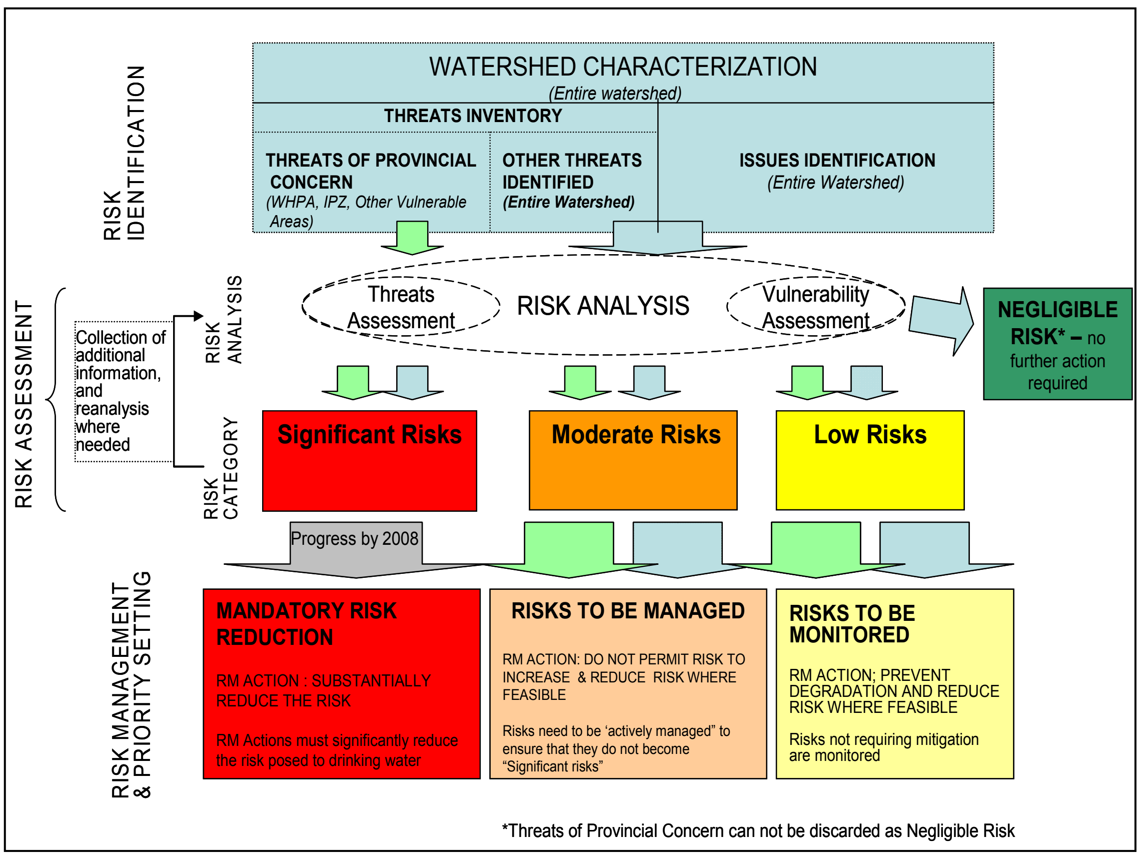
In addition to the need to delineate areas of high aquifer vulnerability, the Technical Experts Committee proposes that significant recharge areas be delineated for incorporation in source water planning. A decline in the recharge rate within these areas might have significant impacts on shallow water table elevations and could result in negative impacts to surface water sources that are dependent on local groundwater discharge. In addition, long term sustained cumulative loadings that occur in significant recharge areas can have consequences for water quality in underlying aquifers. An example of this could be chronic additions of nitrate from a range of sources – nitrate is persistent in groundwater and may accumulate and/or travel substantial distances.

The Technical Experts Committee has put forward some direction for the delineation of these areas under the SAAT approach (see Appendix 5, Discussion Item 4) and recommended further research. The calculated SAAT flux values can be used to assist in the determination of significant recharge areas. In the absence of such an analysis, areas of hummocky topography and/or coarse grained soils can be identified as an initial delineation approach.

SECTION 5: RISK ANALYSIS

As outlined in Figure 5.1, the threats/issue identification process will generate a list of potential risks to drinking water sources. An initial screening will be undertaken to determine which items could actually pose a risk to drinking water sources (Section 3: Threats Inventory and Issues Identification). Any drinking water issues identified would be addressed in the Risk Assessment process, as indicated in the figure. Where the source protection planning committee has determined a threat of provincial concern to be a "significant risk," the provincial government should provide guidance on reducing the risk to drinking water sources. In situations not suited to this "prescriptive" solution, the government should help local communities evaluate risk management options.

Figure 5.1 Overview of the Threats Assessment Framework



Risk Assessment

Recommendation 67: Risks from threats to drinking water quantity and quality should be assessed using a provincially consistent semi-quantitative approach.

Recommendation 68: Where threats of provincial concern are located within a vulnerable area (Wellhead Protection Area, Intake Protection Area or other designated vulnerable area), their level of risk must be assessed according to the semi-quantitative approach used to evaluate other threats in the watershed, and risk management actions must be identified in the Source Protection Plan.

In light of data limitations and the potential need to assess high numbers of threats across the watershed, a semi-quantitative approach is the most practical and efficient method for obtaining a consistent approach to assessing risks. The use of a semi-quantitative approach does not exclude the use of more quantitative methods. In some cases, a source protection planning committee may choose to assess and quantify a risk more closely. For example, when available risk management options are costly, the committee may choose to increase the level of confidence in its assessment by employing quantitative risk assessment methods.

The semi-quantitative risk analysis will evaluate the likelihood and severity of impacts for each risk against criteria pertaining to:

- inherent risk – a determination of the risk associated with the threat:
    - for water quality – characterization of the persistence, mobility and toxicity of the contaminant
- local risk factors – a determination of how local circumstances and conditions contribute to the risk:
    - for water quality - characterization of the contamination/contaminant source, vulnerability of the drinking water source and the potential severity of impact (including population impacted);
- For water quantity – by characterization of the water budget.

Developing a semi-quantitative approach that yields relatively consistent outcomes will prove challenging. The semi-quantitative assessment and the categorization process should be subjected to a sensitivity analysis, and calibrated using a diverse range of scenarios to ensure that the capabilities of this process are clear.

Once risks are initially categorized, it will be important to consider existing risk management activities for each particular risk, so that suitable risk management approaches can be designed (Section 6: Risk Management).

Recommendation 69: The Implementation Committee that was established by the provincial government should identify a suite of tools to enable local committees to manage the risks identified through the assessment process.

Recommendation 70: The provincial government should consider the Implementation Committee's "suite of tools" when establishing and amending the semi-quantitative thresholds for the delineation of Significant Risks.

In areas where the source protection planning committee has identified a threat of provincial concern as a "significant risk," the provincial government should provide clear guidance on how the committee can reduce risks to drinking water sources. This guidance will ensure province-wide consistency. This approach is considered "prescriptive" risk management. In cases not suited to a purely prescriptive solution, the provincial government should help local communities evaluate risk management options. These options should be based on effectiveness, environmental impacts, social acceptability and cost. The Technical Experts Committee understands that the Implementation Committee was provided with the threats of provincial concern, and was informed that the Technical Experts Committee recommended that consistent and significant risk management activities be proposed for those threats on the list identified as "Significant Risks."

Risk Assessment – Considering Vulnerability

The semi-quantitative risk assessment process will provide a systematic way of combining information about the threats/issues with vulnerability. The objective of compiling this information is to devise an estimate of risk. With regard to vulnerability, the Technical Experts Committee addressed the various zones within the vulnerable areas that should be delineated in order to assess and manage specific types of risks (Section 4: Vulnerability Analysis). For example, within the wellhead protection area, special zones for pathogens, dense non-aqueous phase liquids (DNAPLs), and other chemical contaminants are to be identified. These zones influence the risk assessment because they prompt source protection planning committees to consider certain zones as the most "highly vulnerable" for certain contaminants.

Table 5.1 summarizes the threats recommended for inclusion on the list of the threats of provincial concern (Section 3). The table identifies the primary issues associated with each of these threats and the specific vulnerable areas that need to be considered and how the vulnerability influences the risk assessment. Within these vulnerable areas, some form of risk management is advised (Section 6). Within identified vulnerable areas, threats on the list should be subject to provincial requirements that call for the associated risks to be identified, assessed, and managed.

Table 5.1 Issues Associated with threats of provincial concern in Vulnerable Areas, and influence of Vulnerable Area on the Risk Assessment

Threat of Provincial Concern	Scope	Primary Issue[14]	Where/How to assess in particular Vulnerable Area		
			Wellhead Protection Area		
Human-made Pathways to the aquifer	Activities/structures that penetrate the water table and/or aquifer. These include: • Existing wells (water, gas, oil) • Abandoned Wells • Pits , quarries, mines • Other construction activities that provide short or long term direct access to an aquifer	"vulnerability" – direct pathways to current or future potential drinking water	Map and assess risk for all that are found within the 25 yr TOT/SWAT WHPA	Not applicable. *not considered a "threat of provincial concern" with respect to surface water intakes.*	NA – general landscape level policies to address
Liquid Chemical Storage /Use	Includes "commercial quantities"[15] of : • Fuels/ Hydrocarbons • DNAPLs[5] • Organic Solvents[16] • Pesticides (of concern to Drinking Water) • Fertilizers Proposed that only quantities above a certain threshold would be captured	Chemical contamination, nutrients	25 yr TOT – general assessment 5-yr TOT focused assessment Mapped DNAPL sources to default to "very high risk" within the 5 year TOT WHPA	Risk must be assessed within an "overland" and "in stream" Travel Time (TT) zone of 2 hours	Risk must be assessed where a storage occurs: 1) Highly Vulnerable Areas 2) Areas of significant recharge 3) "Valleylands / Natural Hazard Lands[17]
Historical Commercial/ Industrial Sites of Concern	Includes historical land uses/ activities that have a high potential for contaminating drinking water sources[18]	Chemical contamination	25 yr TOT – general assessment 5-yr TOT focused assessment	Risk must be assessed within an "overland" and "in stream" Travel Time (TT) zone of 2 hours	Risk must be assessed within 1) Highly Vulnerable Areas 2) Areas of significant recharge

[14] It is recognized that issues associated with threats of provincial concern, such as nitrate or chloride loadings in source waters, may be identified through the "Issues Identification" process as well as through the Threats Inventory process.
[15] Province to determine what the appropriate "trigger" quantity would be. Suggest considering thresholds or quantities referenced in existing legislation or accepted Environmental Management System schemes (responsible care, CSA, UL) for the purposes of risk management.
[16] As above
[17] Definition for "river or stream valleys" is set out in Regulation 97/04 made under the Conservation Authorities Act; includes an area at least 15 metres from the top of the bank of a river or stream and may extend much further if floodplain, unstable, or erodable.
[18] Province to determine appropriate trigger contaminants
[5] Province to develop list of DNAPL materials

Threat of Provincial Concern	Scope	Primary Issue[14]	Where/How to assess in particular Vulnerable Area		
			Wellhead Protection Area		
			Mapped DNAPL sources to default to "very high risk" within the 5 year TOT WHPA		3) "Valleylands / Natural Hazard Lands
Waste Storage and Disposal Activities	Includes (specified quantities of): • Landfill sites • Organic Soil Conditioning sites (except for biosolids application sites – covered under another item) • Hazardous waste • Liquid industrial waste • Mine Tailings	Chemical contamination	25 yr TOT – general assessment 5-yr TOT focused assessment Mapped DNAPL sources to default to "very high risk" within the 5 year TOT WHPA	An "overland" and "in stream" Travel Time (TT) zone of 2 hours see wording above	Risk must be assessed within 1) Highly Vulnerable Areas 2) Areas of significant recharge 3) "Valleylands / Natural Hazard Lands
Biosolids and Septage	Storage and land application of biosolids and septage	Pathogen contamination, nutrients	Pathogen prohibition zone: 100 m exclusion zone immediately surrounding the wellhead + 2 year time of travel pathogen protection zone for risk management	An "overland" and "in stream" Travel Time (TT) zone of 2 hours see wording above	Risk must be assessed within 1) Highly Vulnerable Areas 2) "Valleylands / Natural Hazard Lands
Manure	Storage and land application of manure	Pathogen contamination, nutrients	Pathogen prohibition zone: 100 m exclusion zone immediately surrounding the wellhead + 2 year time of travel pathogen protection zone for risk management	An "overland" and "in stream" Travel Time (TT) zone of 2 hours	Risk must be assessed within 1) Highly Vulnerable Areas 2) "Valleylands / Natural Hazard Lands
Sanitary Sewage and Septics	Includes: • Sewer infrastructure (sewer mains & connections) • Sewage treatment plants effluent • Septic Systems • Sewage treatment plant by-passes	Pathogen contamination, nutrients	Pathogen protection zone: 100 m exclusion zone immediately surrounding the wellhead 2 year time of travel pathogen protection zone for risk	An "overland" and "in stream" Travel Time (TT) zone of 2 hours	Where applicable: 1) Highly Vulnerable Areas 2) "Valleylands / Natural Hazard Lands

Threat of Provincial Concern	Scope	Primary Issue[14]	Where/How to assess in particular Vulnerable Area		
			Wellhead Protection Area		
	• Combined Sewer overflows • Sanitary Sewer overflows		management		
Road Salt/ De-icing	Includes: Uncontained storage, and application of road salt/ de-icing compounds. Salt-laden snow storage (snow dumps from plowing)	Chloride contamination	5 year TOT	An “overland” and “in stream” Travel Time (TT) zone of 2 hours	Risk to be assessed in: 1) Highly Vulnerable Areas 2) Areas of significant recharge
Cemeteries	Includes: Burial grounds	Chemical contamination	Assess risk within 5 year TOT	An “overland” and “in stream” Travel Time (TT) zone of 2 hours	Risk to be assessed in: 1) Highly Vulnerable Areas 2) Areas of significant recharge 3) Valleylands / Natural Hazard Lands
Stormwater Infiltration	Stormwater collection ponds in urban areas that are designed to allow stormwater to directly infiltrate into groundwater	Chemical/ solute contamination Pathogen contamination	Assess risk within 5 year TOT	An “overland” and “in stream” Travel Time (TT) zone of 2 hours	Risk to be assessed in: 1) Highly Vulnerable Areas 2) Areas of significant recharge
Water Treatment Plant Waste Water	Includes filter backwash discharges to surface water	Pathogen contamination	Not Applicable – (Issue to be assessed for downstream surface water intakes that might be impacted)	An “overland” and “in stream” Travel Time (TT) zone of 2 hours	Not Applicable (Issue to be assessed only for downstream surface water intakes that might be impacted)
Non-sustainable Withdrawals	To be identified through the issues approach as areas with long-term water shortage issues; eg. Situations where aquifers supplying municipal wells have levels which are steadily dropping over time, allocation of Surface Water supplies threatens quantity during low-flow conditions	Insufficient quantity resulting in reduced quality, reduced assimilative capacity, threat to sustainable supply Impact on delineation of WHPAs	Entire Capture Zone 25-Yr TOT Assess impacts of takings on water budget	Assess low flow conditions and impact on water budget	Major recharge areas - determine impact on water budget

Risk Categorization

Recommendation 71: The assignment of risks into risk categories should be based on the risk analysis process.

Recommendation 72: The provincial government should develop a semi-quantitative risk assessment approach and provide guidelines to assist source protection planning committees in their interpretation of results from the assessment.

The categorization of risks to drinking water sources will allow for the identification and implementation of priorities for action. Higher risks will have priority. Categorization is undertaken to ensure that the appropriate degree of risk management is applied to an activity that poses a certain level of risk (Section 6: Risk Management). Provincial government staff suggested that three categories of risk be used: Significant Risks, Moderate Risks and Low Risks. Endorsed by the Technical Experts Committee, these three categories provide an appropriate distinction between levels of risk for the purposes of differentiating the appropriate risk management actions.

The provincial government should establish benchmarks and trigger points to promote consistent categorization and treatment of truly similar levels of risk across the province. For instance, trigger points could be established based on measured concentrations of contaminants (i.e. compared to existing standards), or based on observed trends. In particular, the Committee proposes that careful attention be paid to trends occurring over time. These trends are indicators of potential risks; the rate of change needs to be considered within the assessment and categorization process.

Risk Assessment - Identifying Significant Risks

Recommendation 73: A semi-quantitative analysis, considering uncertainty and the precautionary principle, should be used to determine the threats that pose a "Significant Risk" to a drinking water source, and these risks should be the subject of priority risk management activities.

In its terms of reference, the Committee was directed to define 'Significant Risk' to a drinking water source. In considering the purpose of source protection planning, and its role in a multi-barrier approach to drinking water protection, the Committee determined that a definition could be set out as follows:

> A significant risk is one that has a high likelihood of:
> - rendering a current or future drinking water source impaired, unusable or unsustainable; or
> - compromising the effectiveness of a drinking water treatment process, resulting in adverse human health effects.

The Committee also discussed various aspects of risk management (Section 6), and concurred in general with the examples and explanations as provided in Table 6.2. While a fully rational scientific basis to risk assessment and management would be desirable, the lack of data across the province would lead to inconsistent conclusions by individual source protection planning committees. The Technical Experts Committee proposes the use of this semi-quantitative approach as a means to improve consistency.

SECTION 6: RISK MANAGEMENT

General Concepts of Risk Management

In its discussions on risk management, the Technical Experts Committee (TEC) pondered how much risk reduction would be necessary. The Committee concluded that risk management should be based on three levels of risk (Table 6.1), and that each level of risk warrants some degree of mitigation through appropriate management. For significant risks, the goal should be to reduce risk levels substantially, or at least sufficiently to ensure that a significant risk no longer exists. Overall, the principle of continuous improvement should be the goal of risk management, while the level of effort invested to reduce risks should be proportional to the amount of risk present. Source protection planning committees, when developing source protection plans, would benefit from the guidance of the provincial government in determining where risk reduction is needed and how much is advisable.

Table 6.1 General Risk Management Concepts

Risk Category	Risk Management Concept
"Significant Risk"	Mandatory Risk Reduction – immediately take action to substantially reduce the risk
Moderate Risk	Mandatory Risk Management - Do not permit risk to increase and initiate plan to reduce risk as opportunities arise.
Low Risk	Mandatory Risk Surveillance – Monitor risk and make plans to prevent an increase in risk.

Outcome-Based Approach

Recommendation 74: All "Significant Risks" should be prioritized and substantially reduced in a timely fashion through risk management activities.

Recommendation 75: The provincial government should develop an "outcome-based" approach to risk management. It should be based on targets and guidelines to be established by the local source protection planning committees. The approach should allow local development of options to meet the targets.

Source protection planning committees need to establish goals and action plans that will help them achieve the risk management outcomes anticipated by the provincial government. To help the committee develop appropriate programs, the provincial government needs to define these expected outcomes. Establishing these "outcomes" should convey the level of risk reduction that is acceptable for each of the risk levels in Table 6.1, and should provide a guide-post for source protection planning committees to use when they set specific local targets.

For example, the province may deem accidental spills in an intake protection area to be a "moderate risk" and set the risk management outcome as: "Accidental spills should be minimized and must be contained prior to reaching a municipal intake." A local source protection planning committee might then choose to establish any one of a number of programs to meet this outcome. These programs could include restricting the establishment of new commercial/industrial facilities that pose a risk, or requiring that spill prevention/response plans be put in place at every commercial/industrial facility within the Intake Protection Zone.

This methodology promotes a consistent approach to defining outcomes for risk reduction for drinking water sources across the province, while recognizing local capacity for developing workable solutions to reduce risks. In addition to reducing the risk from current activities, risk management actions can and should be implemented to prevent, as much as possible, the establishment of future risks to drinking water sources. The provincial government could assist the source protection planning committees by providing examples of programs or strategies that meet the established provincial risk management outcomes.

As further guidance, the provincial government could develop specific outcomes for local reference during plan development. These outcomes should be consistent with the general risk management concepts presented in Table 6.1.

Risk Management Approaches

Recommendation 76: The provincial government should develop guidelines on how "Significant Risks" should be risk managed. The guidelines should draw on advice from the Implementation Committee, and the province should develop new Beneficial Management Practices and standards where required.

Within identified vulnerable areas, the risks associated with the threats of provincial concern (Section 3) should be identified, assessed, and managed as part of provincial requirements, and according to provincially established outcomes. The Technical Experts Committee spent much effort dividing vulnerable areas – wellhead protection areas, intake protection zones, and vulnerable areas on the landscape – into management zones (Section 4). The Committee also devised management approaches that could be applied to both existing and future risks associated with these threats (Table 6.2). Similar approaches could be taken with locally identified threats. These approaches are examples of possible risk management strategies, and are meant to represent the range of activities that might be undertaken – depending on the category of risk as determined by the risk analysis process. It must be stressed that these approaches are simply examples of possible risk management strategies, and are meant to represent the range of activities that might be undertaken – depending on the category of risk as determined by the risk analysis process; the list is not meant to be exhaustive.

Table 6.2 Examples of Risk Management Approaches for threats of provincial concern[19] in Vulnerable Areas

	Approaches for Existing Risks	Approaches for Future Risks
Human made pathways to the aquifer	• Locate and properly decommission abandoned wells according to legislation • Inspect existing wells • Wellhead protection programs for private well owners • Ensure pits/ quarries operated in compliance with approvals and BMPs. • Standards developed for assessment of impact to municipal wells to be implemented with major changes to pit/quarry site plans. • Education to private well owners	• Ensure Compliance with existing legislation • No new wells in high risk areas, i.e. pathogen prohibition zone • Assess risk of new pits/quarries and final land use according to new standards for municipal wells and/or restrict new pits/quarries in 5 year TOT.
Liquid Chemical Use and Storage	• Groundwater monitoring down-gradient of underground tanks • All storage tanks upgraded to meet standards • Standards developed/adopted for solvent, pesticide, fertilizer storage tanks	• Restrict, Prohibit or require best practices for storage above certain quantities (commercial/industrial quantities) • Restrict or Prohibit siting of industrial/commercial uses that require storage/handling of liquid chemicals or include appropriate standards • Allow facilities with permit or licensing conditions/controls.
Historical Commercial/ Industrial Sites of Concern	• Encourage owners to register Records of Site Condition • Require owners to report results of contamination assessments to MOE/SPPC/municipality in vulnerable areas. • Groundwater monitoring where warranted • Site remediation of abandoned sites	• Prohibit siting of high-risk commercial/industrial uses • Allow facilities with permit or licensing conditions/controls.
Waste Storage and Disposal Activities	• Relocate organic soil conditioning sites • Monitor down-gradient of landfill sites • Require secondary containment for storage facilities • Prohibit expansion of existing waste facilities	• Prohibit siting of new disposal facilities
Biosolids and Septage	• Require secondary containment for storage facilities • Prohibit land application in highest risk areas, i.e. pathogen prohibition zone • Storage and application to meet Nutrient Management Act requirements and any new Source Protection Act requirements	• Prohibit new storage and land application in high risk areas • Allow storage and application required to meet Nutrient Management Act requirements and any new Source Protection Act requirements
Manure Storage and Application	• All storage to meet Nutrient Management Act Requirements and additional source-water standards as applicable. • Require Farm Water Protection Plans • Prohibit application in highest risk areas, i.e. pathogen prohibition zone • Require application to meet or Nutrient Management Act requirements	• All storage to meet Nutrient Management Act Requirements • Require Farm Water Protection Plans • Prohibit application in highest risk areas, i.e. pathogen prohibition zone • Prohibit new /expanded storage facilities in high risk areas

[19] Note that threats of provincial concern MUST be risk assessed within vulnerable areas (WHPA, IPZ, highly vulnerable aquifers and major recharge areas) and risk management actions must be implemented; RM actions in this table are examples of what might be implemented within these vulnerable areas
Note that a range of approaches is presented; it is key to select the appropriate risk management measure, based on the level of risk present, determined via the risk analysis process

	Approaches for Existing Risks	Approaches for Future Risks
		• Require application to meet Nutrient Management Act requirements and any new Source Protection Act requirements
Sanitary Sewage and Septics	• Upgrade aging infrastructure • Where feasible, require hook-up to sanitary sewer • Implement sewer treatment plant upgrades • Implement performance standards for septics and septic inspection programs • Retrofit septic systems with tertiary treatment in highest risk areas • Mandatory 3-year septic tank pump outs.	• Routine inspection and maintenance of sewer infrastructure • Septic inspections and standards • Mandatory 3 yr septic tank pump outs • Limit density of septic systems • Ensure proper site conditions exist prior to installation of private septic systems • Require tertiary treatment for septic systems
Road Salt/ De-icing	• Relocate snow storage and disposal sites • Require salt reduction strategies for agencies and private applicators	• Limit development/expansion of transportation corridors • Adjust construction to minimize infiltration of stormwater to aquifer (e.g. roadside capture and removal of winter runoff) • Implement BMPs during road and subdivision design
Cemeteries	• Groundwater monitoring where warranted	• No new cemeteries
Stormwater Infiltration	• Groundwater monitoring • Alternate storm water management	• No direct infiltration ponds • Treatment of stormwater
Water Treatment Plant Waste Water	• Ensure Certificate of Approval is adequate and in compliance	• Ensure downstream surface water quality is protected by Certificate of Approval conditions
Non-sustainable Withdrawals	• Implement water conservation plans • Implement water allocation plans for low-water conditions • Protect recharge areas	• Implement long-term water supply plans • Use scientifically rigorous water budgets and watershed flow system understanding to allocate future PTTW • Limit impermeable surfaces in new developments • Protect and enhance recharge areas

To provide guidance on risk management, vulnerable areas are re-classified in Table 6.3 into risk management zones. These zones are established to reflect the vulnerability of the source water to contaminants. Although the risk management actions required will depend on the outcome of the risk assessment (and the resultant risk category – see Figure 5.1), significant risks are most likely to be found in a zone closer to the drinking water source. Indeed, the vulnerability, or pathway, to the drinking water source is a critical determinant of the risk (the shorter the pathway, the higher likelihood a contaminant will reach the source and therefore the greater the risk). Since there is a greater likelihood of risk near the source, more stringent risk management approaches should be devised for the risk management zones nearest to the source. Table 6.3 illustrates how different risk management approaches might be applied within the different risk management zones, in accordance with the general risk management concepts presented in Table 6.1. Table 6.3 differentiates between managing existing and future risks. During its discussions, the Committee recognized that prevention is preferable to mitigation. For example, as required, businesses should install secondary containment tanks and develop spill response plans. These measures will forestall the need to clean up a contaminated aquifer caused by a leaking, above-ground chemical storage tank. This concept also applies to reducing the risk from existing sources of contamination and minimizing the risk from future sources: both are needed and should be considered in risk management.

Source protection planning committees will likely find it more efficient to control the establishment of new activities on the landscape than to modify existing activities. For example, using land-use planning tools to direct development away from vulnerable areas is less difficult and less expensive to implement than to relocate an entire industrial subdivision which overlays a vulnerable aquifer. Although it may be necessary to prohibit certain land-use activities in the future, and even though it may not be feasible to remove existing uses, measures to minimize the risk from both new and existing sources are essential to protecting drinking water sources. The provincial government should consider developing options that are alternatives to, or complementary with, existing *Planning Act* tools that can be used to minimize the risks from future activities while minimizing the impact on existing uses or businesses.

Table 6.3 provides examples for risk management approaches in the context of vulnerable areas. This table does not represent the full suite of risk management tools to be considered by source protection planning committees. Rather, the table serves to provide examples for illustrative purposes only. These approaches are equally applicable to risks outside of vulnerable areas, or to locally identified threats (Section 4: Vulnerability Analysis). The Committee also discussed risk management approaches for the protection of drinking water quantity. The Committee supported approaches focused on reducing the risk of depletion and which address existing water shortfalls. Drinking water quantity protection involves, firstly, a solid understanding of watershed processes including water budgets, flow pathways, etc. Secondly, it involves managing non-drinking water withdrawals and maintaining the recharge that replenishes drinking water supplies. For the protection of sustainable drinking water supplies, the risk management approach must be considered in the context of maintaining a healthy ecosystem. Some wetlands and riparian zones may represent hydrologically important areas to protecting surface water based drinking water supplies. In the case of groundwater, protecting hydrologically important areas may also serve to help maintain the recharge pathways to subsurface aquifers.

Table 6.3. Suggested Risk Management Approaches for Risk Management Zones within Vulnerable Areas

[redacted]

WELLHEAD RELATED						
100 m Pathogen Prohibition Zone	Prohibit Pathogens around Wellhead	Fixed	Fixed	SWAT[20] can inform risk assessment process	• No septic systems • Upgrade old sewer infrastructure • No manure spreading	• No new septics • No new development (requiring sewers) • No manure/ biosolids/ septage spreading
2 Yr Pathogen Concern Zone	Minimize pathogens within area	TOT[21]	TOT	SWAT can be used to inform risk assessment process	• Septic system inspection programs • Nutrient management plans	• No new manure/ biosolids/ septage storage • No new septics
5 Yr DNAPL Restriction Zone	Significantly restrict DNAPLS within area; Curb new DNAPL sources	TOT	TOT	Uniform consideration regardless of SWAT	• Incentives for relocation • Inspection programs for existing sources; • Groundwater monitoring where warranted • Water protection plans	• No new DNAPL sources
5 Yr Contaminant Concern Zone	Reduce Risk from non-DNAPL Contaminants	TOT	TOT	SWAT can be used to inform risk assessment process	• Inspection programs • Water protection plans • Groundwater monitoring where warranted	• Prohibit new high risk threats or establish with adequate controls defined during risk assessment
25 Yr Contaminant Concern Zone	Evaluate long term historical threats and existing threats; consider restriction of new threats	TOT	TOT - SWAT Modified	SWAT can be used to inform risk assessment process	• Water protection plans • Chemical management plans • Inspection programs • Groundwater monitoring where warranted	• Incorporate risk mitigation measures (design/construction) into new industrial facilities • Encourage adoption of BMPs for material handling and storage • Enhanced stormwater management

[20] SWAT – "Surface to Well Advection Time" - (refer to Section 4 – Vulnerability Analysis)
[21] TOT – "Time of Travel" (refer to Section 4 – Vulnerability Analysis)

Entire Capture Zone	Ensure consideration for EA activities - e.g. new landfill siting	TOT	TOT - SWAT Modified	SWAT can be used to inform risk assessment process	• Routine surveillance;	• No new high level threats
OTHER GROUNDWATER AREAS						
High Aquifer Vulnerability (Quality related)	Increase awareness and implement BMP's	ISI[22]/AVI	SAAT[23]	Target responses within area (if they are large areas) - e.g. focus pathogen actions in areas of shallow wells	• Farm Water protection plans • Water Protection Plans • Nutrient Management Plans • Implementation of BMP's	• As for "existing risks" • Avoid establishment of new municipal wells if possible • Land use controls for high risk uses in highly vulnerable areas
High Recharge Area (Quantity and quality related)	Minimize interference with recharge, and protect aquifer from chemical and nutrient threats	1) Water budget 2) Watershed soils mapping 3) Vertical gradient mapping (from Provincial GW studies) · Define high water uses where cumulative annual water taking exceeds a significant percentage of annual recharge	i) Water budget ii) 3-D modeling	Flux analysis from SAAT process can be used to establish baseline recharge rates	• Farm Water protection plans • Water Protection Plans • Nutrient Management Plans • Implementation of BMP's	• No urban development, • Limits for impervious surfaces • No new high level threats (e.g. landfill sites),
SURFACE WATER RELATED						
Intake Protection Zone - Inland River and Inland Lake Sources	Reduce risk from spills and other nearfield threats	Minimum 2 hr response time - TT[24]	Minimum 2 hr response time - TT	Proximity and likelihood of swift action inform risk assessment process.	• Spill response plans • Water protection plans • BMP's	• land use controls to prevent likelihood of high risk spills
Intake Protection Zone - Great Lakes and other large water bodies	Reduce risk from spills and other nearfield threats	Minimum 1 km radius	Modeling of IPZ capture zone	Zone delineation expanded if warranted by known, nearby threats	• Spill response plans • Water protection plans • BMP's	• land use controls to prevent likelihood of high risk spills

[22] IVI – "Intrinsic Susceptibility Index"
[23] SAAT – "Surface to Aquifer Advection Time" (refer to Section 4 – Vulnerability Analysis)
[24] TT – "Travel Time" (refer to Section 4 – Vulnerability Analysis)

Riparian Areas/Natural Hazard Lands	Reduce loadings to surface water	CA definition for valley lands, natural hazard lands	Delineation of areas that readily contribute to surface water	As required to respond to identified issues	• Land/storm water/riparian zone BMP's • Consideration in Water Protection Plans	• no new development on natural hazard lands
Wetlands (and other areas of natural cover)	Reduce loadings to surface water Maintain role of natural areas in maintaining general water quality and in maintaining watershed flow pathways	PPS definition for wetlands Aerial photography	Water budgets to include analysis of % natural areas that perform significant hydrologic function	Target response in proportion to hydrologic function	• Restore degraded areas through land use tools • Consideration in Water Protection Plans	• Maintain/ protect existing areas
OTHER WATER QUANTITY RELATED AREAS						
High Recharge Areas Surface Water Sources	Reduce risk of depletion	Water budgets define high water use issues where cumulative annual water taking exceeds a significant portion of annual recharge	Water budgets define areas with water use issues, areas with low ecosystem tolerance to changes in flows and levels, areas where water quality is sensitive to quantity		• conservation plans among water users to reconcile demand with the resource • operational limits on water taking • water conservation and efficiency BMP's	• Long-term municipal water supply strategies

Pathogens

Numerous experts have confirmed that no drinking water source is completely free from risk of pathogen contamination. For a secure supply of water, some form of treatment is necessary. Treatment provides an additional barrier in the overall multi-barrier approach recommended by Justice O'Connor in *Part Two Report of the Walkerton Inquiry* recommendations. The treatment level will depend on the risk assessment of the source water. For example, for water being treated with chlorine disinfection that comes from a surface water source that has tested positive for *Cryptosporidium*, managers should consider additional treatment to minimize the risk to public health.

Recommendation 77: The provincial government should require that all drinking water sources be treated for pathogens, with the level of treatment based on the results of the source water risk assessment.

Recommendation 78: Source protection plans should specify ways, in applicable watersheds, that Beneficial Management Practices can be used to reduce loading of pathogens (e.g. public education).

The Pathogens sub-committee recognizes that the entire watershed upstream of the intake has the ability to contribute pathogens to the source. It is proposed that continuous loading of pathogens to the source water resulting from land use activities and piped discharges (e.g. combined sewer overflows, tile drains) be addressed through the implementation of Best Management Practices (BMPs) at a watershed level. Best management practices (BMPs) will be the primary tool for mitigating continuous pathogen loadings to surface water and groundwater. However, the capacity of Best Management Practices – one or several – to reduce pathogen loadings has not been formally quantified. This approach aims to reduce the overall loading of pathogens to the river system.

Assimilative capacity, cumulative threats and risk management

Recommendation 79: Approaches modeled after the USEPA program for total maximum daily load (TMDL) should be considered, with an aim to optimize the cost-benefit ratio when designing risk management strategies.

Recommendation 80: Managers and source protection planners must ensure that the risk analysis and characterization used in the development of risk management approaches includes consideration of cumulative threats and impacts on water quality and quantity from multiple point and non-point sources.

Many existing surface water management approaches rely on an estimate of the capacity of the system to assimilate contaminants without causing a significant environmental stress or over-taxing the system. Similar approaches can be utilized for groundwater resources, particularly where the mass flux of materials off-site from a point source or contributed over a broad area by non-point sources can be compared to the estimated volume of an aquifer and/or recharge rate. It is important to characterize multiple sources of the same potential risk (contaminant, withdrawal, pathogen) when they occur together spatially. For this purpose, a GIS (geographic information system) is used in combination with the threats data-base. It is entirely feasible to utilize models for both surface and groundwater (though such models are in their infancy for groundwater) to understand within some margin of error the potential outcomes of either continuous deliberate releases (discharges, applications) or accidental ones (spills).

Uncertainty and risk management

Recommendation 81: Risk management will require statements of uncertainty, variability and accuracy in the analysis. These statements will be important especially where there is high uncertainty, since more and improved data and modeling will be required. Similarly, consequences should be included in the ranking process and risk assessment/management.

In *Part Two Report of the Walkerton Inquiry*, Justice O'Connor discusses the need for careful risk analysis, and advocated use of the precautionary principle as a response to incomplete information about threats and risks. The Technical Experts Committee concurs. In characterizing risks and threats, source protection planning committees must include statements about the quality of knowledge regarding the assessment and evaluation of the risk and threat. In short, source protection planning committees must make statements about how much confidence they have about the information regarding the risk. In cases where insufficient scientific information exists to give committees confidence in the assessment, the committees should use several methods of analysis or confirmation to increase their confidence in the assessment. This approach of using multiple methods of analysis, should it produce common findings, will bolster the committee's confidence in the quality of the assessment.

The provincial government is responsible for ensuring that drinking water is of safe and reasonably consistent quality province-wide. The Technical Experts Committee recognizes that varying socio-economic and environmental circumstances may influence the ability of municipalities and source protection planning committees to meet this goal. Therefore, the provincial government should define the outcomes required and allow local groups to determine how the outcomes and standards will be met. While this rule should be generally applied to assessments and responses to risks, the province may in some cases need to take a more prescriptive approach.

SECTION 7: ECOLOGICAL PROTECTION

Provincial Water Quality Objectives

Recommendation 82: As source protection plans are prepared, the Provincial Water Quality Objectives (PWQO) should be used as the benchmarks for determining surface water quality and issues such as assimilative capacity and overall system health.

The Technical Experts Committee (TEC) reviewed the Provincial Water Quality Objectives (PWQO), and noted that these Objectives are substantially different from the Standards utilized for finished drinking water to protect human health. The Committee therefore limited its discussions to considering how the PWQO could be used by source protection planning committees to complement activities being undertaken initially to protect drinking water supplies. In subsequent planning cycles, the source protection planning committees may choose to place increasing emphasis on the protection of ecology, such as is provided by the PWQO. With guidance from the provincial government, source protection planning committees could use progress toward achieving the PWQO as one step, in conjunction with other actions, to reduce risks to drinking water supplies.

Provincial Water Quality Objectives (PWQOs) are numerical and narrative criteria that represent a maximum desirable surface water concentration of a contaminant. At the maximum concentration, all forms of aquatic life and all aspects of the aquatic life cycles will still be protected, even if the water is indefinitely exposed to the contaminant. The Objectives for protection of recreational water uses are based on public health and aesthetic concerns (e.g. taste and odour of water, tainting of fish flesh).

PWQOs are useful, but not direct, measurements of ecosystem quality. They are not developed to protect human health (except for the *E. coli* PWQO, which is based on health criteria) and are unrelated to Drinking Water Standards. PWQOs are intended to provide guidance in making water quality management decisions, such as designations of which surface waters in the province should be protected from further degradation. PWQOs are often use as the starting point in deriving waste effluent requirements included in Certificates of Approval and other instruments issued to regulate effluent discharges. They are used to assess ambient water quality conditions, infer use impairments, assist in assessing spills, and for monitoring the effectiveness of remedial actions.

Recommendation 83: In source protection planning, watershed characterization should be based on the interpretation of a suite of Provincial Water Quality Objective parameters rather than a single isolated measure. The PWQO should be current and relevant, and may be used as benchmarks for public reporting on the progress of source protection implementation.

In a joint review with Ministry of the Environment experts, TAWG determined that many PWQOs are outdated. They may need to undergo a re-evaluation based on current science and processes, particularly since PWQOs are conservatively derived. As a result, PWQOs may be difficult to apply or attain for a number of reasons. For example, some water bodies are impacted by ubiquitous sources such as road run-off; because the PWQOs are derived to protect ecosystem health, the PWQO values are well below levels commonly found in the environment, and in some cases PWQOs are actually lower than the natural environmental or background level for a particular parameter in certain regions of the province. Individual PWQOs need to be assessed to determine if they are appropriate for source protection purposes. Several PWQOs may be useful as benchmarks for the "issues analysis" that is applied to surface waters and intake protection zones. Source protection planning committees may identify sources of potential risks that they feel should be assessed for their potential ecological impacts. In these cases, new PWQOs may be needed, particularly if they are to be used as benchmarks to assess source protection implementation actions.

It would be onerous to compare water quality monitoring results to every available water quality criteria. Alternatively, a suite of specific PWQOs could be used as a benchmark of total water quality. A similar process, the Water Quality Index (WQI), has been developed by the Water Quality Guidelines Task Group of the Canadian Council for Ministers of the Environment (CCME). This Index was developed after the Group reviewed water quality indices used across Canada and internationally. It is based primarily on the water index formula developed in the mid 1990s by the B. C. Ministry of Environment, Lands and Parks. It was refined with input from Alberta Environment. The resulting CCME WQI looks at the scope, frequency and amplitude of the measured deviation of water quality from a set of guidelines – national, provincial, or site-specific guidelines as applicable – and produces a single number which can be used to designate a water body as poor, fair, good, or excellent in terms of water quality.

Recommendation 84: The provincial government should encourage and help municipalities and Conservation Authorities to facilitate actions that will ensure the ecological sustainability of source waters not used as a drinking water source.

Recommendation 85: Source protection planning committees, with the guidance of the provincial government, should evaluate the application of Provincial Water Quality Objectives with regard to discharges to surface water.

Conservation Authorities, and many major municipalities, are familiar with PWQOs and how they are implemented. This familiarity may make it feasible for source protection planning committees to assess or utilize PWQOs as a benchmark. The provincial government could provide a guidance document to provide advice on the use of appropriate PWQOs and how they may be applied. In particular, when used as a condition of Certificates of Approval, PWQOs would become particularly relevant as a measurement of improvements toward source protection.

Natural areas

Recommendation 86: The provincial government should include the loss of wetlands and riparian zones in threats inventories and develop a process to protect and restore these natural areas in subsequent source protection planning cycles.

Recommendation 87: The initial water budgets developed under source protection planning should include an analysis that estimates the total area or percentage of landscape comprised of natural areas that perform a significant hydrological function.

Recommendation 88: Subsequent water budgets should include an analysis that estimates the total area of lands considered "significant" and ranks the significance of individual parcels of land and land-forms.

Recommendation 89: The provincial government should consider the use of guidelines on minimum levels of natural area cover in watersheds as one measure of watershed health.

Recommendation 90: Specifically within the Intake Protection Zone, artificial wetlands and/or buffer strips should be evaluated to determine their potential to reduce the vulnerability of the source water to degradation in quality or quantity and to improve water quality and quantity.

Recommendation 91: Initial source protection plans should describe the natural areas and their benefits to source water and ecological sustainability so that both source water quality and ecological sustainability can be enhanced via initial and future plans.

The hydrological benefits of natural areas (Appendix 9) have implications both for drinking water source protection and the maintenance of "healthy" ecosystems. This report identifies several areas in the source protection planning process where these benefits should be taken into consideration. These discussions focus on the influences that naturally vegetated areas can have on water quality and quantity. Alterations in water quality, and the amount and timing of surface and subsurface water flows, can negatively impact the ecological, social and economic values of natural areas.

The presence of naturally vegetated areas, distributed across the landscape, is one sign of "healthy" ecosystems. In a drinking water context, watersheds with more vegetative cover are better able to keep soil, nutrients, pathogens and contaminants on the landscape and out of groundwater and surface waters. In an ecological context, vegetated systems help maintain the integrity of surface waters. For example, swamps (forested wetlands) in headwater areas, which are often found in zones of groundwater discharge, help reduce sediment loadings and minimize increases in water temperatures. Many cold-water streams, and most brook trout streams, originate in swamps.

Wetlands, especially small, ephemeral wetlands, can be significant contributors to groundwater in their capacity to capture spring snowmelt and allow percolation into the ground. In this situation, the protection of natural areas, which have important ecological values, can also generate benefits to existing and potential future water supplies. Another example is the restoration of natural areas, especially riparian areas adjacent to streams. The ecological benefits of these restoration efforts include reduced habitat fragmentation and increased viability of wildlife populations (with improved quality of surface waters being the main hydrological benefit).

Wetlands gain a degree of protection by various Ontario government policies (e.g., wetlands component of the Provincial Policy statements). Small, ephemeral wetlands, however, are generally not well protected. The provincial government should continue to strengthen protective instruments for wetland conservation generally, while adding policies that protect the small wetlands that generate groundwater recharge. Indeed, many wetlands are actually a function of groundwater discharge. These areas are considered to be of low vulnerability (in a drinking water context) in the recommendations contained in this report. If found insufficient, existing mechanisms to protect such natural areas as wetlands, as well as those areas that represent a barrier to source water impacts (blocking the pathways) should be evaluated and strengthened. The source protection planning committees may identify, through the issues and threats approach, multiple natural areas that may be beneficial to source protection or could be managed under other initiatives.

Water quantity and quality problems are more likely to occur in watersheds where there is little natural vegetative cover. Watershed characteristics such as extent (% cover) of naturally vegetated areas, and impervious surfaces can be used as measures of watershed health. For example, lake water quality has been found to be high in areas where wetlands occur on the surrounding landscape and the watershed is forested. Ecologically-based guidelines on recommended levels of “coverage” for wetlands, riparian areas and woodlands are provided in Appendix 9.

SECTION 8: DATA REQUIREMENTS AND MANAGEMENT

Recommendation 92: Source protection plans will require significant amounts of data. The provincial government must update key data sets and ensure that provincially held data are available to source protection planning committees at no cost and with no bureaucratic encumbrance.

Recommendation 93: The provincial government must correct, improve and cross reference well information and record databases and provide these databases to source protection planning committees and others involved in ground water study and management. These records are critical to drinking source protection.

Recommendation 94: Existing provincial data sets are critical to the success of source protection planning, and require improvement. These data sets must be accessible within the Ontario Land Information Warehouse (OLIW) by the end of 2005.

Drinking water source protection will require a significant amount of data and information. The provincial government must invest the required resources to develop a rational system of collecting this information. Moreover, the government must pledge to maintain and manage the information, and make it freely available for use by those involved in drinking water protection and management. This information must be made available to source protection planning committees in a timely and unencumbered fashion. In addition to providing existing and operational data, the provincial government should invest in research activities that allow future source protection to be undertaken with improved scientific knowledge. The Technical Experts Committee supports the principle of continuous improvement of scientific knowledge, in that source protection should be based on the sharing of research and data. More information on the Committee's advice relating to data and information is contained in Appendix 7.

Recommendation 95: Adequate, long-term funding for maintaining information and databases is necessary to support long-term planning.

Recommendation 96: The provincial government should provide adequate training for those who generate well information and should ensure that records kept by well-drilling firms are consistent, accurate, and complete, given the tremendous significance of this data-set to source protection.

The Committee discussed the importance of building on the initial enthusiasm that will undoubtedly characterize source protection. Managers of source protection planning and implementation should strive to ensure the long-term sustainability of source protection, including the application of the continual improvement principle. This view is consistent with the Committee's recommendation that plans be updated periodically and vulnerable areas re-defined on occasion.

Recommendation 97: Data-set and database management must include reciprocal agreements that allow for the free flow of information to those involved in source protection planning.

Recommendation 98: In keeping with the principle of free and open data movement, a mechanism must be developed and enforced that will allow source protection planning committees, boards and researchers to exchange information and experiences related to source protection planning and implementation.

Ontario is undertaking the most extensive, coordinated drinking water management in the country, if not the continent. The process will involve the participation of a variety of agencies, researchers, and the public. A systematic process must be established that can allow these different groups to 'compare notes,' share experiences, and learn from one another. There is both an immediate practical intent to the process, and the conception of a large-scale research project. Structured properly, and with some research design perspectives, this process could contribute greatly to creating a strong scientific basis for the source protection planning and implementation process.

Recommendation 99: Methods of monitoring data quality must be developed so that quantitative statements can be made about the quality and level of confidence in data that are held in provincial and local databases.

Recommendation 100: The provincial government should identify the acceptable levels of scale and validation for the studies that are used to develop source protection plans. This guidance should promote consistency, and ensure that the appropriate level of detail and confidence is provided in the risk assessment. A mechanism that will incorporate cumulative effects into decisions regarding the appropriate scale is also necessary so that finer resolution investigations will occur where needed.

Recommendation 101: A provincially managed groundwater inventory should be developed and maintained in the fashion of the data protocols used in Ontario's oil and gas inventories, with this central database and mapping function being freely available for source protection planning and for persons wishing to withdraw water such as through the Permit to Take Water (PTTW).

Recommendation 102: As information is generated on the aquifers and important factors for the aquifers (well locations, geophysical information) it should be mandatory that this information be provided to the provincial inventory.

Recommendation 103: All provincial and local information used in Source Protection Planning should have accessible, authoritative versions.

Recommendation 104: Where possible, all provincial and local information used and generated in Source Protection Planning should be geo-referenced to provincial standards.

Source protection planning will depend on significant amounts of data and information being shared between different agencies and groups. The provincial government must establish and support this process. This cooperation will require setting data standards and ensuring consistency between source protection plans, not only to ensure similar levels of confidence throughout the province, but also because there is much to learn about source protection by sharing plans and experiences between source protection planning committees. The province will benefit the most from these efforts when the plans, data, analyses, monitoring, and follow-up are current and consistent throughout the province.

Recommendation 105: A provincial data coordination body should be established for source protection planning.

Recommendation 106: For each planning team that supports a local source protection planning committee, at least one member should be a GIS professional focused on data management.

Recommendation 107: All provincial and local information used for Source Protection Planning must have a full set of metadata defined and available. Data sets must take advantage of the Provincial government's OLII as much as possible.

In recognition of the importance that data and information management will have in the development of plans (and also their reviews), the Technical Experts Committee discussed the challenges and solutions to achieving the initial targeted priority actions. It also discussed launching a data-system that would be resilient and capable of improvements over time.

Recommendation 108: The provincial government should review completed municipal groundwater studies for key hydrologic and hydrogeologic data (including locations of previously unknown wells) and data refinements to known wells should be reflected in the Water Well Information System (WWIS).

Recommendation 109: The provincial government should strategically expand the collection of relevant water monitoring data sets and make them accessible within the Ontario Land Information Warehouse (OLIW) by the end of 2005. Where comparable local data sets are held by local authorities, the provincial government should assist these groups to ensure the data have recognized standards and are accessible.

The Technical Experts Committee has a good understanding of which data-sets are the most important for the initiation of planning. As a group, the Committee possesses extensive experience in data-generation, management, and practical application. In order to achieve the Minister of the Environment's stated objective of addressing significant risks by 2008, the databases must be prioritized in the short term.

Recommendation 110: The provincial government must initiate the standardized collection of several new sets of provincial data and make these data sets accessible within the Ontario Land Information Warehouse (OLIW).

Recommendation 111: The provincial government should build a threats data model to cover continuous and catastrophic threats.

Although some information and data needs are predictable, source protection planning will undoubtedly require new data-sets and information not foreseen today.

SECTION 9: RESEARCH, DATA AND INFORMATION NEEDS

Recommendation 112: The provincial government should commit sustainable and long-term funding to address fundamental research, data, and information needs, with a focus on but not limited to:

- Methodologies to define vulnerability of groundwater at a regional scale including their relationship to recharge areas and means to assess cumulative impacts;
- In collaboration with the federal government, impacts of and strategies to address climate change;
- Methodologies to establish acceptable rates of aquifer recharge for long-term sustainability;
- Quantitative methods for the delineation of recharge areas;
- Markers for and characterization of landfill leachate/contaminants;
- New chemicals potentially threatening source water to support screening and early warning systems;
- Documenting the beneficial impacts of Best Practices;
- Listing of DNAPLs for assessment in wellhead protection areas;
- Models to link Great Lakes source water to (and to direct) upstream activities;
- Numeric methods for screening land-practices for potential issues, such as density of septics as an indicator of nutrient loadings;
- Benefits of protecting or restoring riparian zones and wetlands;
- Investigation of pathogen threats including viruses for their persistence in source water and implications for intake or wellhead zone delineations;
- Improved approaches to developing water budgets in different types of watersheds under variable development and use;
- Optimizing hydrologic data collection to ensure the correct type and scale of data are collected in the most efficient and cost-effective manner (current topic of research internationally);
- Developing methods for estimating risk to municipal groundwater supplies from historical or legacy land-use practices;
- Developing methods for early detection of significant risks to municipal groundwater supply systems, and ways of accommodating threats (new chemicals) as they become identified.

Research will be a necessary and ongoing activity to keep the planning activities of source protection current and science-based. In many instances, existing methodologies will provide a solid basis to develop initial implementation plans. However, the principle of continual improvement will require that the plans be periodically updated. These updates will benefit from science to fill data-gaps or refine models or approaches. In particular, research will be necessary to evaluate how lessons learned in Ontario can be applied in other areas. Examples include past and present problems for source waters as a result of activities such as landfills or contaminated sites. Tracers, models and early indicators are all areas of study that warrant research, especially models to predict the fate of the plume from a landfill and the resulting impact on raw waters. Finally, the Committee's recommendations on source protection data and information needs is based on the extensive professional experience of its members.

SECTION 10: PERMITS TO TAKE WATER

Recommendation 113: The Permit to Take Water program should be re-oriented to be a component of a larger and more comprehensive government-wide initiative to manage and protect Ontario's water resources, such as through a Provincial Policy Statement for water.

The Technical Experts Committee provided advice to the Minister of the Environment in April, 2004 regarding Permits to Take Water (PTTW). Based on Ministry briefings, the Committee came to the understanding that a number of its recommendations would be addressed in the process of lifting the moratorium. Other recommendations may be addressed through the development of a "manual" for the approval of Permits, but this document was not available for the Committee's review. Many of the recommendations were directed at improving the PTTW process overall. In terms of the water quantity issues discussed in this report, the Committee maintains that integrating the PTTW with source protection programs will be critical to protecting drinking water.

In most Ontario watersheds, the amount of water taken through Permit to Take Water (PTTW) activities is actually a minor issue. In the process of lifting the PTTW moratorium, a science-based process should be used to identify "high-water use" watersheds or sub-watersheds. Special considerations should be given to areas experiencing a stress on water quantity.

In this report, it important to repeat several recommendations made earlier but which appear to be outside the scope of current program amendments, or seem to have not been addressed to date by the government. As such, several considerations are important:

- Due to time constraints the Committee did not review the draft Regulation in detail, though it has received briefings by provincial government staff on the proposed changes and how they may address the Committee's earlier comments;
- The more detailed technical considerations in the Permit approval process are to be contained in a Manual, which is not yet available to the Committee for review.

Reorienting the PTTW program so that it becomes part of an overall "water program" will likely only be achieved through changes to the *Ontario Water Resources Act*. The Ministry of the Environment should consider these changes. In doing so, the government would need to consult broadly with Ontarians on water sustainability, particularly in areas of growth and potential development that may threaten water quantity or quality.

Recommendation 114: The permit application, review and approval process should include a "science assessment" to increase the level of confidence that the taking qualifies as a sustainable use.

The Committee recognizes that the "science basis" for the amended PTTW approval process may have incorporated changes. The Manual on this topic was not available for the Committee's review. In this report, the Committee reiterates its conviction that sound science must be the basis for decision-making, in conjunction with the precautionary principle. In particular, in order for the government to permit a withdrawal, a considerable level of certainty must be provided that the withdrawal is sustainable. The failure to demonstrate this condition or to assess this level of certainly in considering the permit should be grounds for rejecting the application. Subsequently, a review could be undertaken if the applicant provides sufficient scientific evidence.

Recommendation 115: The provincial government should provide regional aquifer and/or surface water data to the applicant upon receipt of an "enquiry" for a Permit.

Provincial information should be made available not only to source protection planning committees, but also to applicants for Permits to Take Water and other interested parties. Until an accessible web-based system is available for all Ontarians, the government should provide available information to individuals to make requests. In addition, the provincial government should ensure a regional context is available, particularly to aid applicants who lack the resources to generate and provide a regional assessment themselves.

Recommendation 116: The provincial government should amend the Permit to Take Water (PTTW) legislation such that if a PTTW is proposed for a wellhead protection area or intake protection zone, the application process will recognize the presence of the zone and the onus will be placed on the applicant to consider/address the potential implications for the proposed withdrawal on that zone, rather than placing the burden on the existing source protection planning committee.

A Permit to Take Water may impact risk management strategies already developed for vulnerable areas. Therefore, the party responsible for protecting the area should be part of the decision-making process for the permit. Large takings can alter flows and hence the definition of the vulnerable area. This process cannot be implemented until the legal structure for developing wellhead protection areas, and for assigning roles and responsibilities for the management of these areas, is finalized. This recommendation should be implemented through the process of establishing authorities and requirements for wellhead protection areas and source protection.

Recommendation 117: The practice of providing exemptions to permitting requirements should be reviewed in the context of source protection planning and consideration should be given for amending the OWRA through the Source Protection Planning Act.

As a basis for exemptions, the "impact" of a water taking is substantially different than the use of water, which is the current basis. The use of a graduated application and approval process can limit the administrative requirements and data needs for smaller/low-impact takings, while ensuring information on withdrawals is available for all such activities. Amendments to the *Ontario Water Resources Act* may be necessary to implement this recommendation. The recommendation might be fulfilled, in part, through amendments under the *Source Protection Planning Act*. In eliminating "exemptions," it will be necessary for the Ministry of the Environment to establish a graduated system of approvals so that minor proposals or major proposals with no implications are processed through a simplified and perhaps localized review process, leaving a more formal review for more complex and large withdrawals.

Recommendation 118: A specific technical quantitative basis for assigning water allocation (to withdrawals) should be incorporated into the Permit to Take Water (PTTW) approvals process in such a way as to harmonize with other jurisdictions, providing a level playing field for major water-taking industries in Canada.

Alberta, Saskatchewan and New Brunswick have shown strong leadership in taking a quantitative approach to groundwater allocation and permitting. This approach should be followed across the country in pursuit of a harmonized process. The Technical Experts Committee acknowledges that the Ontario government's specific technical basis for the permit approval will be included in the manual for permit approvals. The Technical Experts Committee has previously recommended adopting the groundwater permit limits based on the quantitative approach. Provincial government staff have considered this recommendation, but opted instead for a different technical basis that may or may not be harmonized with that taken in other jurisdictions.

Recommendation 119: A scientific rationale for the protection of surface water ecological functions must be adopted for both the Permit to Take Water program and the identification of water quantity risks under Source Protection.

The Technical Experts Committee understands that pilot projects have been initiated to evaluate the impact of low-water upon ecological integrity. These science-based "limits" should be adopted as quickly as is feasible into both source protection and the PTTW program. This recommendation warrants special attention with regard to the harmonization of these two programs.

Recommendation 120: The rationale for granting a permit should be expanded to encompass not only the volume of water but other factors, such as consumption, export from the basin or aquifer to surface water, impacts on water quality, and societal benefits.

Currently, the limitations put on Permits to Take Water are based solely on water quantity. This policy fails to address other important factors, such as the benefit that may be accrued by storage of spring-runoff for summer use or the construction and maintenance of wetlands. Nor does the policy include consideration of deleterious impacts, such as degraded water quality upon its return. It also includes no consideration for water conservation. For water conservation, "best practices for water use/volume of product" should be developed and adopted as benchmarks for permit approval and review. It is the Committee's understanding that under the current Regulatory and Manual changes, Permit limitations are based on quantity alone. The Committee understands that its recommendations can only be addressed if a subsequent review is undertaken. In essence, a Provincial Policy Statement should clarify the terms and conditions upon which a common resource (water) is allocated for private or municipal uses.

Recommendation 121: With the establishment of source protection planning boards, these bodies should be granted a formal role in partnership with the provincial government in the review and approval of Permits to Take Water.

To evaluate water quantity as a “threat,” one must have a broad appreciation for how the water in a watershed is used. This evaluation also provides source protection planning committees with a vested interest in the issuing of Permits. In particular, the requirement for the source protection planning committee to forecast water use and identify “future” water supplies for protection requires that these committees participate in decisions about new PTTW applications. These applications may seek out valuable water resources which may be under consideration for municipal supplies or which are being protected as a result of being vulnerable. The scientific rationale for evaluating water quantity and budgets in developing source protection plans will greatly serve the review and approval of Permits to Take Water. Indeed, the provincial government may wish to consider authorizing the source protection planning committees, or their designate, to approve simple or “class compliant” applications directly, while addressing complex or controversial applications through a joint review with the provincial government. This cooperative work may reduce or eliminate to some extent the duplication between the source protection planning committee’s technical review of water quantity, and permit review undertaken by provincial government staff.

SECTION 11: DRINKING WATER PROTECTION ACTIONS BY 2008

Recommendation 122: The provincial government should encourage the implementation of programs and activities in jurisdictions that have initiated source protection plans for wellhead protection areas through provincial groundwater studies money.

Recommendation 123: A comprehensive program to address private water supplies should be developed and implemented through the source protection planning committees, with a focus on preventing pathogen contamination of aquifers and private wells.

Recommendation 124: In conjunction with Medical Officers of Health, information relevant to private wells should be efficiently communicated to those who may benefit.

Recommendation 125: Risk management actions for high risk/high impact situations that are identified prior to formal plan approval should be implemented as quickly as is feasible. The approval process should not inhibit due diligence.

Recommendation 126: The provincial government should establish a comprehensive and publicly accessible groundwater aquifer data structure to accept 2008 submissions of data to support aquifer mapping.

Recommendation 127: The provincial government should develop a data structure and model that would allow data sharing to occur through distributed and disseminated databases held by various local source protection committees.

Recommendation 128: An assessment report for each source protection area in Ontario should be in progress by 2008.

Many members of the Technical Experts Committee possess practical experience in the delivery of municipal water services or, more recently, the development of protection strategies for the source water serving these systems. The Committee determined that large municipal systems seem to be the most likely candidates for source protection implementation by 2008. This conclusion is based, in part, on the extensive work already undertaken through the province's Groundwater Studies. At the same time, the large municipal systems benefit from secondary barriers that may substantially reduce the risks these areas would otherwise face to drinking water contamination. Therefore, the large municipal systems may not be the most urgent priority for implementing the primary barrier of source protection.

By contrast, private rural wells, when surveyed in the Ontario Farm Groundwater Quality Survey (1991-92), had an unacceptable frequency of microbiological contamination. This finding suggests that the present provincial government water protection programs are insufficient to meet the needs of private well owners. The current provincial and local programs should receive additional resources (staff and funds) to implement a coordinated, proactive program that includes public education and Best Management Practices, inspections, water quality testing, and upgrades of all private wells as necessary. Upgrades could include: replacing seals, installing barriers and buffer strips, extending casings to aboveground surface, and installing a vermin proof well cap. This work can proceed immediately without the need for a comprehensive "threats inventory." These steps address the Technical Experts Committee's concerns that private supplies of water represent a significant risk in the absence of source protection. The Committee anticipates that the broader program of protecting vulnerable areas will confer some protection to the source water for these systems. Introducing source protection measures for each and every well is impractical. At the same time, well owners should understand and appreciate the fact that well design and water monitoring are important tasks, and are the responsibility of the well owner.

SECTION 12: GLOSSARY

Glossary of terms:

Advection - Advection is the transport of dissolved species due to the bulk movement of water. In lay terms, the advection velocity is simply the average velocity of the water in the geologic material. The advective time is therefore the average time that a water "particle" takes to travel from one point to another.

Adverse effect - means one or more of the following,

(a) impairment of the quality of the natural environment for any use that can be made of it,
(b) injury or damage to property or to plant or animal life,
(c) harm or material discomfort to any person,
(d) an adverse effect on the health of any person,
(e) impairment of the safety of any person,
(f) rendering any property or plant or animal life unfit for human use,
(g) loss of enjoyment of normal use of property, and
(h) interference with the normal conduct of business;

Aquifer - A saturated, permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients. Regional aquifers can be thousands of square kilometers in size.

Aquifer vulnerability - An aquifer's intrinsic or inherent susceptibility, as a function of the thickness and permeability of overlying layers, to contamination resulting in an adverse effect, from both human and natural sources.

Aquifer sensitivity - Related to the ability of an aquifer to attenuate, retard, transform, dilute, or otherwise degrade and render harmless a contaminant. A highly sensitive aquifer exposed to a contaminant loading will quickly become contaminated whereas an insensitive aquifer will be able to assimilate a certain contaminant loading without showing an adverse effect.

Aquitard - The geological formation with a low permeability which transmits water at a very slow rate. When located above an aquifer it may form a significant protective layer.

Artesian well - A well in which water from a confined aquifer rises above the ground surface and therefore flows on the surface.

Assimilation - The absorption, dilution and or transformation of contaminants by a water body that maintains concentrations of those contaminants below a standard that ensures the integrity of a system.

Assimilative capacity - The capacity a body of water to receive contaminants with out significant degradation in water quality or quantity such that the integrity of the water body is maintained.

Barrier - A natural or artificial feature in the environment that separates contaminants from drinking water sources.

Biosolids - The official definitions in the Nutrient Management Act Regulation are:

> "*sewage biosolids*" means the residue from a sewage treatment works following treatment of sewage and removal of effluent
>
> "*pulp and paper biosolids*" means solid or liquid material that results from the treatment of wastewater generated by a manufacturer of pulp, paper, recycled paper or paper products including corrugated cardboard.

Black water - water contaminated by sewage.

Capture zone - The area surrounding a well pump that supplies groundwater to the well within specified period of time.

Catastrophic pathogen threat - means rapid onset, severe symptoms and short duration; opposite of continuous. E.g. a manure spill into a river.

Catchment /catchment area - The land surface area that supplies a drinking water source. Land use activities within the catchment area directly influence the quality and quantity of the water.

Continuous pathogen threat - means of long duration; continuing. Lasting for a long period of time or marked by frequent recurrence. For example, wastewater treatment plant discharge.

Connectivity - The degree to which key natural features are connected to one another such as plant and animal movement corridors, hydrological and nutrient cycles, genetic transfer, and energy flows through food webs, etc;

Conservation – On the land - The protection and restoration of surface water bodies such as wetlands, lakes, ponds, streams, etc. Conservation in this context includes their ecological ability to process nutrients and other contaminants as well as their ability to replenish water supply. During human use – the conservation of water by use of efficiency technology and strategies to ensure that a minimum amount of water is consumed.

Contaminant - A substance, including pathogens, with the ability to adversely affect water quality.

Continuous improvement - The process of ensuring that there is an emphasis on the constant and continual improvement and upgrading in the data, science, research, methods, planning and implementation activities during successive plan developments and implementation.

Cumulative - The sum of threats, contaminants or risk that occurs from several sources on a single area in a watershed. This includes any changes to hydrologic and hydrogeologic features and functions that are influenced by multiple or successive land use or site alteration activities over the long term.

Discharge - The volume of water passing through a channel in a given time; in the groundwater context, the term refers to water which exits an aquifer to become surface water.

Down-gradient - The area of down slope in a ground-water area. Normally water will flow this direction to and within an aquifer.

Drinking water source (DWS) - Any surface or ground water body that does or could be used as a source of water for human consumption subsequent to reasonable water treatment

Ecological features - The naturally occurring land, water and biotic features that contribute to ecological integrity.

Ecological functions - The natural processes, products or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes, including hydrological functions and biological, physical, chemical and socio-economic interactions;

Erosion - The process where the materials of the Earth's crust are loosened, dissolved, or worn away.

Eutrophic - The condition where a water body is enriched in dissolved nutrients that stimulate the growth of aquatic plants and usually resulting in the depletion of dissolved oxygen.

Gain Control - The acquisition of all rights to land use and activities that may take place on a piece of land.

Geomorphology - 1. The science of the study of land forms; the description and interpretation of the earth's relief features. 2. The study of the evolution and configuration of landforms.

Grey water - sanitary sewage of domestic origin which is derived from fixtures other than sanitary units, where SANITARY UNITS "means a water closet, urinal, bidet or bedpan washer."

Groundwater divide - The boundary between two adjacent groundwater basins, which is defined by a line connecting the high points in the water table or other potentiometric surface and on either side of which the groundwater flow diverges.

Groundwater - Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

Groundwater-shed - The region found on the down-gradient side of a regional groundwater flow divides

Groundwater recharge - The process of replenishment of subsurface water,

(a) resulting from natural processes, such as the infiltration of rainfall and snowmelt and the seepage of surface water from lakes, streams and wetlands, and
(b) resulting from human intervention, such as the use of stormwater management systems, that specifically direct water into the subsurface (artificial recharge);

Groundwater Under Direct Influence of Surface Water (GUDI) - Groundwater that has a direct, dependent connection to surface water and where contaminants are not filtered by overlying soil. In technical terms, this groundwater has incomplete/undependable subsurface filtration of surface water and infiltrating precipitation;

Hydrological cycle - The cyclic circulation of water from the atmosphere to the earth and back through precipitation, runoff, infiltration, groundwater flow and evapotranspiration .

Hydrological features include:
(a) permanent and intermittent streams,
(b) wetlands,
(c) kettle lakes and their surface catchment areas,
(d) seepage areas and springs, and
(e) aquifers and recharge areas;

Hydrological functions - The functions of the hydrological cycle that include the occurrence, circulation, distribution, and chemical and physical properties of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere, and water's interaction with the environment including its relation to living things;

Hydrology - The science of studying properties, distribution, and effects of water on the Earth's surface;

Impact - The result of a land activity, contaminant, etc. on a drinking water source.

Impervious/impermeable surface - A surface that does not permit the infiltration of water, such as a rooftop, sidewalk, paved roadway, driveway or parking lot.

Indirect threat - Any activity threat that has the ability to impact the quality or quantity of a drinking water source through intermediate processes or steps.

Intake Protection Zone (IPZ) - The contiguous area of land and water immediately upstream of a municipal drinking water intake defined by a specific response time.

Maintaining the integrity of a system - Conservation of existing ecological functions and processes of a drinking water source so that the source can remain sustainable in the future.

Multi-barrier approach - The process of ensuring the presence of several barriers or 'filters' that will intercept or convert threats between the time of arrival of a drop of water on the landscape and its arrival at a DWS intake.

Municipal Wells - Wells that are owned by a municipality or other government for the purpose of providing drinking water to the public.

Natural areas - features of the environment that are not generally used for intensive agriculture or human use. These features include wetlands, lakes, forest, meadows, etc.

Net developable area - The area of a lot or site, less any area that is within a key natural heritage feature or a hydrologically sensitive feature;

Non-point source - Threat sources originating over broad areas, such as areas of fertilizer and pesticide application and leaking sewer systems, rather than from discrete points.

Oligotrophic - The condition of a water body where nutrient content is low, resulting in low productivity.

Outcome based approach - The approach to goal setting and achievement that is based on the provincial government setting the standards (outcomes) and leaving the method of reaching those outcomes to local source water planning committees and boards.

Pathogen - A microbiological organism which, if present in sufficient numbers, has the potential to cause human health problems.

Pathway - The route by which a contaminant may reach a drinking water source.

Point source - A fixed location or land use activity from which threats are potentially discharged; any single identifiable source of pollution; e.g. a pipe, ditch, ship, ore pit, factory smokestack.

Porosity - The property of a solid or aggregate that contains minute channels or open spaces, that allow liquids to seep through. Soil has porosity because of it is made up of irregularly shaped particles.

Potential risks - Threats on the landscape that could be delivered to a water supply if the hazard associated with the threat reaches a pathway to the aquifer.

Potential threats - Threats that exist on the landscape that may or may not have a hazard associated with them that could adversely impact drinking water.

Prescriptive approach - risk management in which the activity to be undertaken to manage the risk is identified by the province, rather than allowing local options to be considered and selected; a less flexible approach than the *Outcome-based approach*..

Precautionary principle - The precautionary principle says that the absence of scientific certainty about a risk should not bar the taking of precautionary measures. It addresses situations in which the risk cannot be estimated with any reliability and in which uncertainty prevails regarding the relationship, if any, between cause and supposed effect.

Prohibition - Disallowance of an activity or presence of a threat in a defined area.

Public water supply - means any drinking-water system that is regulated under the Drinking-Water Systems regulation (O. Regulation 170/03).

Public consumption - The use of a water supply for human consumption.

Receptor - A water source that could receive a threat.

Riparian area - The area that lies as a transition zone between upland areas such as fields, etc. and streams, wetlands, lakes, rivers, etc. The zone is intermittently inundated and usually supports wet meadow, marshy or swampy vegetation.

Risk - The combined probability that a path exists for the hazard associate with a threat to be delivered to a drinking water source and the probability that it will be delivered. Hazard + Pathway + Exposure = Risk.

Risk analysis - The process of determining the seriousness of risks through an examination of the characteristics of the threats and the vulnerability of the water sources.

Risk assessment - The combined process risk analysis and risk categorization, to determine overall priorities for risk management.

Risk management - The process of controlling risk to acceptable levels. This may involve prohibition, regulation and voluntary incentives for management to ensure risk remains at an acceptably low level.

Saturated zone - The zone below the water table where the spaces between soil grains or fractures within rock are filled with water.

Sanitary Survey - Means the on-site review and evaluation of all actual and potential pollution sources and environmental factors having a bearing on area water quality. AND an on-site review of the water source, facilities, equipment, operation, and maintenance of a public water system for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water.

Sensitive water resources - Water sources that have either low assimilative capacity or where withdrawals compromise the ability of the source to maintain existing integrity.

Sedimentation - The process of settling and deposition of suspended matter in the bottom of a water body.

Semi-quantitative - Using ranks or "relative indices" as a means of prioritizing things or ranking things, often with relative weights applied to each criteria contributing to the “index”.

Sensitivity - The likelihood of an adverse effect resulting from the manner in which a water resource will react when exposed to any given threat. Water resources with a higher sensitivity are more likely to be adversely impacted than a water resource with a low sensitivity when exposed to any given threat.

Septage - End-products of municipal and agricultural sewage that is destined for disposal or may be incorporated on agricultural fields, etc.

Stakeholder - The person or group of people affected by, can influence, or is interested in a decision or an action;

Subwatershed - The area that is drained by a tributary or some defined portion of a stream;

Surface catchment area - The area including and surrounding a surface water feature , from which surface runoff drains directly that feature;

Surface water - Water that is present on the earth's surface and may occur as rivers, lakes, wetlands, ponds, etc.

SAAT - Surface to Aquifer Advective Time: The average time required by a water "particle" to travel from a point at the surface to the aquifer of concern. The SAAT is approximated by using the vertical component of the advective velocity integrated over the vertical distance and the average porosity.

SWAT - Surface to Well Advective Time - The average time required by a water "particle" to travel from a point at the ground surface to the well, including both vertical and horizontal movement.
Sustainable - The use of a natural resource such that the activity does not adversely affect the resource and so that the resource is conserved for future use.

Threat - The presence of any land use, contaminant, pathogen etc. that has the capacity to degrade present or future drinking water sources should it be delivered to the drinking water source

Threats assessment - The process where threat characteristics and pathways to drinking water sources are determined for all threats in a watershed.

Threats inventory - The process and tools used to detect land-use and activity-based threats and their locations in the watershed.

Time-of-Travel - An estimate of the time required for a particle of water to move in the saturated zone from a specific point to a groundwater source of drinking water.

Vulnerability - The combination of potential that a threat might be delivered to a DWS and the robustness of the DWS should the threat be delivered

Vulnerability assessment - Evaluation of the vulnerability of all drinking water sources in a watershed.

Topography - The three-dimensional graphic representation of the elevations or inequalities of the Earth's surface;

Transmissivity - The rate at which water is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media and the thickness of the porous media

Vadose - The unsaturated zone occurring above a water table;

Valuation - The socio-economic importance placed on a particular resource including its use for drinking water which may have strong implications as to the level of risk management desired

Velocity - The rate of movement of an object past a point in a specified direction.

Water budget - the description of the inputs and outputs of water through a region.

Water table - the level to which water will rise in an open well within an unconfined aquifer.

Watershed - The area that is drained by a river and its tributaries;

Well-head protection area - The area surrounding a well within which the well's ground water sources are vulnerable to surface threats that would travel to the source within a designated time. This includes the surface and subsurface area surrounding a water well or well field that supplies a public water system and through which contaminants are reasonably likely to move so as eventually to reach the water well or well field.

Well field - The clustering of two or more groundwater production wells which supply water to communal distribution system(s). The wells must be on a single property or directly adjacent properties and can be installed within a single or multi-aquifer system;

Wetland - Land such as a swamp, marsh, bog or fen that exhibits one of the following characteristics:

(a) seasonally or permanently covered by shallow water or has the water table close to or at the surface,
(b) hydric soils and vegetation dominated by hydrophytic or water-tolerant plants, and
(c) been further identified, by the Ministry of Natural Resources or by any other person, according to evaluation procedures established by the Ministry of Natural Resources, as amended from time to time;

Withdrawal - The extraction of water for human consumption or use from a surface or groundwater source.

Zone of contribution - The area from which water pumped from a well for a specified period of time is drawn.

WATERSHED-BASED SOURCE PROTECTION PLANNING

Science-based decision-making for protecting Ontario's drinking water resources: a threats assessment framework

Appendices

November, 2004

Introduction to the Technical Experts Committee Appendices

These appendices contain working documents that were used and/or generated by staff working with or in support of the Technical Experts Committee. The materials in these appendices were considered by the Committee in making their final recommendations. In many instances additional detail in the appendices will help the reader to understand the context and background for some of the recommendations. The reader is cautioned that in some instances the Appendices reflect initial discussions/suggestions that may not have been adopted by the Committee as a whole, or that may have been substantially revised by the Committee. In such instances the Appendices have not been amended or altered in any way to reflect the decision of the Committee, but rather they consistently represent the background materials for the discussions at their initiation only. In all instances primacy shall be given to the formal recommendations made by the Committee. The variability in length and detail of the Appendices does not in any way reflect the level of importance placed upon an issue either by staff supporting the Committee or the Committee itself, but reflect the adoption of a flexible and iterative approach to supporting the Committee's deliberations on various topics.

Appendix 1A. TEC membership

Gayle Wood, Co-chair
Ms Wood is the Chief Administrative Officer of the Lake Simcoe Conservation Authority, and is also a member of Conservation Ontario.

Jim Smith, Co-chair
Mr. Smith is Assistant Deputy Minister – drinking water management division and Chief Drinking Water Inspector, Ministry of the Environment.

Michael Brodsky
Mr. Brodsky served as the chief of environmental microbiology with the Ministry of Health and Long-Term Care Central Public Health Laboratory for more than a decade, served as president of several major associations, and is an expert in bacterial indicator organisms and pathogens in food and water.

Robert Clay
Mr. Clay is a wetland ecologist who has worked for 25 years on preserving and conserving wetlands across Canada. He has managed, designed and implemented wetland conservation programs for Ducks Unlimited Canada's Habitat Conservation Program and has conducted research on wetlands function.

Marg Evans
Ms Evans is senior policy planner with the Oxford County planning department. She has been extensively involved in ground water studies and watershed planning in Oxford County and led the development of the county's wellhead protection program.

Dr. John FitzGibbon
Dr. FitzGibbon is director of the School of Rural Planning and Development at the University of Guelph and chair of the Ontario Farm Environmental Coalition Steering Committee. His areas of academic interest include water resources planning, environmental planning, environmental impact assessment, environmental design, biophysical resource assessment, community impact assessment and sustainable development strategies.

Dr. Michael Goss
Dr. Goss is Chair of Land Stewardship at the University of Guelph. His current research activities concern the impact of agriculture on the wider environment,

including issues related to management of manure and other organic materials in crop production. A key focus is the movement of bacteria through soil and bedrock, and their impact on surface and ground water resources.

H. James Hawken
Mr. Hawken is mayor of the City of Temiskaming Shores. He is a professional engineer with expertise in both drinking water provision and sewage treatment, and knows the technical challenges of source water protection in Northern Ontario.

Eric Hodgins
Mr. Hodgins is a manager for the Region of Waterloo in charge of implementing the source water protection program for the Regions's municipal water supply system. He has a Masters degree in Hydrogeology and his work has focused on the fate of chemicals in ground water and movement of water through fractured bedrock.

Steve Holysh
Mr. Holysh is a hydrogeologist currently working with the Conservation Authorities Moraine Coalition. He has extensive experience and expertise in the technical aspects of developing watershed conservation plans; recently he has been coordinating the York-Peel-Durham Ground water Study.

Dr. Douglas Joy
Dr. Joy led the establishment of the Ontario Rural Wastewater Centre. His research includes field and modelling studies of ground water contaminants (including bacteria), hydrology and studies of surface water quality problems and how to minimize them.

Derrick Kamanga
Mr. Kamanga, P.Eng. is the Quality Assurance Engineer for the Ontario First nations Technical Services Corporation. He is responsible for certification of staff and facilities that provide drinking water and waste water treatment for a number of First Nations communities in Ontario.

Dr. K. Bruce MacDonald
Dr. MacDonald is a retired scientist from Agriculture Canada. His experience includes evaluating risks to water resources from rural and agricultural land use activities. His range of technical expertise also includes modelling, soils science, climatology and climate change.

Dr. Ronald Pushchak

Dr. Pushchak is a professor in the School of Occupational Health with a joint appointment in the School of Urban and Regional Planning at Ryerson University. His areas of research interest include environmental assessment, facility siting, risk assessment and environmental planning.

Dr. Michel Robin

Dr. Robin is a faculty member in the Department of Earth Sciences at the University of Ottawa. His current research interests include solute transport modelling in heterogeneous porous media, GIS modelling of basin-scale hydrogeologic systems, impacts of climate change on water resources, and field studies of surface/ground water interactions.

Dr. David Rudolph

Dr. Rudolph is an associate professor in the Department of Earth Sciences at the University of Waterloo. He is a recognized expert in ground water flow and has worked on the protection of regional aquifer systems in urban areas.

Dr. David Sharpe

Dr. Sharpe is a geologist affiliated with the Geological Survey of Canada. He was involved in the geological/hydrogeological characterization of the Oak Ridges Moriane as part of a multi-disciplinary science team.

Appendix 1B. Threats Assessment Working Group (TAWG) membership

Ian Smith, Ontario Ministry of the Environment (MOE)
Barbara Anderson, MOE
Shelly Bonte-Gelok, MOE
Renée Bowler, MOE
Cynthia Carr, MOE
Victor Castro, MOE
Scott Christilaw, Ontario Ministry of Natural Resources (MNR)
Deborah Conrod, MOE
Scott Duff, Ontario Ministry of Agriculture and Food (OMAF)
Don Greer, MNR
Mesmure Haile-Meskale, MOE
Jason Jessel, MOE
Brian Kaye, MOE
Frank Kenny, MNR
Harry Manson, MOE
Bryce Matthews, MNR
Lorrie Minshall, Conservation Ontario (CO)
Brian Potter, MNR
Tina Schankula, Ontario Federation of Agriculture
Hugh Simpson, OMAF
Richard Stromberg, Ontario Ministry of Municipal Affairs and Housing
Rick Vantfoort, MOE
Ann Marie Weselan, MOE
Charley Worte, CO

Appendix 2. Technical Experts Committee Terms of Reference

Technical Experts Committee

Draft Terms of Reference
revised January 22, 2004

Mandate of the Technical Experts Committee
The responsibility of the Technical Experts Committee is to oversee the development of and make recommendations regarding an Ontario-based process for assessing all threats to the sources of drinking water. The threats assessment process will form the key technical component of the Source Protection Plans (SPP) to be developed across the province.

The Technical Experts Committee will provide a report which outlines its recommendations regarding the key elements of an Ontario-based threats assessment process which can be used across the province in the development of Source Protection Plans. Recommendations will cover the technical aspects of the threats assessment process, as well provide advice (ultimately to the Implementation Committee and/or government) on the process/logistics of conducting the recommended technical threats assessments as part of overall Source Protection Plans.

As part of the development of a threats assessment process, the Technical Experts Committee will also consider the role of Provincial Water Quality Objectives (PWQOs) as a risk management tool for drinking water source protection. The Technical Experts Committee's recommendations on approaches for the peer review of existing PWQOs and priorities for development of new PWQOs should also be included in its report. The Technical Experts Committee will aim to complete its recommendations within six months. When considering the role of PWQO's, the Experts will also consider the interface between water quantity and resulting quality and linkages to fisheries and other "ecological" plans such as may be relevant.

When formulating its advice, the Technical Experts Committee will consider:

- the recommendations of Justice O'Connor's Part II Report of the Walkerton Inquiry;
- the recommendations of the Advisory Committee on Watershed-based Source Protection;
- comments received in response to the EBR posting and the results of other government consultation on the Report of Advisory Committee on Watershed-based Source Protection;
- related Nutrient Management issues being considered by the Nutrient Management Advisory Committee and where feasible provide advice to the

Nutrient Committee to harmonize recommendations where possible.

It is expected that the Technical Experts Committee, once formed, will adhere to these Terms of Reference that outline: mandate, areas of work, timing, attendance, responsibilities of members, replacements, accountability, decision making, confidentiality and meeting schedule.

Areas of Work

The Technical Experts Committee is responsible for providing advice on a threats assessment process, according to the recommendations of the Advisory Committee and as outlined below. Other areas of work may be identified with concurrence of the co-chairs of the Technical Experts Committee.

The Threats Assessment Process is to include the following elements:

- Threats Inventory and Classification
- Water Resource Vulnerability Assessment
- Water Resources Sensitivity Assessment
- Risk Analysis and Risk Management Methodologies

Technical Experts Committee will be requested to make decisions and recommendations on the following four (4) major tasks, with application to water as it relates to current and future usage (both ground water and surface water) for a drinking water supply:

1) Threat Inventory, Classifications and Ranking

1. threats/reference list, threat categories definitions, criteria for ranking threats as well as a definition for "significant direct threats" as recommended by O'Connor.

2) Vulnerability Assessment

2. definition of vulnerable areas, scale of assessments required, model/process to determine vulnerability, criteria for classifying level of vulnerability

3) Identification of Sensitive Water Resources

3. definition of "sensitive water resource", how to address cumulative impacts, criteria for ranking risks

4) Risk Analysis and Risk Management (RM)

4. evaluation of existing RM strategies and best available science, methodology to match RM strategies with predicted risk, define prescriptive RM, prescriptive RM approaches for sensitive water resources, requirements for post-RM monitoring/review of Source Protection Plans and threat assessments.

PWQO Review

Separate but linked to the drinking water analysis the Technical Experts will consider the recommendations of the Advisory Committee with regard to ecological protection and the role of protecting “water” that is not used for drinking water supplies but which may have other significant and important “characteristics”

- recommended approaches for peer review of PWQOs and priorities for new PWQOs, including consideration for whether a similar process such as is being suggested for drinking water protection should be applied to surface waters not being utilized for drinking waters, including the four (4) steps noted above,

Decisions and recommendations on logistical/process issues related to incorporating the threats assessment into the source protection plan will also be required:

Data requirements

- minimum acceptable data quality/ quantity
- consideration for uncertainty and how this should be addressed in recommending risk management strategies

Format for inclusion within the SPP

- appropriate details to be included in templates for reporting on each component of the threats assessment

Technical guidance

- identify need for development of guidance documents for completion of the threats assessment process for local SPP Committees
- considerations for the “reviewers” of the Plans when submitted to the MOE for review and approval

Implications for legislation

- recommendations on elements of the threats assessment process that need to be embodied in legislation, consideration of existing/related legislation - these will be communicated to the Implementation Committee for their review

Revisions

- process/schedule to accommodate appropriate re-evaluation of risks and risk management approaches within the Source Protection Plan as needed,
- Considerations for certain water resources that should be given priority in the planning process should a phase-in of the overall strategy be deemed necessary

Timing
The Technical Experts Committee will be requested to complete its work within six to nine months. Two preliminary reports will be required from the Technical Experts Committee in advance of its final set of recommendations.

To facilitate the work of the Nutrient Management Advisory Committee, the Technical Experts Committee will provide that committee with DRAFTS of the following materials (date to be determined):

- Threat Inventory and criteria to be used for ranking threats;
- Definition of "vulnerable areas" and associated technical rationale;
- Definition of "sensitive water resource" and associated technical rationale; and
- Overview/outline of the threats assessment process.

Committee Membership/Responsibilities of Members
The members of the Technical Experts Committee will be appointed by the Minister of the Environment, based on their science/technical expertise and/or experience in matters related to Source Protection Planning and their ability to contribute to the technical development of a Threats Assessment Process. Members may be from government, academia, private industry, conservation authorities or non-governmental organizations.

The Technical Experts Committee will be co-chaired by the ADM of the Environmental Sciences and Standards Division, MOE and a representative from the Conservation Ontario.

Committee will be made up of 10 -15 representatives.

Province (ADM to sit on the Technical Experts Committee ex-officio):
- The province will be represented by the co-chair from the Ministry of the Environment

Conservation Authorities:
- A co-chair will be appointed to the committee from Conservation Ontario

Other members:
- To be appointed at the discretion of the Minister

Under direction of the co-chairs, the Technical Experts Committee will: review options for the development of the threats assessment process and provide direction, advice and expertise, review and approve workplans, drafts of the reports prepared for government on recommendations for legislation and the threats assessment process, provide periodic updates for the Implementation

Committee as needed, and provide reports to the Nutrient Management Advisory Committee as determined to be appropriate.

Confidentiality
Discussion on the appropriate confidentiality procedures took place at the first meeting. It was determined that confidentiality agreements would not be sought from the members, as it was recognized that the members may wish to seek advice from colleagues on specific topics of interest. Further the members are expected to use their discretion and professional respect when information is provided. In the event that the government wishes to seek the comments of the Committee on items such as legislation/regulation prior to general release, confidentiality will be requested.

Accountability
As recommended by Justice O'Connor and the Advisory Committee, the ultimate responsibility for ensuring source water protection is with the Province, specifically, the Ministry of the Environment, notwithstanding the shared responsibility of all governments and stakeholders. Therefore, all materials drafted by the Technical Experts Committee will be reviewed and approved by the ADM of Environmental Sciences and Standards Division of the MOE and/or their designate.

Decision Making
The committee will make decisions based on consensus. On issues where consensus can not be reached, the committee shall adopt the position of the majority and note this in the recommendations of their report(s). In the interest of keeping to the agenda, timelines and mandate of the committee the Co-chairs will decide when to move from consensus based decision making on a particular issue to a majority vote (as necessary).

Spokesperson for the Technical Experts Committee
Although members are free to provide comments to the media at their own discretion, in the event of a media enquiry regarding the operation of the Technical Experts Committee itself, all members agree to refer the media to the Co-chairs or their media relations support staff. A media relations protocol will be established to ensure consistent communications for all committee members, in particular the co-chairs.

Replacements
Each member is allowed to delegate one alternate only. This alternate would attend sessions which the appointed member was unable to attend. It is the member's responsibility to brief their alternate and the alternate is expected to follow the scientific and technical views of the member. Following the January 22nd meeting, the infrequent use of alternates "when necessary" was reviewed by the Co-chairs and felt to be appropriate.

Agenda
Although the co-chairs will have specific proposals, on which they will want input from the Technical Experts Committee, the members are free to suggest additional issues and topics for consideration. The Technical Experts Committee will meet once or twice a month.

Secretariat
The Secretariat will reside within the Lake Simcoe Region Conservation Authority and will provide administrative support, assist with the coordination of activities to be undertaken by the Technical Experts Committee and the production of deliverables required under these Terms of Reference.

The Secretariat will:
1. co-ordinate arrangements for meetings;
2. prepare agendas for meetings;
3. ensure that summaries of meetings are kept, approved by Technical Experts Committee members and distributed on time.

Support to the Technical Experts Committee

Technical Working Group
The Province will establish a Technical Working Group that will be comprised of staff from the Ministries of Environment, Natural Resources, Agriculture and Food and Municipal Affairs and Housing and others as appropriate. The Technical Experts Committee will consider the need for additional expertise on the working group.

The mandate of the Working Group will be to enable informed decision making by the Technical Experts Committee. The working group will act as an information resource by preparing drafts and options for the committee's consideration, providing comprehensive analysis and responding to comments/requests of the Technical Experts Committee. Staff from outside the OPS may also be asked to join the Threats Assessment Working Group depending on required expertise (e.g. Conservation Authority).

Areas of work will include:
1. preparation of orientation materials for the Technical Experts Committee;
2. development of draft workplans for Technical Experts Committee consideration/approval;
3. facilitating Technical Experts Committee decision making through development of options for creating a threats assessment process which includes the components outlined above (under Areas of Work for the Technical Experts Committee);
4. providing information (and follow-up on requests for additional information) to the Technical Experts Committee to enable decision making;

5. supporting liaison of the Technical Experts Committee with other government advisory bodies as needed;
6. other, as requested by the Technical Experts Committee.

Membership

The Technical Working Group will be led by a staff member from MOE, Environmental Sciences and Standards Division, who will report directly to the Technical Expert Committee Co-chairs. Working group members will be assigned to project teams which will work to support the development of the various elements of the threats assessment process, according to workplans that will be developed. Alternates who are familiar with the work and have the technical background will be permitted. Several technical staff from key stakeholder groups will be invited to participate on the Working Group; such participants will be asked to respect the confidentiality provisions as are noted above for the Technical Experts Committee.

Appendix 3. Threats Subcommittee

Threats Sub-Committee Members

<u>TEC members:</u>
Bob Clay, retired scientist (Ducks Unlimited)
John Fitzgibbon, University of Guelph
Eric Hodgins, Region of Waterloo
Bruce MacDonald, retired scientist (Agriculture Canada)

<u>Staff members:</u>
Harry Manson, MOE

1. Introduction

The committee was tasked with providing a proposed approach to identification of watershed and local threats to be used as part of the risk analysis for source protection. Discussion at the Technical Experts Committee has included several methods for identifying threats and undertaking risk analysis on the inventory. The committee has decided that threats are to be identified using a combination of assessment of watershed and local drinking water management issues, and an inventory of potential threats in the watershed that is linked to a provincial potential threats database. This document summarizes how this data is to be compiled and the extent of information to be collected through this process.

2. Proposed Approach

Understanding the threats to drinking water requires information regarding the type and location of the potential threats. Information is available at several scales and/or through different jurisdictions including local, municipal, watershed and provincial. The level of detail collected for any threat may also vary over time for example, more detailed data gathered to better characterize the threat following the initial development of the Source Protection Plan (SPP) or additional data gathered as required to implement risk reduction measures during Plan implementation. Source Protection Planning Committees (SPPC) will need to integrate all this information if they are to be successful in identifying, evaluating and reducing risks associated with the threats. A consistent approach is needed to gather and integrate information into a single watershed-based database to facilitate implementation decisions.

For each watershed source protection area, threats will be identified using the following approaches:

- issues arising from assessment of watershed characteristics, drinking water supply concerns, local knowledge, *etc*.;
- undertaking a potential threat inventory based on external data sources and linked to individual properties within the watershed; and

- linking properties in the watershed with a generic, Provincial database of threats and related properties.

Below is the description of each method, how information is to be collected, and how information is to be integrated into a single dynamic database.

Issues Approach
Using existing issues in the watershed to identify threats is similar to the process currently undertaken for watershed management in Ontario. Issues will be identified by the source protection planning committee and/or any of its subcommittees through a qualitative and quantitative analysis of source water protection issues in the watershed. These could include:

Water allocation issues
Trends in municipal/communal drinking water systems
Conflicts with other water resource users
Historic problems or information
Others

Once an issue is identified, action would be taken to identify existing threats in the watershed that contribute to the issue, e.g. information gathering. The provincial threat support database is a tool that may be used to identify existing threats in the watershed. The threat information would then be used during the risk analysis stage of source protection planning to identify risk reduction options and develop a risk reduction or management plan.

Potential Threat Inventory

Each SPPC will undertake an inventory of potential threats as part of the development of a source protection plan. This inventory will use existing sources of information that are available digitally or other data sources which could be readily transferred to a digital format. The inventory will rely on these data sources and collection of new field data will be limited to what necessary to check the accuracy of the data in general. The data sources will include but may not be limited to the following.

Data Source	Description
Dun and Bradstreet	Private database of businesses
Regulation 347	MOE registry of waste generators
Technical Standards and Safety Authority	Commercial Fuel Storage Tank registry
Known Contaminated Sites	MOE and municipal/region list of known soil and ground water contamination sites
MOE Closed landfills	MOE Inventory of closed landfills and coal tar sites
Record Of Site Conditions	MOE and municipal/region list of properties where Record Of Site Condition completed as part of site clean-up
Sewer-Use By Law Approvals	Sites with municipal discharge approvals to sewers
Solid Waste Disposal Approvals	Sites from where non-hazardous waste was generated and approval was given to dispose at local landfills
Spill Records	MOE/municipal records of spills
Storm water Ponds	Municipal detention/infiltration ponds
Cemetaries	Municipal zoning/lists
Biosolids and non-municipal sludge Application Sites	MOE list of farms where municipal biosolids, and non-municipal sludges are spread
Intensive Livestock Operations	OMAF list of farming operations with large numbers of livestock
Transportation Yards and Salt Storage Facilities	Municipal records
Pipelines	Municipal records of oil and gas pipelines
MOE Certificates of Approval, Orders, and Waste/PCB Disposal Sites	MOE records
Septic Systems	Public Health and MOE records
Rural Point Inventory	Air photo analysis to identify farm types
Rural Non-Point Inventory	Soil sensitivity mapping, crop application information from Census Canada

This information will be compiled into a series of GIS layers, one layer for each source of data. As new data is collected in future years or where more detailed inventories are collected during implementation of the source protection plan, new GIS layers will be added. The important point is to ensure that all sources of data are collected and maintained because historic activities are as likely or may be more likely than current activities to contribute to water supply and quality problems.

Provincial Threat Database

The provincial threat database will be compiled by the province and will link land uses (through NIACS or equivalent industrial code) to chemicals used and properties of chemicals. Based on this information, each code will be ranked according to potential for impacting drinking water sources. It is intended that NIACS-based land uses will be linked to individual properties so that chemicals of concern and the activities and/or manner in which these chemicals are handled can be categorized for each property identified in the local threat inventory. Many properties will have more than one NIACS code assigned to the property reflecting the variety of activities occurring at existing businesses and historic activities previously undertaken at the property.

Integration with Risk Management

The compiled information will be used as the basis for risk management. In general, threats derived from the Issues Approach, some parts of the Threats Inventory, and the highest threats from the NIACS cross reference would require the development of risk management options. The rationale for this selective approach is as follows:

- Issues, by their nature, have been identified as requiring further management.

- The local threats inventory will identify some potential activities and/or sites that should be considered for further management. The degree of further management options could be undertaken using an “issues-type” approach or a site-based approach. An example of an issues-based approach is development of a septic system inspection program. An example of a site-based approach would be clean up of a contaminated site that is within a sensitive water area.

- The Provincial Threat database would be used to supplement existing information from the threats inventory rather than as a criterion in isolation. For example, a site that has a high NIACS rank and a Certificate of Approval for air or water discharge could be identified for risk management.

It is anticipated that the identification of threats arising from the above process will be used primarily to inform the SPPC of the threats that require some degree of risk mitigation. As information is compiled, it would be integrated into the local threat inventory. The local threat database would be an evolving/dynamic database where more detailed information gathered through implementation of the source protection plan (SPP) or specific risk reduction measures could be placed. It is not the intent to collect detailed site information early in the process for the entire watershed, rather it is the intent to allow incorporation of information that the SPPC might find critical for use in developing risk management approaches in the SPP. The integrated database needs to be easy to use so that it can be used and updated as necessary by committees.

3. Discussion Items

The Threats Sub-committee recommends that the Provincial government design, develop, maintain and support a database that SPPs can use to integrate provincially held threats information with locally held and developed threats information. Specifically, the sub-committee recommends that:

Discussion Item 1

The basic conceptual model be land parcel based and provide a contiguous spatial fabric across the planning area. In simple terms the linkage of information to be modelled is as follows:

- **Land Parcel, land use(s), land based activities, associated threats, profile of threats containing a list of specific contaminants or risk agents and associated properties and characteristics**

- **Issues of water quality threats are more likely to be related to contaminants and their properties, whereas issues of water quantity threats are most likely related to amounts of water required for various land use activities and its subsequent fate (i.e. consumption, degradation, disposition, *etc*.).**

- **The model should include the capability to accommodate temporal aspects of threats as well as cumulative and interaction considerations. Information should be organized in such a fashion that a query can be addressed at any stage in the information chain or planning process and in such a way that the questions can be followed in either ascending or descending levels of detail or spatial direction.**

Discussion Item 2

The database organization and structure design and the data model should be robust enough to serve the provincial needs for a consistent approach to gather and integrate information into a single watershed-based planning tool (at the broad general level). They should also have sufficient functionality to allow upgrading as more detailed information is acquired and serve the needs of local committees as they follow through the source protection planning activities, regardless of whether they have source protection and threats assessment activities underway. SPPC's may choose to adapt the general model to meet local needs. Communities that are well advanced with their own source protection planning activities may use the model as a 'check list' of features and information which these

communities may wish to add or gradually incorporate over time.

Discussion Item 3
The Province develop and maintain a general provincially held inventory database with associated threats' profiles. This database would be maintained by the province and would provide the general level list of threats associated with land use activities. The database would have associated with it a profile for the threats that would list the potential contaminating chemicals, pathogens or physical agents and provide a list of their properties and characteristics; or, for water use considerations, detail the use and consumption requirements. This list would be fairly comprehensive at a general level and have the capability to incorporate 'synonyms' for threats where different communities or different secondary data sources (e.g. census, municipal property tax roles *etc*) identify the same threat with a different name and be maintained and standardized at the provincial level. The database needs to be easy to use so that it can be used and updated as necessary by committees.

Discussion Item 4
The database should be developed to allow local information to be integrated with the provincial information so that SPPCs are able to develop as complete a list of potential threats as possible. The Sub-committee notes that information compiled into a database should be based on data arising from existing sources and only necessary information be collected. But where information is collected it should be able to be incorporated into the data structure.

Discussion Item 5
That SPPCs use the provincially held and local data in the database to identify known water threats in the watershed.

Discussion Item 6
That the province commit to the long-term maintenance of the database and that the database continually be improved and updated by the addition of new data and information so that there is increasing accuracy and completeness available for future source protection planning.

Appendix 4. TEC sub-committee on well vulnerability

Vulnerability Subcommittee Members

TEC members:
Marg Misek-Evans, Oxford County
Eric Hodgins, Region of Waterloo
Dr. Michel Robin, University of Ottawa
Dr. David Rudolph, University of Waterloo
Dr. David Sharpe, Geological Survey of Canada
Steve Holysh, Halton Region Conservation Authority

Staff members:
Barbara Anderson, MOE
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Rick Vantfoort, MOE
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1. Introduction

The Vulnerability Subcommittee undertook to develop a practical approach for evaluating the vulnerability of a ground water receptor, specifically a water well, to contamination from a potential surface source(s). In recommending the approach presented herein, several main issues were considered:

a) Make optimum use of the progress to date in the Province of Ontario through the Ground water Resources Studies, the well-established work on wellhead (and aquifer) protection that has been completed in several jurisdictions and the experience available on the previous attempts to implement vulnerability assessment in Ontario.

b) Remain conscious of the practical reality of implementing new approaches to wellhead protection within the municipal structure with specific awareness of the level of acceptance already achieved for previous approaches.

c) Attempt to develop an approach with methodologies that are transferable between the local scale wellhead analysis and the more regional aquifer assessment, and that will give results that are comparable from one region to another.

d) Take advantage of experience and approaches from other jurisdictions (eg. USA and Europe) and attempt to incorporate the most current scientific understanding and methods (e.g. USGS, 2002; National Research Council, 1993).

e) Consider how the recommended protocols will fit with the threat and risk assessment components of the overall Source Water Protection Plans.

Within the context of the considerations presented above, the Subcommittee has developed a set of recommendations regarding wellhead vulnerability for consideration by TEC. These are outlined in brief form below.

Building on the work of the Pathogen Sub-Committee, the Threats Sub-Committee and the Threats Assessment Working Group (TAWG), this Sub-Committee has considered vulnerability in the context of identified "threats of Provincial concern". Guidance is provided regarding the application of wellhead vulnerability assessment to such threats to help define appropriate risk management measures for future and existing (including historic) land uses and activities.

2. Vulnerability of a Well to Contamination

The primary application of the vulnerability assessment involves three main components:

a) delineation of surface areas around wells or well fields (Wellhead Protection Areas, WHPA) where new land-use activities should be controlled or restricted to minimize potential impacts to ground water quality and where current and past land use activities should be investigated to assess the potential threat that they pose to the receptor. *(Discussion Items 1, 2, 3 and 4)*

b) perform a semi-quantitative evaluation of vulnerability of the land area within the WHPA with respect to contamination of the well, to assess the level of risk associated with various land uses within the WHPA. *(Discussion Item 5)*

c) prepare a threat (risk) prioritization within the WHPA, based primarily on the vulnerability evaluation ((a) and (b) above), where specific proactive or reactive initiatives should occur as defined within protocols established for risk management (some guidance provided). *(Discussion Items 2, 6 and 7)*

2.1 Delineation of Wellhead Protection Zones

As indicated in a) above, the initial stage in the vulnerability assessment for a well or well field is delineating the surficial extent of the wellhead protection areas (WHPA).

Discussion Item 1

1A. The preliminary delineation of the WHPA's should be based on the classical "Time of Travel" (TOT) approach where, through numerical modelling, reverse-travelling tracer particles released at the well screen are permitted to migrate by advection backward through the

aquifer system for prescribed periods of time (eg. 2 years, 5 years *etc.*). After each time period of interest, the subsurface position of each particle is projected vertically to the ground surface and a line encompassing all of the surface-projected particle positions is drawn at ground surface. The land area within this line is referred to as a WHPA associated with the given TOT. When establishing TOTs, several pumping scenarios should be modelled to account for anticipated changes in managing the supply. The resulting TOT line should be drawn at the outer limit of the modelled scenarios.

1B. The modelling should be conducted in either two or three dimensions depending on the local availability of data. The modelling approach selected must be reviewed and approved by a third party technical group (eg. Source Water Protection Technical Review Committee (SWPTRC)). The sub-committee likens the SWPTRC to the independent bodies that undertake NSERC reviews. Alternately, a similar body (with the required expertise) could be established within the MOE.

<u>Rationale</u>

a) This approach to modelling WHPAs has been used throughout Ontario in the past and is well established and fairly well accepted in main jurisdictions already. The approach and methodologies required to determine the TOT's are also extensively documented. It is also an approach that has been used in many areas internationally over an extended time period.

b) The TOT's provide a conservative approach for decision making that minimizes the potential impacts of the uncertainty with which the surface and subsurface conditions are known and appropriately accounted for in the quantitative assessment.

c) Although it is clearly acknowledged that numerical modelling tools require a significant quantity of good quality data and expertise in order to reasonably represent field conditions, numerical modelling is highly recommended. It can be based on as little information as any of the other more simple approaches (ie. fixed-radius and uniform gradient analytical methods); but it offers the great advantage that it can be continually improved as new data become available. The development of a numerical model is advantageous in that it promotes the continual acquisition of good quality data. It also provides the Source Water Protection Committee with a management tool that will be continually improved, and that will ideally evolve into an effective tool used to inform other water related decisions. The use of numerical models will also encourage consistency across the Province.

Within the proposed approach, specific TOT's should be prescribed for risk management purposes as outlined below. For each TOT, the Sub-Committee provides guidance regarding additional risk assessment and risk management measures. While the guidance is offered primarily in the context of threats of Provincial concern, such measures can also be applied in the context of locally-identified threats.

Discussion Item 2

2A. Bacteriological/pathogenic protection zone: Use the 2-Year TOT capture zone, as determined by the Pathogen Sub-Committee. This is longer than the 50-day zone currently used in the "Ground water Under the Influence of Surface Water" (GUDI) assessments because of new information from the microbiologists on the persistence of bacteria and pathogens in ground water. The entire area within this TOT zone will be considered to be the highest level of vulnerability, with respect to bacteriological/pathogenic contaminants. A 100 metre pathogen prohibition area around active wells is also recommended by the Pathogen Sub-Committee. This would be a simple straight-line measure from the well, not dependent on modelling.

Within the 100 metre pathogen prohibition zone, new sources of pathogens such as septics, livestock manure and biosolids application should be banned and existing sources removed. Within the 2-year TOT, new septic systems may require greater site-specific analysis prior to establishment and/or more sophisticated systems, such as the EcoFlow system. Established systems within this TOT may need to be subject to frequent inspections and regular tank evacuation. Land application of livestock manure and/or biosolids within the 2-year TOT should be subject to nutrient management plans and farm water protection plans.

2B. DNAPL Protection Zone: Use 5-year TOT capture zone for protection from Dense Non-Aqueous Phase Liquids (DNAPLs). This 5-year time frame is based on the approximate time required to replace the well (remediation technology is presently incapable of dealing satisfactorily with DNAPLs). The entire area within this TOT zone will be considered to be the highest level of vulnerability, with respect to DNAPLs. Additional recommendations are required regarding the development of a standard list of DNAPLs and protocols regarding risk management measures for uses and activities involving these substances within the 5-year TOT.

With respect to the development of a standard list of DNAPLs, it is anticipated that such a list will also define the quantity of each substance subject to regulation within this TOT. Regarding potential risk management measures, it is recommended that new land uses or activities using or storing DNAPLs, in the quantities identified on

the standard list, be restricted or banned within the 5-year TOT. Regarding existing uses involving DNAPLs within this area, intensive management and possibly monitoring should be undertaken. Existing uses may be required to undertake a contaminant management plan that will identify appropriate management practices for the use or storage of DNAPLs on-site. Municipalities may consider enforcing such practices through a licensing program, with licenses identifying maximum quantity and storage requirements, for example.

2C. **The 5-year TOT zone should also be the defined area where the threats assessment is focused for all other (non-DNAPL or pathogen) contaminant sources in the vicinity of the well. This will be the zone of highest priority for evaluation of current and future risk assessment for the well or well field and where the Source Water Protection response will be the most significant. The TOT process will be used in conjunction with the wellhead vulnerability analysis (Section 2.2) to inform the risk assessment process (not to alter the 5-year TOT). The addition of vulnerability assessment will not change the extent of the classically modelled TOT, but helps to focus additional assessment and/or risk management in those areas of highest potential impact.**

Once the risk analysis is completed, each specific high-risk use may be subject to additional site assessment to further define the magnitude of the specific risk through such means as forward particle-tracking. This will assist in defining appropriate risk mitigation measures (similar to those identified in 2. above) and also, additional ground water quality monitoring in the immediate vicinity of the specific site.

2D. **A 25-year TOT should be defined to delineate a secondary WHPA within which less stringent protocols are followed related to the risk mitigation process. The TOT process will be used in conjunction with the wellhead vulnerability analysis (Section 2.2) to prioritize the relative risk (as in 3. above). The 25-year limit is recommended because it relates to a typical long-term municipal planning horizon.**

Within this area, existing threats of provincial concern should be identified and considered in the long-term ground water quality/quantity protection planning. New threats of provincial concern may be deterred from establishing in this area or provision made to carefully manage them within the scope of the source water protection plan.

2E. The entire capture zone should be defined for long-term planning purposes, as well as to inventory existing uses (particularly historic uses) that may pose a threat to the well.

Discussion Item 3

As part of the TOT assessment, the party conducting the assessment should provide a quantitative evaluation of the level of confidence associated with the delineated TOT areas and assessment of wellhead vulnerability (Section 2.2).

Rationale

This evaluation may influence the final delineation of the TOT area and should also be taken into consideration when developing risk mitigation strategies for these areas. A lower level of confidence in the TOT should also serve as the trigger for collection of additional data and upgrading the model at the 5-year review interval. As confidence in the modelling rises, appropriate adjustments to the risk mitigation strategy for a WHPA can be made.

Discussion Item 4

The delineation of the WHPA's should be reassessed during the 5-year review of the Source Protection Plan and/or when there is a significant possibility that the WHPA will be changing as a result of some activity such as changes in ground water extraction in the vicinity of WHPA.

2.2 Vulnerability of the Well to Land-use Activities Within the WHPA

The TOT areas as determined above, provide a conservative approach to delineating source protection areas for municipal wells. In cases where Source Water Protection Committees deem it appropriate, the TOT areas can be further investigated through a wellhead vulnerability assessment. In order to assess the vulnerability of the water supply system to past, current and future specific land-use practices within the WHPA, the entire pathway from release at ground surface to arrival at the well should be taken into consideration. This additional level of information will provide decision makers with an enhanced understanding of the relative level of vulnerability within the defined WHPA. This information is not available through the TOT analysis alone. The addition of wellhead vulnerability assessment will not change the extent of the classically modelled TOT, but enhances the level of understanding of vertical travel within each TOT and can be used to inform the risk assessment process under source water protection. Of specific interest will be:

a) improved ability to evaluate a proposed new land-use activity within a WHPA through a more complete understanding of the level of vulnerability associated with the specific location in question.

b) prioritizing the level of threat and subsequently the action requirements associated with existing and past land use practices within the WHPA (Discussion Items 2 and 6).

<u>Discussion Item 5</u>

5A. A semi-quantitative approach should be taken to evaluate the degree of protection provided by the vertical travel path from ground surface, through the unsaturated zone and into the aquifer unit being assessed within the WHPA, subject to data availability, the level of understanding of the local system and knowledge of the threats in the WHPA. The wellhead vulnerability assessment will not change the extent of the classically modelled TOT.

5B. The recommended approaches that can be used for this assessment range from conducting no additional vulnerability analysis up to complex three-dimensional modelling. The methods outlined below are listed in increasing order of complexity and will require progressively more information:

- **a. uniform high vulnerability everywhere throughout the specified WHPA. (use TOT's without additional vulnerability assessment.)**
- **b. simple indexing system based on surficial soils, basic hydrogeologic conceptual model and depth to target aquifer.**
- **c. calculation of average vertical advection times from ground surface to top of aquifer unit or particle depth from the TOT model using estimated or known vertical hydraulic gradients and average porosities.**
- **d. fully three-dimensional modelling allowing reverse-travelling particles to migrate to the ground surface thus providing an estimation of the Surface to Well Advection Times (SWAT).**

5C. A technical review body (eg. SWPTRC) will provide advice and review on a case-by-case basis, on the method to be selected. In subsequent revisions of the local SPP, a more advanced approach can be adopted as information permits.

<u>Rationale</u>

A benefit of methods (c) and (d) in Discussion Item 5B. is that they will produce results that are quantitative and comparable across the province. The SPPC, in consultation with municipalities, will determine the desired level of wellhead vulnerability assessment. For example, smaller rural supplies with relatively small capture zones may not require any vulnerability assessment if no threats of Provincial concern are present and the municipality is prepared to take action to prevent new threats from establishing within the WHPA.

<u>**Discussion Item 6**</u>

The application of wellhead vulnerability assessments to TOT zones can be used to assist in determining where more prescriptive tools are required and also where voluntary initiatives can be undertaken to achieve some level of protection in less vulnerable areas. Once threats are identified within the WHPA, the vulnerability assessment can be used to direct additional analysis and/or more aggressive action plans for threats (existing and historical) in highly vulnerable areas. Similarly, the wellhead vulnerability assessment can be used to direct future threats away from highly vulnerable areas. (See also Discussion Item 2)

<u>**Discussion Item 7**</u>

Several pilot projects should commence immediately to demonstrate and evaluate the utility of the approaches presented in Discussion Items 1 to 6. These projects should focus on areas where considerable work has already been done through the Provincial Ground water Studies (eg. Oxford, Waterloo, Oak Ridges, Eastern Ontario and Temiskaming Shores).

<u>Rationale</u>

These projects will establish protocols to define variations in wellhead vulnerability based on, for instance, vertical travel time. The pilots will be relied upon to provide guidance on data collection and in further defining data needs or improvements to existing data sets. The projects will also demonstrate and report on the reliability and validity of each approach and illustrate how the results can ultimately be used. Finally, such pilot projects can be used for education and training for SPPCs.

2.3 Additional Considerations for Prioritizing WHPA's

Building on the first two steps of delineating the wellhead protection zones (2.1) and assessing wellhead vulnerability (2.2), the next step proposed is the consideration of additional, more localized, criteria that can be applied to prioritize WHPAs for additional analysis and/or the approach to risk mitigation (Discussion Items 2 and 6). Criteria that may influence the prioritization of WHPAs include:

- the importance of the well to the supply in terms of volume, quality or longevity, i.e. how long the well is anticipated to be on-line,
- whether the well is showing any early signs of contamination,
- whether the well was found to be a GUDI well,
- the level of uncertainty associated with the modelling or vulnerability assessment or
- other criteria important to the community.

Such prioritization can inform decisions at the SPPC and municipal levels regarding where to target resources for additional analysis and also the approach to risk mitigation or management.

3. Risk Assessment and Reduction Strategies for Delineated Vulnerable Areas

As part of the development of the recommendations for delineating vulnerable areas for WHPAs, and to a lesser degree for regional aquifers, the sub-committee found that it was necessary to consider how the recommended protocols will fit with the threat and risk assessment components of the overall Source Water Protection Plans.

In so doing, a table was developed which harmonizes the delineated areas with the source water protection intention(s), the proposed delineation approach, the risk assessment and risk reduction strategies that the subcommittee thought might be applicable in each identified zone. This is summarized in table 5.1 and generally indicates where prescriptive tools are likely to be utilized and where lesser initiatives, such as incentives and voluntary actions, may be implicated in source protection planning within the delineated areas.

The table is intended to inform the process by which the delineated areas are derived at, as well as the potential risk actions considered appropriate after these areas have been defined. It is not intended to be directive in any particular mitigative tools which might be applied to achieve the source protection plan outcome.

SWAT calculations

Surface to Well Advection Times (SWATs) can be calculated as the advection time from the ground surface to the water table in the unsaturated zone (UZAT) plus the advection time from the water table to the well (WWAT).

In considering:

- the fact that not all threats (leaks/spills) occur at ground surface but rather may occur at some depth below the ground surface from underground pipelines or tanks; and
- the fact that municipal supplies are one of the most significant drinking water source in that they service many individuals, and therefore a conservative approach is required,

it is recommended that the unsaturated time of travel only be considered and incorporated into the advective travel time calculations outside of municipal wellhead protection areas (i.e. within the more regionalized aquifer vulnerability mapping exercise). Therefore WWAT is the sole consideration within the wellhead protection studies.

The WWAT can be obtained from the computer models that were used to calculate capture zones: they are the “travel times” of the reverse particle tracks from the well to the water table. The model can be run with reverse particle

tracks to a predetermined time; and the time and location where the particles arrive at the water table is recorded (the way that this may be accomplished depends on the software).
Summary of effort required for SWATs (over and above the work undertaken for the Municipal Groundwater Studies (2000):

- Re-run steady-state flow model to obtain WWATs,
- re-run model with several plausible scenarios and present composite maps (more details below).

Alternate route when the model cannot be re-ran:

The following is an approximation to be used only when the model cannot be re-ran because it de-couples the vertical component of flow through the overlying layers from the horizontal flow and is much more approximate. The SWAT be estimated from the surface to aquifer advection time (SAAT) and the TOT:

$$SWAT = SAAT + TOT$$

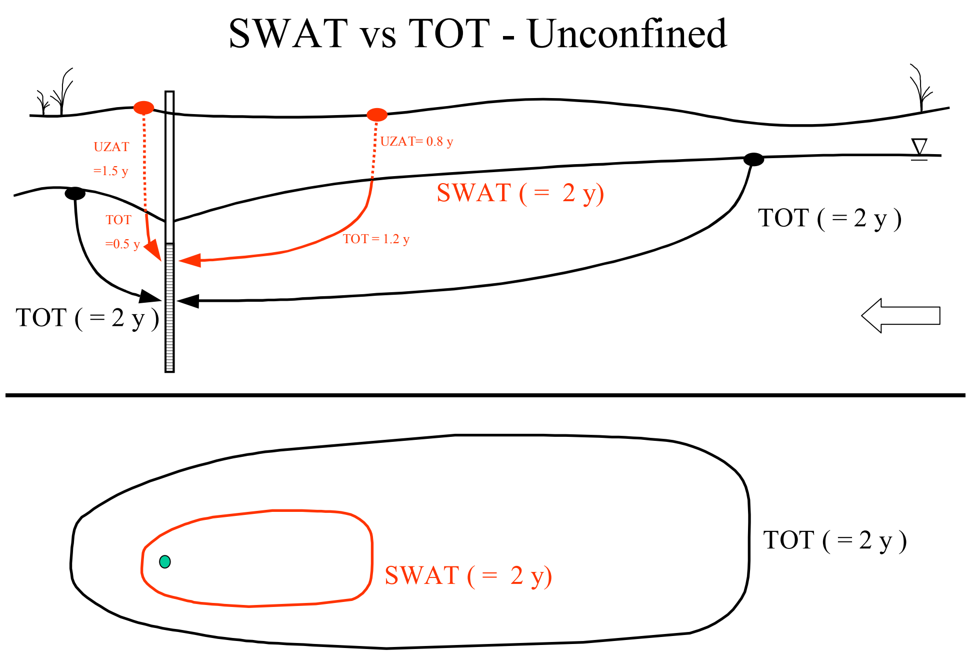
where: SWAT = Surface to Well Advection Time
SAAT = Surface to Aquifer Advection Time
TOT = traditional time of travel

The SAAT is a measure of the intrinsic vulnerability of the aquifer to contamination and is explained in detail in the following appendix.

Difference between TOT and SWAT

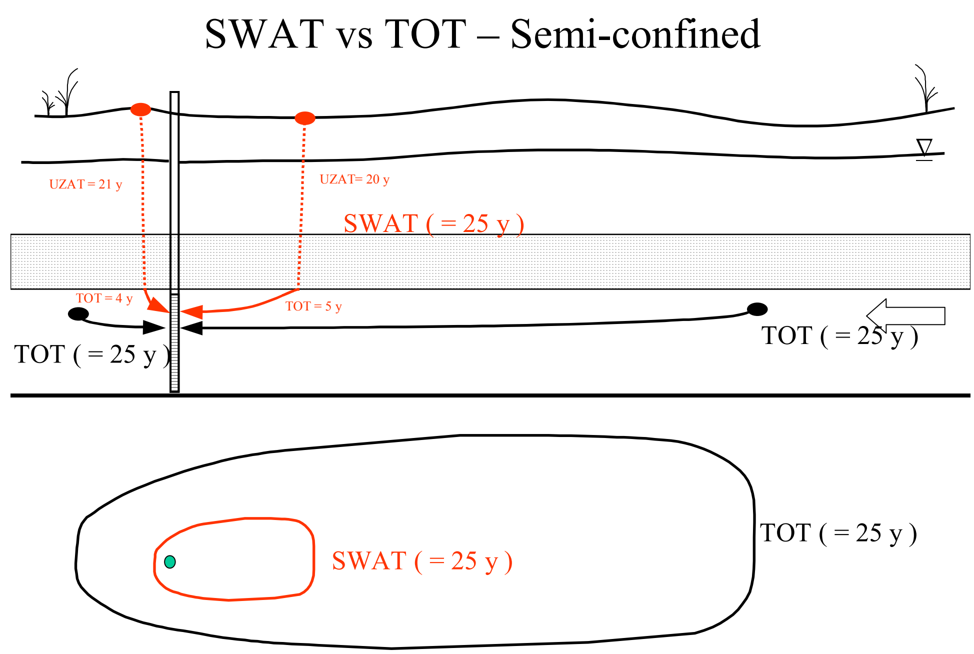
SWATs are what a lay person would understand as a travel time to the well: the actual average time that it takes for a water tracer molecule to travel from the ground surface to the well. Conversely TOT's are plan-view surface projections of reverse particle tracks to the surface at a given time. The difference between the two concepts can be illustrated with two scenarios: the unconfined case and the semi-confined case.

Example 1 unconfined aquifer:
The following diagram illustrates the difference between TOT and SWAT in an unconfined aquifer for a given value of TOT or SWAT (2 years for this illustration) . The difference is simply the time required to travel in the unsaturated zone (UZAT). If this time is short then the SWAT and the TOT will be nearly identical, and vice versa, if the UZAT is long then the difference will be large.



Example 2 semi-confined aquifer:

For semi-confined systems the SWAT zones will possibly be very different than the same TOT zones. In the extreme, for a perfectly confined system (unless they are located near a recharge zone) the SWAT isochrones may be located beyond the boundary of the domain, indicating that the waters entering the well are very old.



Usage of SWAT maps and associated uncertainty maps

Maps of SWATs in the area around the wells will provide a direct physically-based assessment of the intrinsic vulnerability of the well to contamination from the surface. The SWAT zones can be used in exactly the same way as capture zones were used, except that there is no need to consider aquifer vulnerability in a subsequent step (it is already part of the calculation).

Uncertainty in SWAT maps can be estimated by superposing several SWAT maps for several sensitivity analysis scenarios and kriging the composite map to obtain a map of mean SWATs. A standard error map can be produced by mapping the square root of the kriging variance estimates divided by the mean SWATs (multiplied by 100 to obtain % error). The process produces two maps: (1) mean SWATs and (2) uncertainly of the SWATs. Planners (or users) should use both maps in their decision-making. A decision / action grid could be designed that would include uncertainty. For example, high uncertainty areas could require additional data gathering before implementing new land uses.

Appendix 5. TEC sub-committee on aquifer vulnerability

Part 2: Aquifer Vulnerability

1. Introduction

The Vulnerability Sub-Committee undertook to develop a practical approach for evaluating regional aquifer vulnerability to contamination from potential surface source(s) and to changes in land-use practices that could impact ground water quantity. This approach intends to address ground water source protection in areas that are not delineated as municipal wellhead protection areas (WHPAs) (predominantly rural settings). It also intends to recognize different uses of water in a regional setting, including shallow and deep private wells, ecological resources and recharge / discharge areas, and serves as the basis for protection efforts for these resources.

The goals of the sub-committee and the specific objectives of aquifer vulnerability within the context of Source Water Protection include:

a) Developing a consistent provincial methodology to delineate areas of relative aquifer vulnerability related to both ground water quality and quantity, on the land surface for areas outside of WHPAs.

b) Providing information on vulnerability of shallow water table environment and deeper aquifer units of interest.

c) Recommending a set of tools that could be used to assess aquifer vulnerability, ranging from simple to more complex, where the selection of the appropriate approach is dependent on data availability.

d) Recommending approaches to assessment of aquifer vulnerability that permit continuous updating as new information becomes available.

In developing an approach to assessing aquifer vulnerability, the Sub-Committee considered the following applications for the information developed through the aquifer vulnerability assessment:

- Delineate high vulnerability areas (HVAs) that may require a prioritized risk assessment and perhaps mitigation measures to be applied on a site-by-site basis.
- Provide spatial information on regional ground water recharge and discharge.
- Indicate areas that may be the most sensitive to cumulative contaminant loadings, water takings, or change in recharge rates.
- Assist in evaluating potential impacts of industrial mineral extraction operations (quarries and aggregate pits).
- Provide information to assist in evaluating water-taking permits.

- Implement specific land-use management actions, based on vulnerability ranking and threat assessment information, such as:
    - Restrictions on urban and industrial development.
    - Application of Farm Water Protection Plans.
    - Limitations on application of road deicing compounds.
    - Others.

In recommending the approach presented herein, the same rationale was applied as developed for assessment of the WHPAs:

a) Make optimum use of the progress to date in the Province of Ontario through previous Provincial Water Protection Fund Studies, the progress on aquifer protection and vulnerability that has been completed in several jurisdictions.

b) Remain conscious of the practical reality of implementing new approaches to aquifer vulnerability within the municipal structure with specific awareness of the level of acceptance already achieved for previous approaches.

c) Develop an approach using methodologies that improve consistency between the local scale wellhead analysis and the more regional aquifer assessment, and that will give results that are comparable from one region to another.

d) Take advantage of experience and approaches from other jurisdictions (e.g. USA and Europe) to incorporate the most current scientific understanding and methods.

e) Design the recommended protocols to fit with the threat and risk assessment components of the overall Source Water Protection Plans and the Nutrient Management Regulations.

2. Aquifer Vulnerability

Experience to date

Assessment of aquifer vulnerability has been undertaken on an international scale over the last decade and a wide variety of approaches have been implemented. In reviewing many of the most routinely applied methods, the Ministry of the Environment (MOE) selected the Intrinsic Susceptibility Index (ISI) approach as that required within the terms of reference for the second phase of the Provincial Ground water Studies that are currently in final stages of completion (ISI Determination from the MOE "Groundwater Studies 2001/2002 Technical Terms of Reference"). There has been a steady development of methodologies for aquifer vulnerability assessment at the regional scale, primarily with respect to increasing the physical basis for the analysis and enhancing the quantitative nature of the evaluation. The more advanced methods require progressively more data and understanding of the physical conditions. In some areas of Ontario, these advanced techniques have been applied with considerable as part of the Eastern Ontario Water Resource Management Study (EOWRMS, 2002; Robin and Daneshfar, 2004). In many other areas, however, there is not enough information available to warrant a more sophisticated analysis of regional aquifer vulnerability. As such, a range of tools is required to conduct aquifer vulnerability assessments across Ontario that are applicable to local data availabilities, yet they provide the opportunity to be periodically updated as new data become available.

Quantitative approach

A primary goal of the aquifer vulnerability process will be to encourage the adoption of the most quantitative level of analysis possible within local data constraints. This will ensure that the most complete information set possible is derived from the analysis to assist, for instance, in estimations of local and cumulative contamination impacts and recharge magnitudes. The recommended methodologies ranging from relatively simple to highly quantitative are summarized below:

- Intrinsic Susceptibility Index (ISI) and Aquifer Vulnerability Index (AVI) approaches, have been applied throughout many parts of the Province.
- An advective-time approach (SAAT as defined below and in Appendix 4B) based on hydrogeological information that permits the estimation of vertical ground water flow velocity at a regional scale.
- Numerical modelling of water flux within the near surface environment using established simulators such as WATFLOOD (Ref), GAWSER (Schroeter & Associates, 1996) and HELP (Ref).
- Numerical modelling of the ground water flow systems using established models (MODFLOW (Ref.), FEFLOW (Ref.), *etc.*).
- Numerical modelling of coupled ground water/surface water systems using any of a series of emerging modeling tools[1]

Data needs

The overall approach adopted in developing Discussion Items for a regional aquifer vulnerability assessment is to:

[1] The coupled ground water/surface water numerical modelling tools are beginning to be used in commercial applications but it is not anticipated that it will be feasible to use them for aquifer vulnerability assessment in Ontario for at least five years. They are listed here as an approach that will be available for future modifications to Source Water Protection Plans.

- Capitalize on the information that has already been collected throughout the province through the Provincial Ground water Protection Fund (PWPF) studies, and

- Enhance the level of information that can be derived from specific additional analysis.

The initial step will be to estimate the vertical advective travel times for water infiltrating at ground surface to reach the water table or some deeper target aquifer (typically the uppermost aquifer). The advective time methodology incorporates information on the hydraulic gradient and porosity to estimate vertical travel times. Much of this information is already available or can be estimated from the data generated by the PWPF studies and can be used to identify and map recharge and discharge areas. This was a specific Discussion Item of Justice O'Connor's Report (Part 2: Report on the Walkerton Inquiry). It is recognized that some areas may not have the data required to immediately adopt this methodology, and therefore, the ISI/AVI approach is proposed as the initial, interim approach for defining aquifer vulnerability. Over time as additional data become available, the aquifer vulnerability assessments can be updated. Areas that have a significant data base already established may be able to apply more advanced numerical modeling tools as outlined above to address concerns specific to the area of study.

Data integrity and potential use

In developing aquifer vulnerability maps, it must be kept in mind that the ISI/AVI maps are regionally-derived products based largely on water well records. As such, the use of the maps for taking specific prescriptive management actions must be considered carefully. The risk assessment process, carried out during the preparation of source water protection plans, should consider the limited precision of regionally-derived maps as risks are evaluated and ranked within a study area.

Some of the uses for aquifer vulnerability mapping could include:

- Prohibition of certain higher risk land uses, such as those that involve hazardous chemicals (e.g., landfills), in HVAs defined by ISI/AVI mapping.
- All existing and newly approved "threats of provincial concern," in HVAs defined by ISI/AVI mapping might require a contaminant management plan or may be subject to more frequent audits or inspections under source water protection.
- ISI/AVI mapping could be used to direct future development involving risks of provincial concern to lower vulnerability areas.
- The ISI/AVI mapping could be used to direct proposed developments involving higher risk land uses to areas of lower vulnerability.
- Farm water protection plans might be required in areas defined as having high vulnerability defined using SAAT mapping.

- If a community is looking to expand through a secondary planning process the maps could be used (as only one input into the planning matrix) to steer growth and new municipal water infrastructure (e.g., wells) away from areas of higher vulnerability.
- Applications for significant new or expanded permits to take water (surface or ground water) could be assessed in terms of the existing water use in the area to ensure the water resources are used within the limits acceptable to the given jurisdiction. This might include the identification of aquifers that are currently overexploited or sensitive surface features (i.e., wetland areas) that might be susceptible to additional water extraction.

Summary

The assessment of aquifer vulnerability on a regional scale will identify areas of concern within which various risk assessment and mitigation strategies could be applied. It is intended for use as a screening tool with additional investigation or study conducted where necessary. The assessment would be updated periodically as new data become available, or updated coincident with the review of source protection plans. Such improvements will more accurately define areas requiring risk assessment and mitigation, and improve quantitative estimates.

The overall approach is summarized below as a series of Discussion Items related to the development of aquifer vulnerability assessments through the Source Water Protection process.

Discussion Item 1

At a minimum, the initial (not longer than the SPP review) delineation of the aquifer vulnerability areas can be based on the current Intrinsic Susceptibility Index (ISI) or the Aquifer Vulnerability Index (AVI), as appropriate to local conditions and encompassing the information already contained in the Ground water Studies, and should be undertaken by the first 5-year review.

Explanation

These approaches assign an ordinal-scale numerical index of the natural vulnerability or susceptibility of the aquifer to surficial contamination, based on the overlying strata, their hydraulic conductivities and thicknesses. The ISI is calculated for the uppermost aquifer, while AVI values are calculated for deeper significant aquifers. For source water protection purposes, threats to the ground water system would typically be evaluated for their risk to the uppermost aquifer. This would be the most conservative approach. Additional details on both methods are contained in the Terms of Reference for provincially funded municipal ground water studies.

It is proposed that the specific vulnerability values should be categorized as outlined below:

1. **High Aquifer Vulnerability:** AVI or ISI scores of less than 30 (i.e. sandy areas with shallow water table). This will be the area(s) of greatest concern on a regional aquifer scale, with respect to evaluation and consideration for current and future risk assessment and management.
2. **Moderate Aquifer Vulnerability:** AVI or ISI scores from 30 to 80 (i.e. loam soils with moderate depth to water table). These areas might be of concern to the source water protection committees in evaluating their threats.
3. **Low Aquifer Vulnerability:** AVI or ISI scores greater than 80 (i.e. clayey soils with deeper water table). These areas would not factor into the risk assessment process under source water protection.

<u>Rationale</u>

- ISI and, to a lesser extent, AVI has been used throughout Ontario in the recent past, the methods are well known, but are dependent on the integrity and coverage of the water well record database.
- While ISI and AVI consider overlying strata, their hydraulic conductivities and thicknesses, they do not consider the hydraulic gradient and porosity, and therefore are recommended only as the initial default or preliminary step in assessing aquifer vulnerability.

The ISI method provides a basic approach for decision-making, which considers the hydraulic conductivity of the pathway for water infiltrating from the ground surface and, in considering the uppermost significant aquifer, has respect for the shallow ground water. In some areas, for example where extensive shallow unconfined aquifers are present and are not used for drinking water purposes and are not directly associated with sensitive surface water features, the ISI might delineate large areas of high vulnerability. These areas might not be of practical use for source water protection committees in prioritizing their risk management process. In such cases the uppermost aquifer might not be the appropriate target aquifer and the Aquifer Vulnerability Index (AVI) approach can be considered for use, thereby taking into account the protective effect of all the overlying strata above a deeper target aquifer of concern. It is proposed that the AVI may be used in such instances to assist with the identification and ranking of risk management actions under the source water protection process.

The high aquifer vulnerability areas (HVAs), as determined above provide a conservative approach for delineating source protection areas for regional aquifers. However, neither the ISI nor the AVI approach provides information related to the magnitude or direction of the ground water recharge flux. This information is required to determine areas of ground water recharge and discharge and in the evaluation of issues related to impacts on ground water quantity.

<u>Discussion Item 2</u>
A quantitative approach, based on advective times (AT), should be undertaken by the first 5-year review to evaluate the degree of protection provided by the vertical travel path from ground surface, through the unsaturated zone to the top of the water table or aquifer unit being assessed.

Explanation

Ideally, the AT approach should be utilized immediately where possible, but it is recognized that at the onset of the source water protection program, the existing vulnerability indices (i.e. ISI, AVI) may be utilized to target areas of high aquifer vulnerability. In developing source water protection plans and in subsequent revisions of the local SPP, a more advanced approach to aquifer vulnerability is recommended and should include the estimation of the Surface to Aquifer Advective Travel Time (SAAT) (e.g. Robin and Daneshfar, 2003, 2004). Detailed explanations of the method are provided in Appendix 4B. The approach involves the determination of the hydraulic gradients, equivalent vertical hydraulic conductivity and equivalent porosity of the subsurface units. In some cases the magnitude and temporal variability of the hydraulic gradient may also be available and can be used directly in the analysis. The gradient and hydraulic conductivity information will be used to estimate a potential vertical flux, which will identify hydraulic recharge and discharge areas. The equivalent porosity and vertical flux will provide estimates of the ground water velocity that can be used to estimate SAATs. The SAAT methodology will provide decision-makers with an enhanced understanding of the quantitative level of vulnerability within the defined aquifer(s) and will improve the understanding of impacts to the target aquifer related to both water quality and quantity. This information is not available through the AVI/ISI analysis alone.

Similar decisions with respect to the target aquifer will have to be made with this methodology as were made with the ISI/AVI methodologies. In some areas, for example where extensive shallow unconfined aquifers are present and are not used for drinking water purposes, the SAAT methodology, (similar to ISI and AVI) might delineate large areas of short advective travel times and therefore high vulnerability. These areas might not be of practical use for source water protection committees in prioritizing their risk management process. In such cases the uppermost aquifer might not be the appropriate target aquifer and the SAAT methodology would allow for a deeper target aquifer to be the focus of the analysis thereby taking into account the vertical gradient and the protective effect of all the overlying strata above a deeper aquifer of concern. By targeting deeper aquifers, the SAAT methodology would assist source protection committees, in a consistent fashion, with prioritization of risk management actions under the source water protection process.

This level of mapping (SAAT) would be adequate for imposing additional requirements, such as the preparation of farm water protection plans or contaminant management plans, for existing "threats of provincial concern" located in HVAs. In areas with sufficient data, this mapping would distinguish within HVAs between recharge areas, which have a high vulnerability of contamination, and discharge areas, which are not prone to ground water contamination. Care has to be taken to ensure that any vertical gradient that is considered in the SAAT analysis is representative of the gradient between the water table and the uppermost aquifer. Imposing a regional upward (or downward) gradient to inform decisions pertaining to a local ground water flow system can lead to erroneous assumptions. Identification of the spatial distribution of recharge and discharge zones within the given study area, will also provide information in evaluating potential threats to the water resources from additional water takings.

Rationale

- Builds upon the significant effort already invested in the estimation of aquifer vulnerability in the Province of Ontario
- Produces results that are quantitative, physically-based and comparable across the Province.
- Is amenable to evolution as knowledge improves; and to improved accuracy as more information becomes available.
- Provides numerical estimates of the vertical advective times that are fully comparable to SWATs in wellhead protection studies and that are more easily understood by those initiating and implementing source water protection in the Province, and by the public.
- Is based on estimates of vertical flux , which, in a similar fashion to the previous GW studies, can also be used to map areas of recharge and discharge, and fulfill a recommendation in Justice O'Connor's Report (Part 2: Report on the Walkerton Inquiry).
- Provides valuable preliminary insight on a regional basis for assessing potential ground water quality and quantity impacts, and determining where mitigative actions should be undertaken.
- Complements a higher level of quantitative analysis involving more advanced numerical modeling tools.

Discussion Item 3

SAAT values can be categorized and utilized in a similar fashion as for the delineation of WHPAs. It is recommended that criteria be developed that have regard for the application of varying, progressive risk mitigation strategies.

The following list of criteria is proposed for categorizing SAAT values:

- 0 – 5 year SAATs: High vulnerability (pathogens and highly toxic chemicals)

- 5 – 25 year SAATs: Moderate vulnerability
- >25 year SAATs Low vulnerability (including discharge zones)

Rationale

The proposed criteria provide a conservative quantitative approach for delineating vulnerability areas across the province. For instance, the high vulnerability area criteria accounts for the die-off time for pathogens of approximately two years, while acknowledging the uncertainty of parameters that will be used to estimate vertical movement of water. This approach allows the SAAT mapping to be used in combination with the type of threat in a quantitative risk assessment. In addition, as an intermediate step in the calculation of SAAT values, valuable information is provided concerning potential ground water recharge flux, which will be important in addressing resource quantity impacts.

Discussion Item 4

Flux values, as determined either through watershed ground water modeling (preferred) or through the SAAT process (acceptable) should be used to delineate areas that have higher recharge rates and therefore might be susceptible to urbanization and changes to recharge.

Rationale

Since the flux is a required component of the SAAT process, and is therefore available for use once the SAAT analysis has been undertaken, it is recommended that fluxes be used on their own to delineate areas of high recharge. These areas would be considered to be highly vulnerable from a water quantity perspective, specifically with respect to changes in recharge. A decline in recharge in these high recharge areas might have significant impacts on shallow water table elevations and could result in negative impacts to surface water sources that are dependent on local ground water discharge. The sub-committee recognizes that such an analysis would not specifically speak to the "vulnerability" of an aquifer or watershed to water taking stresses from excessive pumping. This would require a different type of assessment than aquifer vulnerability mapping (Martin, 2004).

Several methods could be used by the SPPC to delineate the high recharge areas including:

- Summing (from the SAAT flux values) the total estimated flux (recharge) within a (sub)watershed and then delineating those areas that contribute the top x% of recharge
- Same as above except that the areas having greater than x% of the average (sub)watershed recharge are delineated

Determining the average water budget surplus for a given geographical location and then assessing the estimated flux values to arrive at an appropriate delineated area

<u>**Discussion Item 5**</u>

The collection of regional hydrogeologic and hydrologic data is recommended to support the application of statistical and numerical modeling tools that can be used to enhance quantitative assessment of aquifer vulnerability (e.g. USGS, 2002; National Research Council,1993). This includes piezometric information that can be used to estimate vertical hydraulic gradients, hydraulic conductivity, geochemistry, meteorologic and surface water flow data.

<u>Explanation</u>

For example, municipalities or SWP boards may wish to request that water quality data be used to define quantitative estimates of vulnerability in highly vulnerable areas, using methods endorsed and documented by the US National Research Council. Probability estimates relate the occurrence of measured water quality constituents in ground water to explanatory variables such as intrinsic aquifer properties. This statistical method uses available aquifer properties to describe the relative ease with which constituents migrate to the aquifer/well using a built-in correlation between vulnerability level and observed contamination patterns. The method predicts water quality as a probability that can produce a quantitative risk assessment, e.g. likelihood of exceeding a nitrate threshold concentration in ground water at well 'x' compared to the likelihood of an exceedance over the whole study area.

This method does not require a large number of difficult to map input parameters such as infiltration rate, porosity, dispersion coefficient, retardation factor *etc.* that are not readily available for regional numerical models. Where sources are known, the method provides an improved estimate of travel times from surface to aquifer/well, thus providing an independent check on the results from numerical modeling where data support is available.

- This method makes use of existing water quality data, combined with intrinsic aquifer properties (sediment type / thickness, depth to water table *etc.*), to provide a more realistic vulnerability estimate of travel time based on measured tracer rates (e.g. nitrates, pathogens *etc*).

- New baseline water quality data can be acquired for this analysis where continued improvement in aquifer assessment is deemed to be appropriate and/or cost-effective.

- Approach provides calibration for numerical modeling scenarios

- Most scientifically defensible vulnerability zoning for decision making

<u>Rationale</u>

- The Source Water Protection Plan is intended to be an evolving entity that will be able to take advantage of new data as it becomes available in order to improve the ability of the plan to provide adequate protection of the water resources while supporting sustainable land-use practices.
- New analytical tools are being developed and have been successfully applied in several parts of Ontario to more quantitatively evaluate impacts to both ground water quality and quantity.

Discussion Item 6

It is recommended that the siting of new municipal wells should be guided by aquifer vulnerability information, considering both quality and quantity concerns, to avoid construction in highly vulnerable areas. It is also recommended that the construction of new private wells should be field verified and their construction methods strictly enforced in highly vulnerable areas.

Rationale

- Municipal wells, and their associated water systems, constructed in highly vulnerable aquifers**,** not necessarily highly vulnerable areas, are and will continue to be costly to operate. Under the Safe Drinking Water Regulation 170, wells that are constructed in highly vulnerable sources (e.g., ground water sources under the direct influence of surface water) require high levels of treatment (i.e., chemically-assisted filtration) that have significant capital and long-term operation and maintenance costs. There are cases in Ontario where operators of some small communal water supply systems have abandoned them because they have high costs to upgrade and operate under the requirements of Regulation 170.

- Municipal wells constructed in highly vulnerable aquifers would also have broader social and economic costs. For instance, land use activities (e.g., privately serviced development, municipal sewers, animal agricultural operations) located in highly vulnerable aquifers would likely experience significant limitations on their ability to remain and operate within the immediate vicinity of these wells.

Discussion Item 7

It is recommended that the Province evaluate methodologies for assessing the vulnerability of regional ground water supplies, including both long and short–term cumulative quality and quantity impacts.

Rationale

The IVI/AVI and SAAT methods, which will be the subject of the first generation of source protection plans, will provide limited means for the quantitative evaluation of cumulative impacts to ground water. New methodologies will be required, once the adequate data are available, to conduct quantitative evaluations. An example of this is the development of water budgets on a watershed scale to evaluate the cumulative impact of water takings in both the short and long term. A similar methodology would be needed to evaluate the cumulative impacts of potential contaminant sources on a watershed scale.

SAAT calculations

Surface to Aquifer Advection Time (SAAT) is a measure of the intrinsic vulnerability of a specified aquifer to contamination. It is the average time required for a water "particle" to travel from the ground surface to the specified aquifer. (A bit more technically: it is the breakthrough time of the mean concentration of the advancing front of a conservative tracer, for a continuous source; or the breakthrough time of the centre of mass for a pulse source.) SAAT maps can be calculated for each aquifer of interest in the system, however from the point of view of evaluating threats to the groundwater system in the source water risk analysis the SAAT Map for the uppermost aquifer would be the one considered. Other SAAT maps might be of interest to staff involved in water supply issues. The best way to calculate SAATs is from regional groundwater flow models. However there are very few locations in Ontario where such calculations have been done. Alternatively, as a first step, SAATs can be estimated from data layers that have already been compiled in the groundwater studies or that can be readily generated.

The SAAT estimation procedure uses the same information that was used in the Intrinsic Vulnerability Index (ISI) and the Aquifer Vulnerability Index (AVI) calculations with additional information on the vertical hydraulic gradient and the porosity. The ISI and AVI were therefore important first steps.

<u>Unconfined aquifers:</u>

For unconfined aquifers, use the UZAT as follows:

$$UZAT = \frac{d_{wt} \cdot \theta_r}{q_z}$$

where: UZAT = Unsaturated Zone Advection Time [Time]

d_{wt} = depth to the water table [Length $_{bulk}$]

θ_r = residual moisture content [Length$^3_{water}$ Length$^{-3}_{bulk}$]

q_z = downward Darcy Flux [Length$^3_{water}$ Length$^{-2}_{bulk}$ Time^{-1}]

= infiltration rate [Length $_{water}$ Time^{-1}]

In the case of the aquifer vulnerability, there is no groundwater flow model to calculate d_{wt} and q_z and so we have to estimate them differently.

The depth to the water table, d_{wt} , can be obtained by subtracting the water table elevation from the ground surface elevation. The water table elevation should be determined from direct measurements, either from: i) records tied to the water well record database (caution: the column assigned to static water level should be used for this rather than the column recording “depth to first water”); ii) from other more detailed studies; or iii) from the water levels of permanent water bodies (that are not perched). Some judgment has to be made to determine which wells most accurately represent the water table as opposed to those representing the hydraulic head of deeper aquifers. In the Technical Terms of Reference for the Groundwater Studies 2001/2002, the Ministry of the Environment recommended that local expertise guide the decision making process as to which wells would best reflect the water table surface. Once all points have been compiled and assessed the water table surface can be interpolated across the SPP area (e.g. Desbarats et al., 2002). The water table elevation can then be subtracted from the DEM (digital elevation model), to obtain d_{wt}. Negative values should be weeded out by ensuring that the water table surface is “corrected” so that it remains, at the most, 0.5 m below the ground surface. Within these areas the UZAT should not be used: only the saturated time of travel should be considered for the aquifer vulnerability mapping.

The infiltration rate, q_{z}, can be estimated with an evapotranspiration model like HELP or the simpler (but less accurate) Thornthwait Model. The data layers required for this will depend on the approach used, and may include precipitation, topography (slope), soil type, d_{wt} , and vegetation cover.

The “residual” moisture content of the surface material, θ_r , is used as a surrogate for the average moisture content of the soil under steady-state drainage at the infiltration rate. The value is can be taken from locally known information or, as is more likely the case, it can be estimated from a map of the quaternary geology and the following approximate table:

Overburden texture	Approximate residual moisture content
Sand	10%
Loam	25%
Clay	40%

If the unsaturated zone contains several layers, then the equivalent θ_r should be calculated as the arithmetic mean of the θ_r weighted by the layer thickness.

The assumptions underlying the UZAT estimation are: (1) transient effects in the unsaturated zone are ignored; the implication is that the moisture content profile is at equilibrium, on average. (2) The moisture characteristic curve is approximated as a step function with a saturated moisture content at (and below) the water table and the residual moisture content above the water table. The approximation is best (and fairly accurate) for coarse materials with a deep water table, and worse (but still acceptable) for fine materials (with a large capillary fringe) with a shallow water table. In these situations, where the approximation is worse, the UZATs will be short anyway and will therefore contribute little to the overall SAAT; conversely the UZATs are of most interest (i.e. they will have the most impact on the SAATs) when the water table is deep and our approximation is best.

Semi-confined aquifers:

For semi-confined aquifers, in addition to the UZAT (the advective time in the unsaturated zone as described above), the SAAT calculation requires the vertical distance between the water table and the aquifer, the piezometric surface of the aquifer, the hydraulic gradient between the unconfined aquifer and the target aquifer, the equivalent hydraulic conductivity, K, of the material between the water table and the aquifer and the equivalent porosity, η, of the material between the water table and the aquifer

Much of this information is already available or can be estimated from the groundwater studies.

The approach:

The advective time for a given aquifer is the sum of the vertical advective times of the overlying layers.

Calculation:
Following the development given in the EOWRMS (Section 5.5.7 and Fig 5.27). The potential surface to aquifer advection time is given by:

$$SAAT = \frac{\eta D}{q}$$

where:

SAAT = potential surface to aquifer advection time [T];
η = Equivalent effective porosity of the material overlying the aquifer [L^3 L^{-3}]
D = Thickness to the material overlying the aquifer [L]
q = Potential vertical component of the water flux (i.e. potential recharge/discharge) [L^3 L^{-2} T^{-1}]

The Equivalent effective porosity can be estimated as the arithmetic mean of the porosities of the individual layers above the aquifer, weighted by their respective thicknesses:

$$\eta = \sum_{i=1}^{N} \eta_i D_i \Big/ \sum_{i=1}^{N} D_i = \sum_{i=1}^{N} \eta_i D_i \Big/ D$$

where:

i	=	i^{th} layer overlying the aquifer
N	=	total number of layers overlying the aquifer
η_i	=	Effective porosity of layer *i* overlying the aquifer
D_i	=	Thickness of layer *i*

and

D, is the overall thickness to the material overlying the aquifer:

$$D = \sum_{i=1}^{N} D_i$$

The EOWRMS ignored the porosity in the first equation because it varies by less than an order of magnitude in the EOWRMS territory (compared to several orders of magnitude for *q*). Province-wide, the porosity can vary over one or two orders of magnitude and it should therefore be considered. Section 5.5.7 of the EOWRMS report gives a more in-depth discussion of the pros and cons of the approach.

In the above equation the potential vertical flux is actually the discharge/recharge or the net infiltration (if we just consider the downward component). The vertical flux can be estimated from Darcy's Law, using the hydraulic conductivities (which are necessary for the ISI calculations) and the water levels as follows:

$$q = K \Delta h / D$$

where:

q	=	Potential vertical component of the water flux (i.e. potential recharge/discharge) $[L^3 L^{-2} T^{-1}]$
K	=	Equivalent hydraulic conductivity of the material overlying the aquifer $[L T^{-1}]$
Δh	=	Hydraulic head difference between the surface and the aquifer [L]
D	=	Thickness to the material overlying the aquifer [L]

The way that it has been defined, a positive value of *q* is a recharge and a negative value is a discharge. So a map of *q* will give the recharge/discharge areas, although as discussed below, the regional surfaces used for this approach might not always reflect the actual recharge/discharge areas due to the lack of data.

The hydraulic conductivity is the parameter that formed the basis of the ISI and AVI methods. If we can assume that the material overlying the aquifer consists of uniform layers, then K can be calculated as the harmonic mean of the individual layer's K values, weighted by the layer thickness'.

$$K = \left(\sum_{i=1}^{N} K_i^{-1} D_i \Big/ \sum_{i=1}^{N} D_i \right)^{-1}$$

If the material is more like lenses than layers, then it is more appropriate to use a weighted geometric mean:

$$K = \log^{-1}\left(\sum_{i=1}^{N} \log(K_i) D_i \Big/ \sum_{i=1}^{N} D_i \right)$$

These estimations for K are actually the ISI and the AVI in mathematical disguise.

The last bit of information required for the recharge/discharge calculation is the hydraulic gradient. This can be estimated from the water levels (as was done in the EOWRMS, Section 5.5.4 and Figure 5-18) and/or from the DEM (as a first approximation).

A potential difficulty arises in trying to obtain accurate head measurements for the aquifer of interest. In homogeneous settings the aquifer of interest or the "target" aquifer might be a thick bedrock aquifer that is tapped by many wells and the hydraulic head within the aquifer is straightforward. The required flux and eventual SAAT calculations would be similarly straightforward. However, in complex glaciated terrains the uppermost "target" aquifer might be a geographically restricted sand or gravel lens that is more difficult to trace over significant areas. As such there might be very few or no accurate hydraulic head measurements within the "target" aquifer. Two issues require an approach:1) the aquifer has to be delineated over a geographical area so that the calculations can be undertaken; and 2) a hydraulic head has to be assigned to the aquifer. Some ideas are put forward here for consideration by SPPC.

Aquifer delineation – In order to better define the "target" aquifer, a geological analysis could be undertaken to "regionalize" any of these more geographically isolated aquifer systems. This would involve the development of a regional geological conceptual model and the interpolation of the top of the uppermost "target" aquifer system. Limitations of this approach would be that the process might not accurately reflect the true top of the aquifer (e.g. in areas where the aquifer was absent, for example due to non-deposition, this regionalization approach might interpolate the aquifer where it in reality does not exist) and therefore the resultant SAAT might over or underestimate the actual travel time to the aquifer. This is the type of problem that arises with regional mapping and the reason that more detailed studies are required before adopting very prescriptive impositions on landowners in areas of high aquifer vulnerability.

Another approach to addressing the uppermost "target" aquifer could be taken from the approach used to develop the ISI in the last round of Provincial groundwater studies. In those studies, one approach that was taken was for each well to be considered individually to determine the "target" aquifer (e.g. the first 2 m thick sand or gravel lens). An interpolation of this uppermost aquifer pick could then be undertaken to develop the elevation of the top of the aquifer. Alternatively, at each well the actual SAAT could be calculated based on the estimated hydraulic conductivity and porosity of the stratigraphy within the well above the "target" aquifer. This unfortunately might lead to a very "noisy" irregular upper most aquifer surface and therefore a "choppy" resulting vulnerability map. The surface would however be more "true" to the data. The regional hydraulic gradient developed from the water table and potentiometric surface maps (see below) would be used to generate the gradient. The smoothing or regionalization of the hydraulic gradient helps to offset the irregularity introduced by moving on a well by well basis to determine the uppermost aquifer.

Hydraulic Gradient – from the previous groundwater studies there was a requirement to produce a water table, as well as a potentiometric surface map. The potentiometric surface map may or may not accurately reflect the hydraulic head in the "target" aquifer. None-the-less, the regional gradient between the two surfaces may be proportionately applied to arrive at the vertical flux for the purposes of calculating SAATs. The limitations of this approach are:

- that the regional surfaces determined in this manner might not accurately capture upward vertical gradients beneath streams and other groundwater discharge areas; and
- the regional gradients might over-(or under)estimate the actual downward gradients to the "target" aquifer

One should be aware that:

- The best approach is 3-dimensional modeling – but it is not feasible at this time.
- The advection time approach uses potential vertical advective time from the surface to the aquifer as a measure of vulnerability. The approximation ignores the horizontal component of flow. This does not change the vertical advective time but it produces a horizontal shift in the "position of the vulnerability value" that depends on the ratio of the vertical to horizontal components of flow. In practice, this is problematic only in the few instances when the horizontal component is large in combination with a horizontal flow path that intersects changes in hydrostratigraphic units.

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Appendix 6. TEC Pathogens sub-committee

Pathogen Subcommittee Members

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Summary of Recommendations to TEC

Introduction

The Pathogen Sub-Committee has endeavoured to develop a strategy to protect drinking water sources from disease-causing microbial contaminants (i.e., pathogens) from a public health perspective. According to a United States Environmental Protection Agency (US EPA) Science Advisory Board, contamination of drinking water by pathogens is the greatest remaining health risk challenge to drinking water suppliers (EPA/SAB, 1990). Serious outbreaks of waterborne disease in Canada, the United States and in other parts of the world over the past decade indicate that contamination of drinking water by pathogens is a complex issue and continues to be an issue in the delivery of safe drinking water to the public.

The Technical Experts Committee (TEC) on Source Water Protection recommended that a sub-committee be created to address the issues of pathogens which represent a threat requiring special emphasis because the appropriate knowledge is relatively new and it is known that these living organisms behave differently from other contaminants of concern. As such, the Pathogen Sub-Committee was established, comprising of four TEC members and staff from the Ontario Ministry of the Environment and Ontario Ministry of Agriculture and Food, and Ministry of Health and Long-Term Care. The overall objective and purpose of this committee was to develop recommendations for pathogen management zones for all source waters. In developing the recommendations several guiding principles were applied, including the multi-barrier approach to source water protection, the need for watershed protection, a scientific approach to decision-making based on risk assessment, the recognition that a single microbial indicator is insufficient to address source water protection from all pathogens and the need for continuous improvement in all program aspects. The group carried out an extensive review of the literature, conducted in depth consultations with international experts, and held a workshop to obtain additional information from experts in the field.

In developing its recommendations, the sub-committee felt it was important to:

a) Avoid duplication of effort and to gain information based on experience in other jurisdictions. Consequently, a review of the scientific literature was undertaken and expert opinion was sought so that the most current scientific understanding of the epidemiology, fate and transport of pathogens in the environment was made available to the committee.

b) Make optimum use of existing available Provincial information including studies, existing experience and policy development that has resulted from other initiatives (Ground water Under the Direct Influence of surface water - GUDI, Nutrient Management Act *etc.*).

c) Take advantage of experience and approaches from other jurisdictions (other Provinces in Canada, USA, New Zealand) related to source water protection.

d) Remain aware of the implementation challenges, including costs, when proposing the implementation of new approaches to source water protection.

e) Look toward establishing long-term goals that would ideally be reached but may not be currently attainable due to the current state of knowledge. Source protection planning needs to reflect the evolution of the scientific and technical knowledge.

The following summary Discussion Items were consensually agreed upon by the Pathogen Sub-Committee. Detailed discussion on these items can be found in the supporting document entitled "**A Recommendations Rationale Document**" and discussion paper entitled ***"Protecting Source Waters from Pathogens- a Discussion Paper"***

Part 1: General Discussion Items

Discussion Item 1

That the Province require all water sources used for public consumption to be treated for pathogens where the level of treatment is based on results of the source water risk assessment.

Rationale

Consultations with numerous experts have confirmed that no drinking water source is completely free from risk of pathogen contamination and thus for a secure supply of water, some form of treatment is necessary. Treatment provides an additional barrier for the overall multi-barrier approach that was recommended by Justice O'Connor, in the Walkerton Report Part II Recommendations. Treatment level will depend on the risk assessment of the source water (see Discussion Item 3). For example, a surface water source that has tested positive for Cryptosporidium, and that has chlorine disinfection should consider additional treatment such as filtration to minimize risk to public health.

<u>Discussion Item 2</u>
Best management practices should be implemented in appropriate watersheds to reduce the loading of pathogens through a variety of measures, such as public education and other tools to be applied according to the source water protection plan (SWPP) at the discretion of the SPPC's.

<u>Rationale</u>
The sub-committee recognizes that the entire watershed upstream of the intake has the ability to contribute pathogens to the source. It is proposed that chronic loading of pathogens to the source water resulting from land use activities and piped discharges (e.g. combined sewer overflows, tile drains) be addressed through the implementation of Best Management Practices (BMPs) at a watershed level. Best management practices will be the primary tool for mitigating chronic pathogen loadings to surface water and ground water. However, the capacity of different BMPs to reduce pathogen loadings, either individual or in combination has not been formally quantified. This approach aims to reduce the overall loading of pathogens to the river system.

<u>Discussion Item 3</u>
All municipal source waters should be characterized microbiologically. The data should be used in conjunction with hydrologic and hydrogeologic information to determine their risk category.

For surface waters, the information generated through characterization should be made available to water system purveyors downstream to assist in making management decisions.

<u>Rationale</u>
1. Each of these source categories, such as municipal well, rivers, lakes *etc*., has different physical characteristics and vulnerabilities to contamination by pathogens. Furthermore, pathogens have different survival times and to behave and travel differently to and through these different source water categories. The information requested for each source category is necessary to evaluate the risk associated with the source. Further, evaluation of the microbiological risk assessment will allow for the development of a primary risk category whereby the assignment into a particular category would determine the required actions to protect or improve source water quality. Development of adequate protective measures depends on understanding these characteristics and having knowledge of the intrinsic levels of pathogens that might be present.

To move forward and accomplish a watershed approach, input from the local SPPC's on source water inventories from each municipality would need to be uploaded to the CAs for mapping of the bigger picture.

The risk associated with the source will be evaluated as part of this process. The characterization of the water source with respect to quality, treatment and vulnerability is consistent with Recommendation 30 by Justice O'Connor (Report of the Walkerton Inquiry) that - "All raw water intended for drinking water should be subject to a characterization of each parameter that could indicate a public health risk. The results, regardless of the type of source, should be taken into account in designing and approving any treatment system."

Discussion Item 4

A multi-indicator approach should be adopted by the province and used to establish new microbiological raw water quality standards/objectives for all drinking water sources (rivers, lakes, reservoirs, and ground water) to provide consistency.

Rationale

Due to variation in transport, survival and response to environmental stress, the use of a single faecal indicator bacterium as an index of risk to human health may significantly over or under estimate risks from pathogens. Proposed indicators include:*E. coli,* enterococci, coliphage, and *Cryptosporidium.*

The raw water standards/objectives will set achievable, protective targets and- ranges for all drinking water sources that will serve as an additional barrier to protect drinking water in the event of a failure at the drinking water plant. These targets will identify appropriate management strategies to reduce the loading of pathogens to the water. Also, by striving to achieve the standards/objectives, the overall water quality for other uses (e.g. recreational) should improve.

Part 2: Ground water Source Recommendations

The results of a study of ground water quality of about 1300 wells in Ontario showed that 30 to 50% of rural wells contained indicators of faecal contamination above drinking water standards (Ontario Farm Ground water Quality Survey, 1992). More than half of the waterborne disease outbreaks in the U.S. between 1971 and 1996 were associated with ground water sources and of these, 25% were attributable to specific viral or bacterial pathogens (USEPA).

Discussion Item 5

Within the WHPA, two pathogen management zones should be delineated, namely a 100 metre pathogen prohibition area in which the wellhead operator would restrict any human activity that could create new pathogen sources, and a 2-year TOT zone to be considered to be the highest level of vulnerability, with respect to bacteriological/pathogenic contaminants.

Rationale

The two-year TOT is based on an extensive review of scientific literature on pathogen survival and transport. An inventory of pathogen sources in the pathogen protection zone will be compiled by the *SPPC* and included in the Assessment Report since any source within this zone has the potential to adversely affect the water source. The inventory will include pathogen sources such as those on the Threats of Provincial Concern list as well as private wells in the protection zone.

Pathogen sources resulting from human activity should not be permitted within the 100 metre prohibition zone. This prohibition zone is identified to recognize the inherent uncertainty in the subsurface zone that is expected to provide some mitigation to pathogen transport. Thus, over short distances, it is essentially impossible to provide a detailed enough characterization to the hydrogeological setting to assess the potential risk of pathogen travel. The 100 metre prohibition zone is consistent with practices in other jurisdictions and is consistent with other provincial legislation.

Discussion Item 6:
For Private Wells:

Programs of education, inspection, water quality testing and upgrading for private well owners should be improved.

Rationale
The private rural wells, when surveyed in the Ontario Farm Ground water Quality Survey, had an unacceptable frequency of microbiological contamination. This indicates the present programs (MOE Regulation 903, MOHLTC Safe Water Program) are not adequate to meet the needs of private well owners to protect their water source. Present provincial and local programs should receive additional resources (staff, funds) to implement a coordinated, proactive program that includes public education, inspections, water quality testing, BMP's, and upgrades of all private wells as necessary. Upgrades could include; replacing seals, installing barriers and buffer strips, extending casing to above ground surface, and installing a vermin proof well cap.

Part 3: Surface water Sources Recommendations
The US EPA reported that between 1971 and 1996, there were a total of 643 waterborne disease outbreaks infecting nearly 600,000 people with one incident in Milwaukee, which relied on a surface water source affecting 400,000 people.

Discussion Item 7
A pathogen risk zone, (a contiguous area of land and water immediately upstream or around a municipal surface water intake) needs to be delineated using a site-specific response time or a minimum predetermined time of travel, based on standard protocols established by the Province. Within the pathogen risk zone there should be risk management for activities that pose an acute pathogen threat.

Rationale
Severe storms, spills or failures that result in a release of pathogens are acute threats to the intake and require a reactive approach. The pathogen risk zone is the area, which if a spill occurs; there is not enough time for the drinking water plant operator to turn off the intake.

Discussion Item 8
For Private surface water sources:
That the province requires all owners of private drinking water supplies derived from surface water; appropriately treat the water to eliminate pathogens where the level of treatment is based on results of a source water quality evaluation. That the province issue guidelines to the SPPCs on risk management.

Rationale
Surface water drinking sources are distinctly different from ground water drinking sources and require additional consideration. Ground water is filtered by the subsurface materials and this natural filtration is considered in provincial treatment requirements whereas surface water does not have the benefit of natural filtration and must be assumed to be contaminated. A precautionary approach for surface water drinking sources is warranted and a minimum level of treatment should be required. A source water quality evaluation should be used to determine if the current treatment is sufficient or what additional treatment is deemed necessary to minimize the microbial risk.

In addition, the province should prepare guidelines to assist SPPCs in performing the assessment and making decisions on risk management in the watershed. Guidelines from the Province will help to ensure a consistent approach across the province. Experience has shown that surface water supplies can be more vulnerable to contaminant inputs that originate from the areas immediately upstream of the intake and Risk Management in the watershed area upstream of the intake to reduce pathogen loadings is an approach that should be considered by SPPCs. Risk management activities to reduce the loadings of pathogens are consistent with the precautionary approach.

GLOSSARY

Municipal Wells: means a public water supply owned by the government

Gain Control: means to purchase, lease, or expropriate a parcel(s) of land within the prohibition zone

Prohibition: means a decree that prohibits no new activity and or remove existing activity within the 100m protection zone.

Acute pathogen threat: means rapid onset, severe symptoms and short duration. Opposite of chronic. For example, a manure spill into a river.
Chronic pathogen threat: means of long duration; continuing. Lasting for a long period of time or marked by frequent recurrence. For example, wastewater treatment plant discharge.

Public Consumption: means any drinking-water system that is regulated under the Drinking-Water Systems regulation (O. Regulation 170/03).

Sanitary Survey: means the on-site review and evaluation of all actual and potential pollution sources and environmental factors having a bearing on area water quality. AND an on-site review of the water source, facilities, equipment, operation, and maintenance of a public water system for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water.

Appendix 6A: TEC Pathogen sub-committee

A Recommendations Rationale Document

Ontario

Ministry of the Environment

Ministry of Agriculture and Food

Ministry of Health and Long-Term Care

Protecting Source Waters from Pathogens- “A Recommendations Rationale Document”

Report prepared by: The Technical Experts Pathogen Sub-Committee on Source Water Protection

September 30 2004

Acknowledgements

The following individuals, arranged alphabetically, comprised the Pathogen Sub-Committee on Source Water Protection and supported the development of this document:

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Introduction

The Pathogen Sub-Committee has endeavoured to develop a strategy to protect drinking water sources from disease-causing microbial contaminants (i.e., pathogens) from a public health perspective. According to a United States Environmental Protection Agency (US EPA) Science Advisory Board, contamination of drinking water by pathogens is the greatest remaining health risk challenge to drinking water suppliers (EPA/SAB, 1990). Serious outbreaks of waterborne disease in Canada, the United States and in other parts of the world over the past decade indicate that contamination of drinking water by pathogens is a complex issue and continues to be an issue in the delivery of safe drinking water to the public.

The Technical Experts Committee on Source Water Protection recommended that a sub-committee be created to address the issues of pathogens, which represent a threat requiring special emphasis because the appropriate knowledge is relatively new and it is known that these living organisms behave differently from other contaminants of concern. As such, the Pathogen Sub-Committee was established, comprised of four TEC members and staff from the Ontario Ministry of the Environment and Ontario Ministry of Agriculture and Food, and Ministry of Health and Long Term Care. The overall objective and purpose of this committee was to develop recommendations for pathogen management for all source waters.

The Pathogen Sub-Committee took into consideration the need for an approach that was fair and reasonable for all stakeholders. In developing the recommendations presented in this section, several other guiding principles were applied, including the multi-barrier approach to source water protection, the need for watershed protection, a scientific approach to decision-making based on risk assessment, the recognition that a single microbial indicator is insufficient to address source water protection from all pathogens and the need for continuous improvement in all program aspects. The group carried out an extensive review of the literature, conducted in depth consultations with international experts, and held a workshop to obtain additional information from experts in the field.

In developing its recommendations, the sub-committee felt it was important to:

f) Perform a review of other jurisdictions and the scientific literature and solicit expert opinion to ensure that the most current scientific understanding of the epidemiology, fate and transport of pathogens in the environment was made available to the committee.

g) Make optimum use of existing available provincial information including studies, existing experience and policy development that has resulted from other initiatives (Ground water under the influence of surface water, Nutrient Management Act *etc.*).

h) Avoid duplication by taking advantage of experience and approaches from other jurisdictions (other Provinces in Canada, USA, New Zealand) related to source water protection.

i) Remain aware of the implementation challenges, including costs, when proposing the implementation of new approaches to source water protection.

j) Look toward establishing goals that would ideally be reached but may not be attainable at present. Source protection planning is an ongoing development process not a one-time change, and that the process has to evolve with scientific and technical knowledge.

Based on the outcomes of these discussions and considerations, the following draft recommendations for consideration have been consensually agreed upon by the Pathogen Sub-Committee. Detailed discussion on these items can be found in Appendix 6B under the discussion paper entitled ***"Protecting Source Waters from Pathogens- a Discussion Paper"***

RECOMMENDATIONS GENERIC TO ALL SOURCES

Discussion Item 1:

"All sources of water intended for public consumption should be treated for pathogens where the level of treatment is based on results of source water protection"

Rationale:
There was consensus among the experts consulted that all drinking water (surface water and ground water) should be treated to minimize risks to human health. Zero risk is unattainable in natural source waters and there exists significant uncertainty related to the effectiveness of subsurface materials to filter out or attenuate pathogens under all circumstances. The 1991-1992 Ontario Farm Ground water Quality Study showed that 30 to 50% of rural wells contained indicators of faecal contamination above drinking water standards. A recent American Water Works Association Research Foundation study of public ground water supplies in 35 states across the United States identified viruses (infectious and non-infectious) in 53 of 236 samples (22.5%) collected. Consequently, wellhead areas need constant surveillance, and all water used for potable supplies should be treated. Treatment provides an additional barrier for the overall multi-barrier approach that was recommended by Justice O'Connor, in the report on the Walkerton Inquiry.

Considerations:
In addition to gastrointestinal illness (GI), there are many waterborne pathogens which can cause non-GI infections, particularly in susceptible hosts, e.g. *Legionella, Pseudomonas aeruginosa, Nageleria fowlerii*, *etc*. No single microbial indicator is suitable for all situations and a multi-indicator approach is preferred.

Discussion Item 2:

"An inventory of all source waters used for the purpose of a drinking water supply must be prepared using the following source categories:

- ***Municipal well***
- ***Municipal well under the influence of surface water (GUDI)***
- ***Reservoirs***
- ***Lakes***
- ***River and Stream***
- ***Private wells"***

1. The following information shall be gathered for each category:

Table 1: Drinking Water Source Inventory

Source	**# of Systems**	**System Size**		**Population served**
		capacity	# of connections	
Municipal Well				
Municipal Well- Gudi				
Reservoir				
Lake				
River/Stream				
Private Wells				

2. The Source Water Protection Planning Committees (SPPCs) in conjunction with the various agencies (Ministry of the Environment, Municipality, and public health units, Ministry of Health and Long-Term Care and Conservation Authorities (CA)) within the local SPPC jurisdiction will collaborate to collect and include the information in the Technical Assessment Report.

Rationale:
Each of these categories has different physical characteristics and vulnerabilities to contamination by pathogens. Furthermore, pathogens have different survival times and appear to behave and travel differently to and through these different categories of drinking water sources. The information requested for each category is necessary to evaluate the risk associated with the source. Development of adequate protective measures depends on understanding these characteristics and having knowledge of the nature and intrinsic levels of pathogens that might be normally present. To move forward and accomplish a watershed approach, input from the local SPPC on source water inventories from each municipality would need to be uploaded to the CAs for mapping of the bigger picture.

Considerations:

1. The definition of municipal may need to be clarified and reworded in order to capture those systems not currently identified as municipal under Ontario Regulation 170/03.

2. The province needs to provide definitions for each source category.

3. The Province would need to establish who would be responsible for creating this inventory. It is the recommendation and suggestion of the Pathogen sub-committee to use the local proposed SPPC.

4. An important aspect to adopting a watershed approach is the need to incorporate private wells into the source water protection planning process. As such, the Province needs to identify private wells in the wellhead protection area. Ministry

of Health and Long –Term Care data records and involvement are important and required in order to achieve this objective.

5. The Implementation Committee and Data sub-committee need to consider how this collaborative exchange of information would come about. For example, a memorandum of understanding may be required between government agencies.

Discussion Item 3:

"Source waters should be characterized for hydrologic, hydrogeologic and water quality attributes"

1. The following information shall be gathered for each category.

Table 2: Drinking Water Source Characterization

Source	Microbiological water quality parameters ***E. coli,* enterococci, coliphage and Cryptosporidium**	Treatment		Hydrology	Hydrogeology	Turbidity
		Treatment present or absent	Type of treatment present			
Municipal Well	*E. coli,* **and** coliphage					
Reservoir	*E. coli* & or enterococci **and** *Cryptosporidium*					
Lake	*E. coli* & or enterococci **and** *Cryptosporidium*					
River/Stream	*E. coli* & or enterococci **and** *Cryptosporidium*					
Private Wells	*E. coli* & or enterococci **and** Coliphage					

1. The Source Water Protection Planning Committee (SPPC) in conjunction with the various agencies (Ministry of the Environment, Municipality, public health units, Ministry of Health and Long-Term Care and Conservation Authorities (CA)) within

the local SPPC jurisdiction will collaborate to collect and include the information in the Source Protection Plan (SPP).

2. Historical data should be given consideration as part of the characterization step. Characterization of microbial parameters could be culled from existing records such as the MOHLTC dbase, or municipal records. The situation where new information is required, the local SPPC will collaborate with the municipality(s) to acquire and include the information in the SPP

3. A minimum 24 month characterization period for water quality parameters would be required to assess the quality of the water source with respect to pathogens. This does not mean however that a system cannot be commissioned for use until such time as the 24 month characterization period has been completed.

    a. Samples collected for the purposes of water quality characterization will be taken at the intake.
    b. Samples collected taken for the purposes of water quality characterization shall be untreated. For example, if the intake sample line has treatment for zebra mussel control, this treatment must be offline for a certain period of time prior to collection of the sample.
    c. Samples taken for microbial analysis would be collected on, for example, a monthly basis and submitted to an accredited testing facility that is licensed for the required test parameters.

4. The proposed approach would lead to a primary classification scheme based upon the combination of evidence (a sanitary survey, and microbiological quality assessment) through which a source water resource would be assigned to a risk and a class. For example; very poor, poor, fair, good, excellent.
    a. The approach would require a detailed sanitary survey within the defined zone for that source waters intake. For example Lakes would require a sanitary survey for the ‘pathogen risk zone’ to be equated with the response time (RT).
    b. The approach would require routine monitoring of suitable microbiological indicators and or pathogens.

Example: Obtaining a classification would incorporate results of both the sanitary survey and the initial microbiological quality assessment. Once categories for each criterion have been determined by the Province, a table such as this can be used to classify source waters.

		Microbiological Assessment Category		
		A (objective of 0-30 CFU *E. coli*/100ml)	**B(objective of 30-100 CFU E. coli/100ml)**	**C (objective of >100 CFU *E. coli*/100ml)**
Sanitary survey category	Very low risk	Excellent	Good	Fair
	Low risk	Excellent	Good	Fair
	Moderate risk	Good	Good	Poor
	High risk	Good	Fair	Poor
	Significant risk	Fair	Fair	Poor

- Different classifications would have different prescribed actions associated with them. For example, a very low or low risk resulting in a classification of good or excellent would result in the "**monitoring**" of the watershed. An assignment of a fair classification would result in the "**management**" of the watershed and an assignment of a "poor" classification would result in the "**mandatory reduction**" of the watershed.
- The proposed approach would allow for "reclassification" of source water through evidence of the effectiveness of management action (BMPs).

Rationale:
Moving away from the traditional regulatory scheme based on compliance and towards developing an approach that better reflect health risk should provide for effective management intervention. The characterization of the water source with respect to quality, treatment and vulnerability is consistent with Recommendation 30 by Justice O'Connor, in the Report on the Walkerton Inquiry that states "All raw water intended for drinking water should be subject to a characterization of each parameter that could indicate a public health risk. The results, regardless of the type of source, should be taken into account in designing and approving any treatment system."

The characterization is also consistent with the approach taken by other jurisdictions. For example, in British Columbia, wells are characterized according to water system size and hydrogeologic setting such as the type of aquifer (e.g. unconfined and confined sand and gravel aquifers, fractured bedrock aquifers). Guidance is provided for delineating the assessment areas for each drinking water source type (e.g. streams with watersheds above a certain size, lakes with watersheds above a certain size, springs or wells). The inventory of water sources and their characterization will be used in the risk assessment to prioritize water sources by identifying those that are or have experienced pathogen contamination and that are vulnerable to future contamination.

Considerations:

1. The Province needs to establish who would be responsible for creating this inventory. It is the recommendation and suggestion of the Pathogen sub-committee to use the local proposed SPPC.
2. The province would need to provide definitions for each category.
3. The Province (Data committee) would need to establish a centralized repository for the data already in existence and disseminate to SPPC committees.
4. The Implementation Committee and Data sub-committee need to consider how these collaborative exchanges of information would come about. For example, a memorandum of understanding may be required between government agencies.
5. An important aspect to adopting a watershed approach is the need to incorporate private wells into the source water protection planning process. As such, the Province needs to identify private wells in the wellhead protection area. Ministry of Health and Long –Term Care data records and involvement are important and required in order to achieve this objective.
6. The Province would need to determine who would be responsible for sampling and testing, including for those test parameters for which there is insufficient data and who will pay for these tests
7. The Province needs to establish sampling and testing protocols for microbial and chemical test parameters. (For example, adopt those published by the USEPA)
8. Testing facilities (laboratories) need lead time to acquire microbial test methods, accreditation and licensing.
9. The Province needs to establish an appropriate timeline for re-characterization surveys. The pathogen sub-committee recommends ongoing characterization.
10. The Province needs to provide guidance to the SPPC on ongoing evaluation of source water characterization.
11. Province would need to establish an appropriate classification/grading framework.
    a. For example: A grading framework establishing the microbiological assessment categories or ranges to which **surface waters** could be classified. This for example could be defined as must meeting a microbiological guideline of 0-30 CFU *E. coli* to be graded as a very low risk. With a score between 30-100 CFU *E. coli* per 100ml, water would be graded as moderate risk and if a water scores greater than 100 CFU *E. coli* per 100ml then it would receive a grade of significant risk.
    b. For example: A grading framework establishing the microbiological assessment categories or ranges to which a **ground water** could be classified as follows: a water meeting only a 0-2 log reduction in *E. coli* then it graded as significant risk, if it scores 2-3 log reduction *E. coli* then it is graded as moderate risk and if it scores greater than 4 log reduction *E. coli* then it receives a grade of low/moderate risk**.**
    c. The Province would need to determine who would be responsible for the task of "assigning" a water source to a particular category or group.
12. The SPPCs should review the data under the context of the watershed description step in the watershed characterization that will form Part 1 of the Technical Assessment Report that will be required by the Drinking Water Source Protection Act.

Discussion Item 4:

"Province needs to identify and research "Best Management Practices" that would result in the reduction of pathogen loads to the watershed"

Rationale:
Best management practices (BMPs) will be the primary tool for mitigating chronic pathogen loadings to surface water and ground water. However, the capacity of different BMPs to reduce pathogen loadings, either individually or in combination has not been formally quantified.

Considerations:

1. The province needs to undertake the following tasks to identify and quantify the capacity of BMPs to reduce pathogen loadings:
    a. Conduct a literature review that identifies candidate BMPs;
    b. Generate a database that summarizes the capacity of candidate BMPs to reduce pathogen loadings, including the different assumptions and limitations of contributing research;
    c. Generate a preliminary list of appropriate BMPs that estimates the pathogen loading reduction;
    d. Generate a list of items that require research to quantify the reduction of pathogen loadings from BMPs; and
    e. Formulate and support an ongoing research program to quantify benefits of BMPs.

Discussion Item 5:

"The province needs to establish a monitoring framework that defines the monitoring frequency and methods (sampling and analytical)"

Rationale:
For a universal classification scheme to work, monitoring must be carried out in a consistent manner across the province. Therefore, to provide consistency with the analysis of monitoring, along with database compatibility across water sheds, frequency of samples collected, sampling protocols and analytical methods should be established.

Considerations:

1. Province needs to determine who will be responsible for analyzing and storing of monitoring data.

2. Province need to issue guidance to the SPPCs on sampling frequency, and accepted analytical methods. For example, sampling would need to be collected from a non chlorinated intake line (awareness for zebra mussel control systems)
3. Laboratories will require lead time to acquire accreditation and licensing for new methods.

Discussion Item 6:

"The province needs to establish microbiological standards/objectives for all source waters intended for the purpose of a drinking water supply"

1. The microbiological water quality standard (raw water) should be based on the use of multiple indicators and consider utilizing a combination of; *E. coli* and/or enterococci, coliphage and *Cryptosporidium*.

2. The microbiological water quality standard for wells should maintain risk below the rate of infection, per year, per person, of no greater than 1 in 10,000.

Rationale:
A microbiological water quality standard and or objective will provide consistent source water protection to all source waters across the province, the use of faecal indicator bacteria alone as an index of risk to human health may significantly over or under estimate risks where the indicators are derived from sources other than human and or animal. This standard or objective would define the microbiological assessment categories and be used as the benchmark in ongoing monitoring efforts.

Considerations:
1. Province needs to undertake the standards development process to develop raw water microbiological water quality standards (risk based) for *E. coli*, *Cryptosporidium* and enterococci and coliphage.
2. Laboratories need lead time to acquire test methods, accreditation and licensing

SOURCE SPECIFIC RECOMMENDATIONS:

<u>Discussion Item 7:</u>

River Source:

"A pathogen risk zone' is to be established which equates to the response time (RT) to manage threats to the surface water intake. The RT translates to a defined area based on the annual average flow rate of the river, including storm events and transport rate at and upstream of the intake, and would have a minimum of two hours."

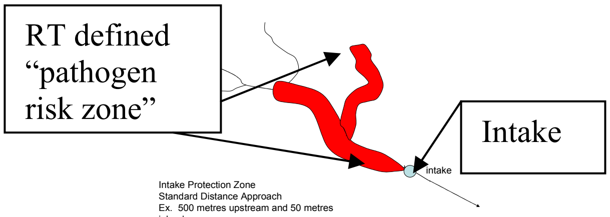
AND

"A river intake water quality standard should be established to ensure ongoing efforts to reduce levels of pathogens"

1. This approach requires that best management practices and risk management are being implemented upstream from the intake.

2. The approach assumes that the local SPPC will utilize the threats assessment inventory checklist to assess upstream within the "Pathogen Risk Zone" and identify those point sources and non point sources requiring further in depth investigation and or follow up action, also known as "management". As such, an inventory of pathogen sources in the pathogen risk zone will be compiled by the *SPPC* and included in the Assessment Report. The inventory will include pathogen sources from the list of Threats of Provincial Concern.

FIGURE 1: River RT upstream "managed zone" and intake



a. Where the area depicted in red (response time) has been identified as the **Pathogen Risk Zone**. The critical zone is a more restricted zone whereby certain activities that have been identified as part of the risk management list are managed **and monitored** through Best Management Practices (BMPs), **to reduce peak microbiological contaminant loads**.

For example, as a goal, combined sewer overflows (CSOs) and the release of untreated sewage should not be permitted within this zone; zone includes pathways for pathogens that are overland and under-land inclusive of such things like piping (sewer, tile drains).

Rationale:
Two approaches are proposed here to deal with the two distinct types of threats to drinking water that are taken from river systems: chronic pathogen loading and acute spills of pathogens. Chronic loading of pathogens to the river resulting from land use activities and piped discharges (e.g. combined sewer overflows, tile drains) will be addressed through the implementation of Best Management Practices (BMPs) at a watershed level. This approach aims to reduce the overall loading of pathogens to the river system. A "BMP Pathogen Index or Hazard Analysis Critical Control Point (HACCP)" which quantifies the benefits of implementing BMPs individually and cumulatively is needed to responsibly allocate resources. To ensure that this approach is effective ongoing monitoring for pathogens of concern is proposed at the intake.

Severe storms, spills or failures that result in a release of pathogens are acute threats to the river and require a reactive approach. The Pathogen Risk Zone (PRZ) is the area, that if a spill occurs, there is not enough time for the drinking water plant operator to turn off the intake. As such it is proposed that in the PRZ there will be restrictions in this zone. For example, no new manure storages or untreated discharge from CSOs would be permitted.

Considerations:
1. Province needs to issue guidance to the SPPCs on how to characterize and determine the risk associated with flow condition.
2. Province needs to establish how the flow rate, is to be calculated, and issue a protocol for that calculation where a PRZ greater than 2 hours is necessary.
3. Province needs to determine who will be responsible for calculating the RT, flow rate, and pathogen risk zone zones, where a PRZ greater than 2 hours is necessary.
4. The Province in conjunction with other agencies within the SPPC jurisdictions would need to determine the watershed scale as appropriate.
5. The Province in consultation with the municipalities and local SPPC would need to establish an approach to manage vast areas that extend across municipal boundaries
6. Province needs to identify and research "Best Management Practices" that would result in the reduction of pathogen loads to the watershed.
7. Province needs to undertake the standards development process to develop raw water microbiological water quality standards/objectives (risk based ranges)

8. The Province needs to establish a monitoring framework that defines the monitoring frequency and methods (sampling and analytical)

Discussion Item 8:

Municipal wells:

"A two-year Time of Travel (TOT) pathogen zone will be delineated for all municipal drinking water wells"

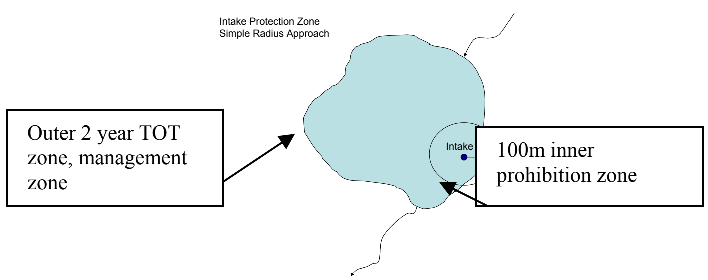
AND

"Within the 2 year TOT, there will be a 100 metre radius prohibition zone"

AND

"A microbiological water quality standard (raw water) should be established using E. coli and coliphage"

FIGURE 2: Pathogen Zones for Municipal Wells



1. For wells that are determined to be **of low/moderate vulnerability**, for example; as defined by Vulnerability Sub-Committee (ISI > 30), and including the result of the microbiological assessment, land use practices within the 2 year time of travel (TOT) will be **managed and monitored** to prevent any additional activity which could increase the risk of pathogen contamination.

2. For wells that are determined to be **highly vulnerable** for example; as defined by Vulnerability Sub-Committee (ISI < 30), and including the result of the microbiological assessment, land use practices within the 2 year TOT would **be managed to eliminate**, where practical or restrict any activity which is contributing to the risk of pathogen contamination,

Rationale:
The most stringent restrictions on activities and practices related to pathogen sources will be applied in the **100m prohibition zone**, however, the Source Protection Planning Committee (SPPC) may also recommend restrictions or best management practices outside of this zone (e.g., within the pathogen management zone, within highly sensitive ground water settings) to further reduce the risk of pathogen contamination of the source.

The two year TOT is based on an extensive review of scientific literature. The 100 metre **"prohibition**" zone is consistent with practices in other jurisdictions, is consistent with other provincial legislation.

An inventory of pathogen sources in the pathogen zone will be compiled by the SPPC and included in the Technical Assessment Report. The inventory will include pathogen sources from the list of Threats of provincial Concern. In addition sources of pathogen sources in the watershed will be identified through the watershed approach. Priority will be given to reducing the impact from Risks of provincial Concern that are evaluated to be significant in the pathogen restriction zone.

Considerations:
1. Province needs to provide guidance to local SPPCs to support 5.1, 5.2, and 5.3. For example, the province needs to establish and issue a protocol on how to calculate the two year time of travel and identify who will be responsible for performing this function.
2. TEC may want to recommend that the criteria for Ground Water Under the Direct Influence of Surface Water (GUDI) wells be re-evaluated in light of the information collected in the literature review done by the Pathogens Working Group. The literature clearly indicates that pathogens can survive in soils and ground water for longer than the 50 day criteria used to identify GUDI wells.
3. The Province, in consultation with the municipalities and local SPPCs would need to establish an approach to manage vast areas that extend across municipal boundaries
4. Province needs to undertake the standards development process to develop microbiological raw water quality standards using a risk-based approach.
5. The Province needs to establish a monitoring framework that defines the monitoring frequency and methods (sampling and analytical).
6. Laboratories need lead time to acquire test methods, accreditation and licensing.
7. Province needs to consider impact on the installation of new municipal and private systems (wells and septics) in these areas. For example; for new municipal wells to

be constructed in highly vulnerable areas, the SPPC uses the source water protection plan framework to plan and consider implications.

8. Province needs to address existing municipal and private systems in these areas.
9. Province needs to identify and research “Best Management Practices” that would result in the reduction of pathogen loads to the watershed.

Discussion Item 9

Private Wells:

“A microbiological water quality standard (raw water) has been identified as necessary (E. coli and coliphage)”
AND

“The program of well education, well testing and well upgrading for private well owners be improved.”

Rationale:
The wells, when surveyed in the Ontario Ground water Survey, had an unacceptable frequency of contamination by indicator organisms. This indicates the present programs are not properly protected the private well source waters.

The Province of Ontario currently uses an effects-based model, which is applied on a voluntary basis, for addressing concerns with microbial pathogens that may adverse private well water quality. The premise for this model is that private well owners are the most appropriate persons to manage private well water systems. Under this model, the province provides support to private well owners in two ways.

First, licensed well contractors will construct and maintain wells in a manner that meets the requirements stipulated under the water well regulation (Regulation 903) under the Ontario Water Resources Act. Well owners are provided with education materials concerning the proper construction, maintenance and decommissioning of wells to assist them in making good management decisions. Investigations are undertaken by provincial staff in response to complaints. Second, private well owners are provided with complementary water quality testing for indicator bacteria through public health laboratories operated by the Ministry of Health and Long-Term Care (MOHLTC). Technical assistance for well owners that have adverse water quality tests is provided by public health units operating under the jurisdiction of the Safe Water Program, a mandatory program administered by the Public Health Branch of MOHLTC. This includes the distribution of educational materials such as the “Keeping Your Well Water Safe to Drink” kit.

This model assumes that the risk of ground water contamination from pathogens is greatest at the well itself, and decreases as the distance from the well increases, and according to the following risk hierarchy:

a. Greater risk - poor construction and maintenance of the well that can allow the direct entry of surface water and contaminants into the well, or down the annular space of the well;
b. Moderate risk – potential point contaminant sources (e.g., pesticides, manure storage) located in the immediate vicinity of the well (e.g., around the farm yard);
c. Lesser risk - potential non-point contaminant sources located away from the well (e.g., land application of materials containing nutrients).

This hierarchy is designed for use with large rural properties, such as farms, where the private well owner has control of the lands that replenish the well (i.e., property contains private wellhead and capture zone). With a privately serviced subdivision, either rural or urban, numerous private wells and onsite sewage disposal systems will be located within close proximity of each other. In these situations, a private well may be equally prone to impact from by activities on a neighboring lot (e.g., inappropriately sited onsite sewage disposal system) as by the activities of the well owner on the home property. As a consequence, the current model for private wells appears to be appropriate for large rural properties such as farms, but a different approach is needed for privately serviced subdivisions.

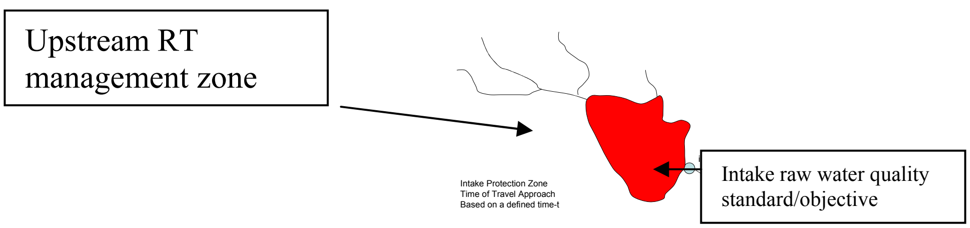
Considerations:

1. Province could implement random inspections of wells completed by licensed well contractors;
2. Province could develop a check-list of minimum requirements that would be signed and submitted by licensed well contractors once the well has been commissioned;
3. Additional resources (staff, funds) would be required to expand existing education programs to include all private well owners. Current programs are resourced to only deal with complaints (Regulation 903) or those with adverse water quality test results (Safe Water Program). This could include inspection of existing private wells by licensed well inspectors (under Regulation 903);
4. An expanded educational program could encourage regular testing of all private wells to ensure that they are providing a safe supply of water, and encourage well owners to install water treatment equipment where appropriate with assistance of local public health unit staff; and
5. Province could prioritize resources for expanded education program, focussing on areas of greater significance. A possible hierarchy could include, from higher to lower priority:
    a. Highly Vulnerable Municipal Well Pathogen Prohibition Zones;
    b. Moderately/Less Vulnerable Municipal Well Pathogen Prohibition Zones
    c. Highly Vulnerable Municipal Well Management Zones;
    d. Moderately/Less Vulnerable Municipal Well Management Zones;
    e. Highly Vulnerable Aquifer Areas; and
    f. Moderately/Less Vulnerable Aquifer Areas

Discussion Item 10:

Lakes (Great and or inland) and Reservoirs

"Use an effect-based approach, requiring a microbiological water quality standard (raw water) based on enumeration of E. coli and/or enterococci, and Cryptosporidium"



AND

"A pathogen risk zone' is to be defined as a contiguous area of land and water immediately upstream of a drinking water intake that is delineated using a site-specific response time of the system or could be delineated using a minimum predetermined time of travel. This zone would be a "managed zone."

1. The water quality at the intake must meet the Raw Water Quality Standards/objectives based on a geometric mean of samples for example, collected at least monthly taken over a 24 month characterization period.

2. Consider historical data where available as part of the source water characterization characterization.

3. In addition if the water quality standard is exceeded the local SPPC will utilize the threats assessment inventory checklist to assess upstream within the “protection zone” and identify those point sources and non point sources requiring further in depth investigation and or follow up action. As such, an inventory of pathogen sources in the pathogen zone will be compiled by the *SPPC* and included in the Assessment Report. The inventory will include at minimum pathogen sources on the Risks of Provincial Concern list.

Rationale:
A raw water standard provides a clear indication of what level of water quality is acceptable for drinking water sources in Ontario. The standard or objective should set an achievable, protective target for lakes in Ontario that serves as the second barrier to protect drinking water in the event of a failure at the drinking water plant. A value for example of 30 colony forming units of *E. coli* per 100mL is cited in literature as the concentration at which health effects are observed when people swim in the water. This *E.coli* concentration was proposed by the TEC members of the Pathogen Sub-committee as an ambient water quality objective that if adopted would benefit overall water quality for other uses (e.g. recreational).

Similar to river sources the chronic loading of pathogens to lakes resulting from land use activities and piped discharges (e.g. combined sewer overflows, tile drains) will be addressed through the implementation of Best Management Practices (BMPs) at a watershed level. This approach aims to reduce the overall loading of pathogens to the lake. A “pathogen index / HACCP” which quantifies the benefits of implementing BMPs individually and cumulatively is needed to responsibly allocate resources. To ensure that this approach is effective the drinking water plants will need to expand their current program to include the pathogens of concern (*Cryptosporidium, E. coli,* and enterococci).

Considerations:
1. Province needs to undertake the standards development process to develop raw water microbiological water quality standards/objectives (risk based) for Cryptosporidium and enterococci.
2. Province needs to identify & research “Best Management Practices” that would result in the reduction of pathogen loads to the watershed.
3. The province needs to establish a monitoring framework that defines the monitoring frequency and methods (sampling and analytical) (sampling would need to be done from a non chlorinated intake line- zebra mussel control systems)
4. Laboratories need lead time to acquire test methods, accreditation and licensing.

Discussion Item 11

For Private surface water sources

"That the Province require all owners of private drinking water supplies derived from surface water to provide an appropriate level of treatment to eliminate pathogens. The level of treatment should be based on results of a source water quality evaluation conducted by the SPPC, using risk management guidelines issued by the province."

Rationale:
Surface water drinking sources are distinctly different from ground water drinking sources and require additional consideration. Ground water supplies are typically protected by - subsurface soils because infiltrating water is filtered and purified as it moves down into the subsurface. Ground water is generally considered to be uncontaminated because the natural processes of filtration and purification are assumed to exist with the exception some vulnerable areas (e.g., shallow soils), As a consequence, private ground water systems generally do not require treatment except where private wells have adverse sampling results for indicator bacteria. In contrast, surface water is generally considered to be contaminated because surface water lacks these natural processes. A precautionary approach for surface water drinking sources is warranted, and a minimum level of treatment should be required. Source water quality evaluations should be used to determine if the current treatment is sufficient, or if additional treatment is necessary to minimize the microbial risk.

In addition, the province should prepare risk management guidelines to assist SPPCs to complete source water quality evaluations in the watershed. Provincial guidelines would help to ensure a consistent approach across the province. Experience has shown that surface water supplies can be more vulnerable to contaminant inputs that originate from the areas immediately upstream of the intake. Implementation of risk management practices in the watershed area upstream of the intake should be considered by SPPCs to reduce pathogen loadings. The use of risk management activities to reduce the loadings of pathogens is consistent with the precautionary principle approach.

Considerations:

1. Province needs to develop guidelines on risk management for surface water used as a source of drinking water.
2. Province needs to develop a guidance document for the source water quality evaluations that will be undertaken as part of source protection planning.
3. Province should undertake a program of education and awareness for private home and cottage owners who take their drinking water from a surface water body.
4. Province should monitor some "hotspot" surface waters that are used for drinking water and that have a history of pathogen contamination to assess the impacts of source protection planning (e.g. implementation of best management practices in the upstream watershed, educational programs *etc.*) on the water quality.

GLOSSARY:

Municipal Wells: means a public water supply owned by the government

Gain Control: means to purchase, lease, or expropriate a parcel(s) of land within the prohibition zone

Prohibition: means a decree that prohibits no new activity and or remove existing activity within the 100m protection zone.

Acute pathogen threat: means rapid onset, severe symptoms and short duration. Opposite of chronic. For example, a manure spill into a river.
Chronic pathogen threat: means of long duration; continuing. Lasting for a long period of time or marked by frequent recurrence. For example, wastewater treatment plant discharge.

Public Consumption: means any drinking-water system that is regulated under the Drinking-Water Systems regulation (O. Regulation 170/03).

Sanitary Survey: means the on-site review and evaluation of all actual and potential pollution sources and environmental factors having a bearing on area water quality. AND an on-site review of the water source, facilities, equipment, operation, and maintenance of a public water system for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water.

Appendix 6B: TEC Pathogens Subcommittee

PROTECTING SOURCE WATERS FROM PATHOGENS - A DISCUSSION PAPER

Prepared by:

The Technical Experts Pathogen Sub-Committee on Source Water Protection

&

Ontario Ministry of Agriculture and Food

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Ontario Ministry of the Environment

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Ontario Ministry of Health and Long-Term Care

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BMPs – best management practices

cm – centimeters

cm/hr – centimeters per hour

CFU/g or per ml - colony forming units per gram or colony forming units per millilitre

E. coli - *Escherichia coli*

m - metres

µm - micrometres

mL – millilitres

nm - nanometres

OMOE – Ontario Ministry of the Environment

OMAF – Ontario Ministry of Agriculture and Food

OMOHLTC – Ontario Ministry of Health and Long Term Care

PSC – Pathogen Sub-committee

SDWA – Safe Drinking Water Act

SWP – source water protection

SWPP – Source Water Protection Plan

SWPPC- Source Water Protection Planning Committee

TEC - Technical Experts Committee

TOT – time of travel

USEPA – United State Environmental Protection Agency

UV- Ultraviolet

WHPA - well head protection area

WHO - World Health Organization

GLOSSARY

Advective transport. Horizontal movement by a fluid.

Bacteriophage. Viruses that infect bacteria

C/Co. Ratio of output concentration to input concentration

Desorption Opposite of absorption or adsorption. In filtration, it relates to the downstream release of particles previously retained by the filter.

microspheres. Man-made spheres of different sizes and materials that can be used as a surrogate for pathogens in microbiological studies.

Monodispersed. Dispersed somewhat uniformly

Microcosm. A small system that is considered to be representative of the larger, complete system. A miniature model.

Sorption. Adhesion onto surfaces

ACKNOWLEDGMENTS

This discussion paper was developed through the combined efforts of the Technical Experts Pathogen Sub-Committee. The committee was comprised of a team of scientific experts representing the fields of microbiology, hydrogeology, soil science and engineering. Each committee member contributed to the development of this review and without their enthusiasm and support, completion of this document would not have been possible.

The following individuals, arranged alphabetically, supported the development of this document.

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EXECUTIVE SUMMARY

A 16-member Technical Experts Committee was announced in November 2003 to provide advice to the government of Ontario on the following components of the source water threat assessment process:

- threat categories;
- linkage of ground water protection to surface water management;
- effects of water-takings on the availability and quality of drinking water;
- appropriate risk management tools for various levels of threats; and
- protecting both current and future drinking water sources.

The committee recognized that an important component of this process involved understanding and managing concerns associated with waterborne pathogens. To address these concerns, a Pathogens Sub-Committee was formed to develop a series of recommendations concerning pathogen management in source waters.

The Pathogens Sub-Committee was guided by several principles:

- a multi-barrier approach is necessary for source water protection;
- a scientific, risk-based approach should be applied during decision-making and,
- a source water protection program should incorporate continuous improvement.

These principles were used to guide the collection of information and development of recommendations.

To provide background and context for its work the Pathogens Sub-Committee undertook several tasks:

- a review of measures in other jurisdictions for managing pathogens;
- an evaluation of scientific literature concerning pathogen survivability and fate; and
- consultation with pathogen experts from Canada and the U.S.A. by telephone and through hosting a one-day symposium.

The review of other jurisdictions determined that no other jurisdiction has developed a comprehensive, science-based approach for managing pathogens, however, a number of useful approaches were identified that could be used in combination to achieve a comprehensive program. Evaluation of scientific literature concluded that a single microbial indicator is insufficient to address source water protection from all pathogens; the survivability and transport of pathogens is highly variable; and, confirmed that a multi-indicator strategy is necessary. The consultations with experts reinforced the findings of the jurisdictional and literature reviews, and supported the premise that an Ontario-based approach should include a combination of approaches based on a multi-indicator strategy.

1.0 INTRODUCTION

The Technical Experts Committee (TEC) held broad ranging discussions on a full range of technical issues affecting source water protection. Where certain issues required additional detailed study and analysis, subcommittees were formed to focus on these and report back to the TEC with their recommendations. Each subcommittee prepared a report on their findings.

The Pathogen Sub-Committee (PSC) was formed as it became clear that strategies for protecting source water against chemical contaminants such as organic solvents was not appropriate for protection against pathogens. It was recognized that pathogens behave quite differently from other contaminants with respect to survivability and transport in the water environment. The PSC was formed with a core group of TEC members and staff from various ministries. This report summarizes the work of the Pathogen Sub-Committee (PSC).

The main task for The PSC was to provide recommended approaches to protect drinking water from microbial contaminants. The PSC took a three-step approach to work through this task. The initial step was a jurisdictional review followed by a, an extensive literature review and finally the PSC consulted with world renowned microbiologists.

The PSC recognized that drinking water must be kept pathogen-free through a multibarrier approach, including: (a) selecting high-quality, uncontaminated source waters; (b) applying efficient treatment and disinfection measures to water; and (c) protecting water from contamination during distribution to the user.

The type and effectiveness of the disinfectant and treatment should depend on the type and level of pathogens present and the physical characteristics of the water being treated. A well-managed, adequately treated system should be effective in removing or inactivating disease-causing organisms.

1.1 Creation of the Technical Experts Pathogen Sub-Committee

As part of the Government's commitment to implement the recommendations Justice O'Connor made in the Walkerton Report (OMOE, 2001), the Ontario Ministry of the Environment (OMOE) is in the process of creating the comprehensive legislative framework for source water protection (SWP). To support that process the OMOE formed a Technical Experts Committee to provide advice on the identification and effective means of addressing possible threats to drinking water.

The Technical Experts Committee on SWP recommended that a sub-committee be created to address the issue of pathogens, which represent a threat to drinking water safety and quality. This issue required special emphasis because the transport and survivability of pathogens in the environment is currently not well understood; however it is known that these living organisms behave differently from other contaminants. The Pathogen Sub-Committee was established, comprised of four TEC members and staff from the Ontario Ministry of the Environment, the Ontario Ministry of Agriculture and Food and the Ministry of Health and Long Term Care. The overall objective and purpose of this committee was to develop recommendations for pathogen management for all source waters in Ontario.

The PSC considered the need for an approach that was fair and reasonable for all stakeholders. In developing the recommendations to protect source water from pathogens, several other guiding principles were applied, including the multi-barrier approach to source water protection, the need for watershed protection, a scientific approach to decision-making based on risk assessment, and the need for continuous improvement in all program aspects. The PSC carried out an extensive review of the literature, conducted in depth consultations with international experts, and held a workshop to obtain additional information from experts in the field.

In developing its recommendations, the PSC believed it was important to:

- review comparable activities by other jurisdictions and information in the scientific literature as well as solicit expert opinion to ensure that the most current scientific understanding of the epidemiology, fate and transport of pathogens in the environment was made available to the committee;
- make optimum use of existing available provincial information including studies, existing experience and policy development that has resulted from other initiatives (ground water under the influence of surface water, *Nutrient Management Act etc*.);
- avoid duplication of effort by taking advantage of experience and approaches from other jurisdictions (other provinces in Canada, USA, New Zealand) related to source water protection;
- remain aware of the implementation challenges, including costs, when proposing the adoption of new approaches to source water protection; and
- look toward establishing goals that would ideally be reached but may not be attainable at present; and
- source water protection planning was seen by the Committee as an ongoing developing process rather than a one-time change, and it was recognised that the process has to evolve with scientific and technical knowledge.

1.2 Background

Contaminated ground water is responsible for approximately 68% of the waterborne disease outbreaks reported in the USA every year (CDC, 2000). This accounts for approximately 7 outbreaks and over 1,000 individual cases annually. In the USA, ground water is the source of drinking water to 40% of the population. In Ontario, 1996 data indicate that 28.5% of the population relies on ground water for municipal, domestic and rural use (CCME, 2004). Contaminated surface water also contributes to many waterborne disease outbreaks. For example, in the USA between 1971 and 1996, a total of 652 waterborne disease outbreaks were reported, infecting nearly 600,000 people. One outbreak in a Milwaukee drinking water supply caused over 400,000 people to become ill and over a 100 people with weakened immune systems died as a result (Corso et al., 2003).

There is a strong belief amongst health officials that there is an endemic level of illness associated with drinking water that goes undetected and unreported (Borchardt et al., 2003). Waterborne outbreaks probably occur with greater regularity; however, reporting of such incidents is uncommon and waterborne outbreaks are often not recognized or, if they are, are not traced as being due to the drinking water supply. In Ontario from 1974 to 2000, there were only 39 published reports of waterborne outbreaks/incidents associated with drinking water. The data identified that 20% of the reported incidents were associated with municipally treated distribution systems, 23.3% were associated with consumption of water from an unprotected source, 3.3% of reported incidents were associated with trucked-in water and 53.3% of reported incidents were associated with well water. Of those incidents involving well water, 31.2% were associated with communal wells and 68.8% were involved with private wells.

The outbreak in Walkerton, Ontario resulted in 7 deaths and made more than 2300 people ill; some who will be dealing with the effects of the sickness for the rest of their lives. In North Battleford, Saskatchewan, an outbreak of *Cryptosporidium* made several thousand people ill. Thousands more were also affected in *Cryptosporidium* outbreaks in Cranbrook and Kelowna, British Columbia (CCME, 2004).

Clearly pathogens are a significant health concern with respect to drinking water quality, as demonstrated by the large number of waterborne outbreaks around the world. It is important to understand how pathogens behave in the environment to better protect the integrity and quality of source waters in Ontario.

1.3 Significance of Pathogens and Related Indicators

Vertical distribution and transport of microorganisms in soils has been studied since the early 1900's. These early studies indicated and assumed that, the numbers of microbes declined sharply with depth that organic nutrients were probably too restricted to support life, and that ground water was considered pure because it was protected by soil (Waksman, 1916). As such, scientific, public health and government agencies perceived there was no need to study ground water systems. However, the fact that 35% of domestic farm wells in Ontario were found to be contaminated with bacterial indicators of faecal importance indicated cause for concern (Goss et al.,1998). A study in the USA involving 448 municipal wells in 35 states identified that 31.5% of the wells tested positive for viruses (Abbaszadegan et al, 1999). Outbreaks, such as that in Walkerton, and the pre prevalence of microbiologically contaminated drinking-water wells in Ontario, has led to considerable increase in the interest in the fate and transport of these contaminants in the subsurface environment.

Microorganisms are everywhere and live on everything; water systems are not sterile. To put this point into perspective, the World Health Organization (WHO) guideline for “general bacteria” in water is 500 per 1 millilitre (ml); this is the same for the province of Ontario. When this value is extrapolated up to 500 ml, the typical volume of bottled water, this general bacteria population becomes 250,000 bacterial cells in a bottle of drinking water. The concern is for those microorganisms that can cause disease in humans (pathogens), and not those microorganisms indigenous to the environmental.

The pathogens of concern in drinking water are those which are waterborne (transmitted by water). These pathogens are generally faecal in origin and referred to as enteric pathogens. Enteric pathogens are excreted from infected individuals and animals in high numbers and may directly or indirectly contaminate water intended for drinking. The human and animal population serves as a constant source of pathogens because it is recognized that these can be shed continuously by both via a number of pathways.

The WHO, the Guidelines for Canadian Drinking Water Quality and the Ontario Drinking Water Standards identify that no indicator of faecal contamination or pathogen be present in drinking water.

The pathogenic agents involved include bacteria, viruses and protozoa which may cause disease that vary in severity. These organisms range in size from 23 nanometres (nm) to 15 micrometres (µm) (Table 1). Some human pathogens potentially transmitted in drinking water are those listed in Tables 2, 3, and 4.

Ground water and surface water are subject to faecal contamination from a variety of sources, including sewage treatment plant effluents, on-site wastewater treatment system (septic system) discharges, storage and land application of manure, runoff from urban and natural areas, and storage and application of biosolids and septage and natural sources. Septic tank systems in the USA are frequently associated with ground water contamination and ground water disease outbreaks (Yates, 1990). Azadpour-Keely et al. (2003) cite results of several studies indicating that viruses commonly make it through the septic systems and enter soil and ground water.

Table 1: Relative Size of Microorganisms

Microorganism	**Size**
Viruses	23-80 nm
Bacteria	0.5-3 µm
protozoan parasites	4-15 µm

Table 2: Bacterial pathogens of concern in water

Bacterial Pathogens (not indicators)	**Disease**
Vibrio cholera	Cholera
Salmonella typhi	Gastroenteritis
E. coli 0157	Gastroenteritis, haemolytic uraemic syndrome
Shigella spp.	Bacillary dysentery, Gastroenteritis
Legionellla	Legionnaires
Campylobacter	Gastroenteritis
Yersinia enterocolitica	Gastroenteritis
Helicobacter pylori	Gastritis, peptic ulcer, gastric cancer
Mycobacteria"Mycobacterium avium complex"	Tuberculosis
Aeromonas hydrophila	Gastroenteritis
Pseudomonas aeruginosa	Skin, ear infections

(note: this is not an exhaustive list of all pathogens that can cause waterborne disease).

Table 3: Viral pathogens of concern in water

Viral pathogens of concern in water	**Disease**
Adenovirus	Gastroenteritis, eye and respiratory
Calicivirus	Gastroenteritis
Coxsackievirus	Meningitis, myocarditis, respiratory disease
Echovirus	Meningitis, diarrhea, respiratory disease
Enteroviruses	Meningitis, conjunctivitis
Hepatitis A, and E	Epidemic hepatitis
Norwalk virus	Influenza
Poliovirus	Paralysis, meningitis

Table 4: Parasites of concern in water

Parasitic pathogens of concern in water	Disease
Protozoa	
• *Cryptosporidium* oocysts	Enteritis, diarrhea
• *Giardia* cysts	Enteritis, diarrhea
• Microspora "Microsporidia"	clinical manifestations of microsporidiosis are diverse, varying according to the causal species
Helminth Worms	
• Ascaris	Ascariasis: abdominal pain, intestinal blockage, fever.
• Trichuris	Trichuris: locate in various organ systems of the human body, perhaps eliciting a fever and diverse complications.
• Taenia	Taenia: mild abdominal symptoms
Other microbiological agents of concern	
• Cyanobacteria (toxins)	Are toxins which accumulate in the liver, and can cause damage over the long-term.

2.0 JURISDICTIONAL REVIEW

The PSC looked to a number of other jurisdictions to see how drinking water is being protected from pathogens in other parts of the world. The intent was to learn from the approaches taken by others and, where appropriate, determine whether there were pieces that might be relevant to an Ontario setting. The review considered provinces in Canada including British Columbia, Nova Scotia, New Brunswick and Quebec, the United States federal programs together with those of several states including Florida, Kentucky, New Jersey, New York, Ohio, and Oregon, and other international approaches being applied in New Zealand, England and Wales, Scotland and Northern Ireland. Only a subset of these jurisdictions addressed pathogens specifically in their approach to SWP; a subset of these approaches are described in the following sections.

2.1 United States

The *Safe Drinking Water Act* (SDWA) of the United States includes requirements for states to develop wellhead protection and source water protection plans. The Wellhead Protection Program, in-place since 1986, directed all states to develop plans for all public water-supply wells. Amendments to the SDWA in 1996 required all states to develop source water protection assessment plans (SWAP). The preparation of a SWAP includes delineation of the drinking water source protection area, inventory of significant contaminants in these areas, determination of the susceptibility of the drinking water supply to contamination, notification and involvement of the public, implementation of management measures, and development of contingency planning strategies. Although not mandatory, most states are following through with the Source Water Protection Plans (SWPP).

In the USA, best management practices (BMPs) are encouraged through the implementation of land use restrictions. These land use restrictions are enforced through the use of ordinances that are specific to a particular county. Properties that are located within a wellhead protection area (WHPA) are governed by restrictions applicable to that zone. In one Maryland county for example, land use restrictions apply to many things including golf courses, riding stables, metal plating establishments, livestock animals in excess of 25 animal equivalent units per acre and poultry. In addition, livestock animals have to be kept at least 50 feet from public water supply wells. These ordinances usually have an exemption or variance clause that may permit the property to conduct 'restricted activities' within a WHPA as long as certain conditions (e.g., nitrate in ground water will not exceed 5 mg/L) and operating guidelines are met (containment, emergency plan, inspections, reporting of spills, ground water monitoring, limits on alterations and expansions).

2.1.1 United States Environmental Protection Agency

The United States Environmental Protection Agency's (USEPA) source water protection program focuses on the protection of drinking water sources from all contaminants. The protection of drinking water supplies from pathogens are covered in a number of regulations including the Surface Water Treatment Rule and the Interim Enhanced Surface Water Treatment Rule (to protect all public systems that use surface water or ground water that is under the influence of surface water from pathogens), the Total Coliform Rule (sets requirements for monitoring of total coliforms, used as an indicator of faecal contamination) and the Proposed Ground Water Rule.

The proposed Ground Water Rule (USEPA, 2000) sets out a multi-barrier approach for ensuring public health protection from the entry of pathogens to ground water supplies. The USEPA rejects the use of a federally prescribed time of travel (TOT) because of uncertainty related to the calculations and the uncertainty in predicting the leading edge of the plume of microbial contaminants. The USEPA's reasons for not requiring a TOT approach are as follows:

- all travel time calculations require the measurement of porosity and this type of data is rare and as a result values are only estimated;
- ground water travel times require knowledge of distance traveled and water velocity; however, calculating travel time is complicated because ground water does not travel in a straight line; and
- ground water travel time represents the average travel time of a large water volume moving toward a well. A calculation of the average ground water travel time is not as protective as the calculation of the first arrival time of the ground water volume. The USEPA argue that because of this uncertainty in calculating first arrival times, the use of TOT must be augmented with a safety factor.

The USEPA proposes a multibarrier approach with five major components: (1) sanitary surveys of ground water systems requiring evaluation of eight elements and identification of significant deficiencies; (2) hydrgeologic assessments to identify wells sensitive to faecal contamination (e.g., karst, fractured rock, gravel aquifers); (3) source water monitoring for systems drawing water from sensitive wells with or without treatment or with other indications of risk; (4) a requirement for correction of significant deficiencies and faecal contamination through prescribed actions; and (5) compliance monitoring.

2.1.2 New Jersey Department of the Environment

The New Jersey Department of the Environment (NJDEP) is in the process of performing source water assessments for all public water supply wells in the state. NJDEP has taken a TOT approach to the protection of ground water resources, using 2 year, 5 year and 12 year protection zones. The 2-year TOT has been established to protect wells from pathogens. NJDEP cite bacteria transport distances of up to 170 day TOT and virus survival in ground water of up to 270 days (NJDEP, 2003). NJDEP went with a 2 year TOT to provide a “margin of safety” beyond the 170 and 270-day results. NJDEP point out that the TOT approach represents an average and the leading edge of a plume may reach a well before the average TOT. With reference to surface water intakes in New Jersey, the entire drainage area is included in the intake delineation area. In addition, a 5-year ground water flow delineation area is required to account for ground water contributions to base flow.

2.2 Canada

In May 2004, the Canadian Council of Ministers of the Environment published a guidance document on the topic of source water protection entitled: “From Source to Tap: Guidance on the Multi-Barrier Approach to Safe Drinking Water” (CCME, 2004). This document provides guidance to drinking water system owners and operators on the application of a multi-barrier approach to protecting drinking water supplies in Canada. In general, this approach is an integrated system of procedures, processes and tools involving the main elements of a drinking water system; the source water (aquifer/watershed), the drinking water treatment plant and the distribution system. The guidance document provides information such as the risk management process, identification of drinking water hazards (including microbiological contaminants), protecting source waters, designing treatment and distribution systems, operator training, audits and emergency response.

2.2.1 British Columbia

In British Columbia there is an amended Drinking Water Protection Act and regulations which came into force on May 16, 2003. The changes establish a comprehensive and co-ordinated framework for protecting the province’s drinking water from source to tap.

Under the new drinking water legislation, the province has increased the basic expectations around assessing water systems, certifying operators and suppliers, and monitoring and reporting on water quality. Regional health authorities appoint drinking water officers which are dedicated positions created under the Act. These drinking water officers will oversee a source-to-tap assessment of every drinking-water system in the province to address all potential risks to human health.

A Drinking Water Source-to-Tap Screening Tool is provided to owners of drinking water supplies. It is a self-screening questionnaire which provides information on the water supply system for assessment. It is the first tier in the drinking water assessment process. The Drinking Water Officer evaluates the results of the screening tool and can either be satisfied with the safety of the water supply, or where significant risks are identified, can order a comprehensive source to tap assessment.

The Ministry of Health Planning, and the Ministry of Water, Land and Air Protection have developed a draft guideline for Comprehensive Drinking Water Source to Tap Assessment. When it is finalized it will provide a structured approach for evaluating risks to drinking water quality and quantity when a detailed, comprehensive assessment is required. The drinking water hazards are identified and evaluated according to the following steps:

- delineate and characterize drinking water source(s)
- conduct contaminant source inventory
- assess water system components
- evaluate water system management, operation and maintenance practices
- audit finished water quality and quantity
- review financial capacity and governance of the water service agency

This characterization and the hazard identification steps are done in the context of a multi-barrier approach to drinking water protection. The characterization provides an integrated assessment of the water supply system. A risk management strategy then follows which provides timelines and responsibilities for addressing the hazards. Decisions about the implementation of the strategy are made by the water supplier in consultation with the drinking water officer, as part of an assessment response plan.

The draft guideline provides technical information on drinking water hazards, information needed on source assessments, data elements and data sources, delineation options for assessment areas for streams, methods for estimating aquifer vulnerability, delineation methods for well capture zones, and potential sources of contamination for ground water and surface water sources.

The approach in British Columbia is to specify a process to assess the risks to drinking water, and to implement a plan to respond to the risks. Technical guidance is provided on the steps to carry this out. However the specific requirements or standards to manage risks are not mandated. It is process-based, with allowance given to the discretion of drinking water officers to make decisions on requirements.

2.2.2 Nova Scotia

The Nova Scotia Department of Environment and Labour require that each municipality or water utility develop a Source Water Protection Plan for their drinking water source area. They follow a 5-step process as given below:

Step 1 – Form advisory committee

Step 2 – Delineate boundary

Step 3 – Assess risks

Step 4 – Develop Management Plan

Step 5 – Monitor results and Evaluate plan

In Step 2, the wellhead protection zones are delineated. The three zones are:

Zone 1 – 2 year time of travel

Zone 2 – 5 year time of travel

Zone 3 – 25 year time of travel

Numerical modelling methods are recommended for the delineation of the wellhead protection zones.

2.2.3 Ontario

In Ontario, the OMOE has produced two wellhead protection related documents for municipal ground water supply wells under the direct influence of surface water. They are:

- “Guidance Document – Development of Microbial Contamination Control Plan for Municipal Ground water Supply Wells under Direct Influence of Surface Water with Effective In-Situ Filtration” January 2004; and
- ”Reference Document – Model Microbial Contamination Control Plan for Municipal Ground water Supply Wells under Direct Influence of Surface Water with Effective In-Situ Filtration” January 2004.

The documents are intended to provide guidance to owners of municipal residential drinking-water systems, who must submit for approval a Microbial Contamination Control Plan, if they wish to apply for a relief from the regulated requirement to provide chemically assisted filtration for a GUDI (ground water under direct influence of surface water) system with “effective in-situ filtration”. The Guidance Document is the document the owner must use in preparation of the plan, and against which the director will evaluate the Plan submitted for approval. The reference document contains additional information that may be helpful to the owner, including models that the owner may wish to adopt in the development of certain parts of the Plan.

In the Guidance Document, it is stated that the microbial contamination control plan must delineate microbial risk management zones. Two saturated horizontal time of travel (TOT) zones are to be identified:

- 0 to 50 days
- 50 days to 2 years

The delineation must be completed in accordance with the "Protocol for Delineation of Wellhead Protection Areas for Municipal Ground water Supply Wells under Direct Influence of Surface Water." Three-dimensional, steady-state computer models e.g. MODFLOW should be used to delineate capture zones unless site-specific conditions suggest other methods. The microbial contamination risks are to be assessed. Then microbial contamination control measures are to be developed and applied. These measures include recommendations to reduce/manage the risk of contaminant release to ground water, and recommendations for control of new development and specific activities within the area. More stringent risk measures are used within the 50-day TOT zone.

2.2.4 Quebec

Quebec has a Ground water Catchment Regulation which requires owners of spring water, mineral water or ground water catchment sites intended to supply drinking water, where the average operation flow rate is greater than 75 m^3 per day, to prepare plans signed by an engineer registered in Quebec. These plans include one showing the location of the bacteriological protection area (migration time of ground water over 200 days), and the virological protection area (migration time of ground water over 550 days).

Where the catchment site supplies drinking water to more than 20 persons, the bacteriological protection area is set within a 100 m radius from the catchment site, while the virological protection area is set within a 200 m radius.

Special provisions are given to farming areas. The spreading of animal waste, farm compost, mineral fertilizer and fertilizing waste substances is prohibited less than 30 m from any ground water catchment work intended for human consumption. The distance is increased to 100 m for sludge that comes from municipal wastewater treatment works, or for substances containing sludge that are not certified to comply with provincial standards. There are restrictions for spreading of nutrient materials within the bacteriological and virological protection areas.

2.3 New Zealand

New Zealand has one of the highest rates of gastroenteritis in the developed world, due in part to their large primary industry base (NZMOE, 2004). The New Zealand Ministry of the Environment and Ministry of Health are working together on the development of a multi-barrier approach to drinking water management. The New Zealand Ministry of the Environment has recently proposed to develop and implement a national standard for the monitoring, grading and reporting of raw drinking water sources. This approach would include a catchment risk assessment, grading of the waters and reporting of the grading. The catchment risk assessment is essentially a qualitative estimate of the suitability of the water as a raw drinking-water source (catchment risk category). The drinking water source is graded using two types of grades; one is a grade for each identified contaminant (a water quality category) and the second is an overall grade that characterizes the suitability of the raw water source (based on the catchment risk category and the water quality category). Individual contaminant grades are used to establish grades for 5 contaminant classes (chemical contaminants-aesthetic, particles, chemical contaminants – health significant, microbes and toxins). The contaminant class grade will equal the worst grade in a contaminant class. The overall grade is then based on the lowest contaminant class group grade of chemicals-health significant, microbes and toxins. The scale spans 5 grades, from very poor suitability (colour code is black), to very good suitability (colour code is green).

3.0 MICROBIAL INDICATORS AND PATHOGENS IN THE ENVIRONMENT

Survival and retention by soil particles are the main factors controlling the persistence and transport of pathogens in the subsurface (Bitton and Gerba, 1984). There are multiple factors affecting survival and retention including the type of microorganism, temperature, rainfall, predation, indigenous microbial activity, ability of pathogen to adsorb, climate, and properties of the soil (e.g., pH, particle size, cation exchange capacity, clay content, organic matter, moisture content). A summary of physical and chemical factors that may affect the fate of pathogens in the environment is presented in Table 5. The influences of the various factors on the survival and transport of bacteria, viruses and pathogens are discussed in the following subsections.

Table 5: Factors affecting the retention and survival of enteric bacteria and viruses in soil

Moisture content	Greater survival time in moist s oils and during times of high rainfall	Some viruses persist longer in moist soils than dry soils
Moisture holding capacity	Survival time is less in sandy soils than in soils with greater water-holding capacity	Soils with a larger water holding capacity will retain moisture longer than those with a smaller capacity
Temperature	Longer survival at low temperatures; longer survival in winter than in summer	Viruses survive longer at lower temperatures
pH	Shorter survival time in acid s oils (pH 3-5) than in alkaline soil	Most enteric viruses are stable over the pH range 3 to 9: survival may be prolonged at near neutral values
Sunlight	Shorter survival time at soil surface	Desiccation will reduce survival
Organic matter	Increased survival and possible re-growth when sufficient amounts of organic matter are present	Presence of organic matter may protect viruses from inactivation: others have found that it may reversibly retard virus infectivity
Antagonism from soil micro flora	Increased survival time in sterile soil	Some viruses are inactivated more readily in the presence of certain micro-organisms: but, adsorption to the surface of bacteria can be protective
Salt species and concentration	Salt concentration is important for the initial retention of bacteria in soil	Some viruses are protected fro m inactivation by certain cations: the reverse is also true
Association with soil	Adsorption onto soil particles is important for bacterial retention	In many cases, survival is prolonged by adsorption to s oil: however, the opposite has been observed
Aggregation of microbes	Reduces their mobility and hence increases the retention of bacteria in soil	Enhances survival
Soil properties	The mobility, and hence the residence time of bacteria, is very dependent on the surface properties o f soil particles	Effects on survival are probably related to the degree of virus adsorption
Microbe physiology	Different pathogenic bacteria vary widely in their response to environmental stress	Different virus types vary in their susceptibility to inactivation by physical, chemical and biological factors

From: Goss et al. (2003)

3.1 Environmental Considerations

The potential for pathogens to contaminate ground water and surface water is dependent on a number of factors including the physical and chemical conditions of the site. In addition, the specific characteristics of the pathogens present in the source material affect the probability that the organism will contaminate source waters. The following subsections provide some additional detail on factors that are common to most pathogens including depth, filtration, nutrients and pH. The implications of other factors such as temperature, and soil properties on the survivability and transport of bacteria, viruses and protozoa are discussed in detail in Section 3.3.

3.1.1 Depth

An Alabama study observed that microbial biomass and activity declined with increasing depth in four soil types (maximum depth studied 200 centimetres (cm); however the magnitude of the decline and their abundance was a function of soil type (Federle, 1986). Pepper (2000) states that the greater the thickness of the unsaturated zone (i.e., the distance between the soil surface and the water table), the less likely ground water contamination will occur. Thus, microbial removal as it travels through unsaturated zone is exponential with depth, which is often observed.

3.1.2 Filtration

It has been well studied and documented that soil serves as a natural filter that limits microbial transport; however, there are limitations as evidenced by ground water source outbreaks and contamination studies. Filtration of bacterial cells has been correlated with bacterial size (Gannon, 1991). In soil types containing silt or clay particles, filtration is a major mechanism by which bacteria cells are removed. However, for viruses, filtration does not appear to have a significant affect on movement through the soil.

3.1.3 Nutrients

It was once thought that ground water was sterile and that organisms would be unable to survive due to a lack of nutrients at depth. The nutrition of the microbiota of deep zones, below the root-zone, relies on organic material that is leached from the surface or that was originally in the geological material when deposited (Wilson, 1983). Nutrients are limiting in the saturated zone (i.e. subsurface materials below the water table), and thus a large proportion of the bacterial population present may be in starved or semi-starved states. It has been shown in studies that bacterial cells in starvation become significantly smaller under these conditions and therefore, the potential for further movement through the subsurface material would increase.

3.1.4 pH

Surface charge varies between types of microorganisms (bacteria, viruses, protozoa) and species within these types. As such, different species can be affected by pH of the matrix solution differently (Pepper, 2000). Viruses are known to carry a negative charge and thus would not be expected to adhere to soil, which also carries a negative charge. However viruses have the ability to change their surface charge depending on isoelectric points. Bacterial cells however, differ in their overall charges on the surface and as such each species is affected differently by changes in pH.

3.2 Hydrogeologic Considerations

Preferential flow of water in the subsurface can permit the movement of pathogens over large, somewhat unpredictable distances. Mechanisms in the environment that permit this type of flow include macropores and fractures. As discussed in the previous section, there are various soil properties that are important for retaining pathogens; however, in situations where the matrix is effectively bypassed, pathogens can move through unaffected.

Powell et al. (2003) observed the rapid penetration of low levels of sewage-derived microbial contaminants in two sandstone aquifers in the United Kingdom to depths of 60 and 91 metres below ground. Based on the results of the study, the authors considered the transport to have occurred via microscopic preferential pathways (non-matrix).

McKay et al. (2000) conducted a natural gradient tracer test in the water table zone of a Tennessee saprolite (fine-grained weathered parent bedrock). The tracers (bacteriophage MS-2 and PRD-1, *Pseudomonas syringae* and 0.1 micron diameter latex microspheres) were detected in monitoring wells located 2 to 35 metres downgradient within only a few hours. Previous tracer studies using solutes (e.g., dyes and dissolved gases) at the same location had taken considerably more time to migrate to the same downgradient locations. McKay et al. (2000) indicated that the solutes migrated much slower because they were retarded by diffusion into the fine pore structure of the saprolite. Due to their size, the microbial tracers and microspheres were excluded from the matrix and were transported much faster in fractures and macropores.

A study of soil from 20 to 85 m below the water table, in an aquifer in Kansas, found that the diversity of bacteria in soil was similar to that found in soils at the ground surface. However, the density of bacteria at the surface was 10 to 1000 times greater than that of subsurface soil. Population densities of protozoa were small in coarser-grained materials, and the types found were similar to those encountered in surface soil Bacterial density was noted to be greater in soil with a high sand to clay ratio than in soil with a low sand to clay ratio (Sinclair, 1990).

3.3 Survivability and Transport of Microbial Contaminants

As noted above, a basic understanding and appreciation of the chemical and physical properties of the subsurface materials is necessary to assess microbial transport and survival potential in the environment. Many of the factors that affect the survivability also influence or affect the transport of pathogens through soil. According to Pepper (2002), the transport of viruses is greater than bacteria which are greater than that of protozoa. Further he noted that transport was greatest through sand and least with clay. Table A2, Appendix A identifies the sizes of different soil types.

Microbes are ubiquitous. In soil, they degrade compounds that reside in the environment. Most soils do not contain abundant microbial nutrients because microbial communities that reside in the soil utilize those that are available. The nutrition of the microbiota of zones below the root zone relies on organic material that is leached from the surface or that was originally in the geological material when deposited (Wilson, 1983). Soil is a unique ecosystem that provides a constant supply of substrate and growth factors for organisms through the release of organic material (leaves, roots, secretions, *etc*). Soil microbiology has been studied since the early 1960's, and it is well known that indigenous bacterial density in soil from the rhizosphere is around 1.2 X 10^9 colony forming units per gram (CFU/g), protozoa 2.4 X 10^7/g, and fungi 12X10^5/g. These numbers do not change significantly between the rhizosphere and non-rhizosphere zone. Protozoan populations mimic bacterial populations because they predate upon bacteria, their major food supply. Deep regions of the unsaturated zone and shallow water table aquifers can contain bacterial numbers similar to the soil at the ground surface (>10^6 CFU/g) (Wilson,1983).

According to the WHO (2004) bacteria live for days to months; viruses for months and parasites for years. Specifically the WHO states that bacterial indicators and pathogens live less than 10 days, viruses are viable for 11 to 304 days, and parasites are viable for 180 days. Based on the literature review performed by the PSC, survivability was dependant on site specific conditions. Survivability of pathogens in soil is well studied in the context of looking at survival after land application of a waste. Both laboratory and field studies focusing mostly on bacteria, viruses and protozoa have been conducted. Ginn et al. (2002) note from a review of field studies that the rate of attachment to aquifer materials of protozoa, bacteria and viruses decreases with distance traveled.

3.3.1 Bacteria

The bacteria most commonly studied in terms of environmental survival and transport were as follows:

- *Escherichia coli*
- Coliform
- *Campylobacter*
- Enterococci and
- *Salmonella*

Since, the results were obtained principally from laboratory studies, many conditions were controlled and thus, may not represent all of the contributing factors that exist in the natural environment.

Furthermore, studies comparing environmental and clinical bacterial isolates in terms of survivability and transport have not been well documented. Although a study by Terzieva and McFeters (1991) found that animal strains of *Campylobacter jejuni* and *Escherichia coli* survived longer in stream water than human strains. A 90% reduction of *C. jejuni* was reported to be 2.5 days in the animal strain and 1.9 days in human strains. Similarly, 90% of *E. coli* was reduced in 1.7 days in the animal strain and 0.8 to 1.4 days in human strains. Thus, results may differ depending on the whether the isolates were obtained from the environment or from humans in the studies.

Based on the extensive literature review, the range of survivability in soil and water for bacteria is considerable, and ranges from a few hours to 500 days, depending on the genus and species of bacteria and temperature of the environment of interest, as well as the other specific environmental factors/conditions mentioned previously.

Analytical methods used to determine survivability at the time of experiment is also crucial in drawing conclusions about a microorganism's behaviour in the environment. The following referenced studies will demonstrate this point which is the amount of variability in the literature on bacterial species survivability even within the same species. *Yersinia enterocolitica* can survive in soil greater than 35 weeks at 4°C, and greater than 15 weeks at 20°C (Tashiro, 1991). *Salmonella* spp. were shown to survive in deeper soil for up to 36 and 88 weeks (Wray, 1966). Lau (2001) reported prolonged survival of *E. coli* and enterococci at 19 weeks at 9 to 21°C. Ogden (2002) demonstrated the survival of *E. coli* O157:H7 for 15 weeks in the United Kingdom. Bitton et al., (1983) observed that total and faecal coliforms were reduced by one order of magnitude in a 2 to 6 day time period in a microcosm study.

In general, at pH 6-8, as temperature increases, bacterial survival times decrease. As soil moisture decreases, bacterial survival time decreases. Thus, with increased desiccation bacterial survival times decrease. Bacteria survive longer below the soil surface (approximately twice as long) than on the surface. This is most likely the result of reduced ultra violet (UV) light exposure and desiccation.

Romero (1970) observed that vertical transport (percolation/infiltration through unsaturated zone) of pathogens is limited to approximately 3 metres. The results showed that coliform bacteria were completely removed in 0.9 to 2.1 metres of a dry California soil. The dry soil exhibited 92 to 97% retention in upper 1cm. In a direct injection experiment in a deep aquifer in Germany, faecal bacteria were observed at a well 18 metres downgradient of the injection point after 11 days. *Bacillus coli* in fine sand were observed to travel 20 metres laterally in 187 days. In general, aquifer properties that provide maximum retardation of pathogens are uniformly composed of fine grained sand with high clay content. In general, limits of bacterial transport are between 15 to 30 m.

Hendry et al.(1999) noted through column experiments using coarse-grained silica sand that sorption characteristics of pathogens to soils are species-specific, and the sorption coefficient is a function of flow velocity. He observed that sorption was influenced by the flow velocity, and that the peak C/Co concentrations of both bacteria (*Klebsiella oxytoca, Burkholderia cepacia*) showed greater attenuation as velocity decreased. Thus, pathogens may travel further with greater flow velocities of water, although it should be noted that the interaction between different pathogens and soils will have varying results.

Bacteria may have a variety of appendages such as pili, flagella, or fimbriae. These appendages reside on the outside of the bacterium and are responsible for bacterial motility. It has been mentioned that these may assist in or play a role in bacterial transport. Pepper (2000) notes that the overall transport by this mechanism in general would be minimum, as water films would be needed to support microbial movement. This advective transport does exist in high soil moisture content soils. A study by Reynolds (1989), demonstrated the motile *E. coli* was four times faster than non motile *E. coli* in the same soil column. Therefore, under certain circumstances measurable increases in microbial transport can occur.

The literature suggests that survivability and transport distances vary depending on the genus and species of the bacteria, and the environmental conditions. Longer survival times can be attributed to lower temperatures, decreased UV exposure, neutral pH, and increased soil moisture content. Bacteria that were studied under these various conditions produced survivability ranges from a few hours to 500 days in soil and water. Moreover, bacteria are able to travel further in saturated conditions, especially when the flow velocity of water increases, and also may be affected by the presence of bacterial appendages. Generally, bacteria can travel 0.9 to 18 metres vertically, and approximately 20 metres laterally although several studies have reported greater distances. Thus, the results from numerous studies support the vast ranges of bacterial survivability and transport due to the type of bacteria, environmental considerations, and detection methods used.

3.3.2 Viruses

Recent studies in the USA have reported viruses in large percentage of ground water used by municipalities as public supply, even when in compliance with bacteriological guidelines. The viruses most commonly studied in terms of environmental survivability and transport were as follows:

- bacteriophage;
- poliovirus;
- hepatitis A virus;
- echovirus; and
- coxsackievirus

As with the bacteria studies, the results presented for viruses were obtained principally from laboratory studies where many conditions were controlled and thus, may not represent all of the contributing factors that exist naturally in the environment.

Moreover, comparative studies on the survivability and transport of environmental versus clinical viral strains have been limited. However, it is likely that viruses found and tested in their natural environment may be better adapted to survival and thus may be able to travel further in the environment than clinical strains. Accordingly, the findings from studies may vary due to the virus strain used to deduce results.

In general, at pH 6 to 8, as temperature increases, virus survivability times decrease. As soil moisture decreases, virus survival time decreases. Thus, with increased desiccation virus survival times decrease. It was also noted that soil aggregation of viruses and bacteria would survive longer in soils than monodispersed microbes. Also noted was that soil adsorption prolonged virus survival although rainfall could cause desorption.

A review of viral survivability by Yates (2002) found that hepatitis A virus survived longer than poliovirus and echovirus at 25°C and that more than 150 days later, viable phage were recovered. Also, Lefler and Kott (1974) found coliphage f2 to survive less than one year in dry sand at room temperature. Hepatitis A was noted to be the most resistant to inactivation in acidic environments (pH of 1 for greater than 8 hours) (Scholz et al., 1989). Coxsackievirus B3, adenovirus 1 and echovirus 7 at 4-7^0 C were observed to survive longer in ground water with soil than in ground water without soil. Hepatitis A showed similar findings. Furthermore, Yeager and O'Brien (1979) observed that poliovirus survived 180 days in saturated sand and sandy loam at 4°C and no viruses were recovered at 37°C after 12 days. In a separate study, Bagdasaryan (1964) observed that poliovirus1, coxsackievirus B3, and echovirus 7, 9, can survive 60 to 90 days in soil with 10% moisture as compared with 15 to 25 days in air-dried soil and another noted 99% inactivation of poliovirus after 7 days in soil when moisture was reduced to 0.6% and 7-8 week's & 10-11 weeks with 25 to 15% moisture. Bitton (1983) found poliovirus to be very stable, whereas bacteriophage viability declined rapidly (5 days) in ground water microcosm studies.

The presence of certain chemicals such as aluminum metal, magnesium peroxide and magnesium oxide, may render viruses more or less susceptible to inactivation (Thurman and Gerba, 1987). In one study it was observed to take 42 days for 99% poliovirus inactivation at 20 to 25°C, 175 days 1 to 8°C. Faster inactivation rates were observed near soil saturation (15 to 25%) but column studies have demonstrated viruses penetrate deeper under saturated conditions (160 cm) versus unsaturated conditions (40 cm). The presence of aerobic organisms was observed in one study to have a 3-fold increase in virus inactivation rate (1°C, 23°C, 37°C) whereas, anaerobes did not have any significant effects on virus survival. It is thought that 77% of the variation in virus inactivation may be explained by temperature effects.

A study by Rhodes et al. (1950) indicated that poliovirus survived in river water at 4°C for 188 days. Azadpour-Keely et al. (2003) report that a direct relationship between temperature and virus survival exists; the higher the temperature, the higher the viral inactivation rate.

DeBorde et al. (1999) report that the effects of different hydrogeologic settings on virus transport is poorly documented, especially in high ground water velocity aquifers (e.g., gravel aquifers). DeBorde et al. (1999) injected bacteriophages, attenuated enterovirus and sodium bromide into an unconfined floodplain aquifer and found that the average rate of transport of viruses (based on the indicators used), was the same as the average ground water velocity (as defined by the tracer), virus attachment to aquifer materials significantly reduces virus concentrations during transport and once viruses enter an aquifer, some of the attached virus slowly releases into ground water over time. The results of transport of viruses in a septic system and a unconfined aquifer indicate that coliphage moved in ground water as quickly as the bromide tracer (DeBorde et al.,1998).

In the past 10 to15 years, there have been numerous studies on virus transport in the subsurface. Viruses have been observed to travel more than 100 m through the subsurface (Keswick, 1982). In fact, Fletcher and Meyers (1974) found that coliphage T4 traveled 1,600 metres horizontally in ground water through carbonate rock terrain. A review of viral transport by Yates (2002), found that soil properties had profound influence on virus movement in subsurface. Virus migration is greater in coarse-textured and karstic terrain than in fine textured soils. For example, 3 types of bacteriophage were observed to migrate 355 m from injection site 5 hours after introduction, and more than 150 days later viable phage were recovered. This review also noted that transport was retarded by association with soil particles and there was no correlation to adsorption and total phosphorus or total exchangeable iron, calcium and magnesium within soil, but transport was retarded in high concentration of ionic salts and cation valences. One study (Wallis, 1961) noted that poliovirus and echovirus have enhanced stabilization at 4 to 50°C in high concentration of MgCl (1M). Another study (Gerba, 1981) reported that for group I viruses (coxsackie B4, echo 1, OX174, MS2), pH was important for adsorption yet for group II (polio 1, echo 7, coxsackie B3, and phages T4, T2) it was not.

From the literature, the survival times and movement of viruses are dependent on the virus used in the study as well as multiple environmental conditions. Longer survival times can be attributed to lower temperatures, decreased UV exposure, neutral pH, increased soil moisture content, increased soil aggregation of viruses and the absence of certain chemicals. Viruses that were studied in this assortment of conditions produced survivability ranges from 8 hours to more than a year. Thus, survivability times varied depending on the type of virus studied. Viruses will travel greater distances in coarse textured and karstic terrain under saturated conditions. Greater adsorption to soil will decrease the movement of viruses, although pH, ionic salts and cation valences may not have an effect on this factor. Thus, viral transport through these diverse conditions ranges from 40 cm to 160 cm vertically, although other studies have suggested greater ranges, and from 100 m to 1600 m laterally. It was also noted that coliphage were found to be at the upper limits of these ranges of viral survivability and transport.

3.3.3 Protozoa

The protozoa most commonly studied in terms of environmental survivability and transport were as follows:

- *Cryptosporidium*
- *Giardia*

Limited studies have been done on the survival and transport of protozoa in the environment. The oocyst of the protozoan parasite, *Cryptosporidium* is of significance because it encloses and protects the infective agent that causes the disease in humans. The oocvst is resistant to chlorine, and can remain infective for years at low temperatures (4°C). The USEPA uses this agent as the indicator organism for those source waters systems seeking relief from minimum treatment (Surface Water Treatment Rule). In general, at pH 6-8, as soil moisture decreases, protozoan survival time decreases. With increased desiccation protozoan survival times decrease although the thick walls of the cyst or oocyst may prolong their survival. Olson (1999) found *Giardia* cysts non-infective in soil and water following one week of freezing to -4C, and within two weeks at 25°C. *Cryptosporidium* oocysts however, could survive greater than 12 weeks but viability was reduced at temperatures above 25°C.

A study of well fields in sand and gravel aquifers hydraulically influenced by surface water showed that although other indicators of surface water were found in ground water samples collected and analyzed (57% of 128), no pathogens (*Cryptosporidium* or *Giardia*) were detected in 285 samples that were collected and analyzed. The results of this study indicated that riverbank filtration can be highly effective in removing pathogenic protozoa (Gollnitz et al., 2003).

The literature regarding the survivability and transport of protozoa's in soil and water is quite limited although it is known that they exhibit prolonged survival times because of the production of a thick-walled cyst or oocyst that is resistant to many extreme conditions, such as chemical disinfection and drying. Survivability ranges were observed to be less than 2 weeks to greater than 12 weeks.

3.4 Use of Indicators

Detecting faecal contamination by testing for all possible pathogens is neither practical, nor cost-effective thus; indicator organisms are used to represent the range of survivability and transport characteristics of different pathogens. Drinking water must be kept pathogen-free water by (a) selecting high-quality uncontaminated source waters, (b) applying efficient treatment and disinfection measures to water, and (c) protecting water from contamination during distribution to the user.

Traditionally, *E. coli* has been used as a bacterial indicator of faucal contamination, but the literature cites that it does not correlate well with the presence of enteric pathogens, nor does it correspond to the characteristics of viruses and protozoa, which also contribute to various waterborne diseases. Indicator organisms should be more appropriately interpreted as a reflection of both the susceptibility of a water source to environmental contamination and the source of such contamination. The literature confirms this observation. Nasser (2003) observed the die-off of *E. coli* in stream water at 15°C reached four orders of magnitude in 6 days. Whereas the die-off of coxsackievirus A9 reached two orders of magnitude after 30 days and no decrease was detected in the concentration of *Cryptosporidium* oocysts after 30 days. Nasser (1999) also reported that *E. coli* was inactivated the fastest in ground water at 4°C and 37°C, compared to poliovirus 1, hepatitis A virus and F+ bacteriophages, which persisted the longest. Accordingly, bacteriophages have been proposed as an indicator for viruses because of their similarities in size, structure, morphology and mode of replication Grabow (2001). A soil column experiment by Meschke and Sobsey (2003) demonstrated that coliphage MS2 was a conservative indicator for poliovirus 1 and Norwalk virus. MS2, poliovirus 1 and Norwalk virus had increased elution when simulated rainwater was applied, whereas no increased *E. coli* elution was observed. In soil (Corolla sand, Ponzer organic muck and Cecil clay) columns at steady-state, the average reduction of infectious poliovirus 1 and *E. coli* was generally greater than or equal to the reduction of infectious MS2 in all soil columns. MS2 and poliovirus 1 had similar interactions with soils but the results of *E. coli* were considerably different. Also, Medema et al, (1997) found that the die-off rate for *Cryptosporidium* oocysts was ten times less than the *Escherichia coli* and *Enterococcus faecium* die-off rates in natural river water at 15°C. This would support the use of a multi-indicator approach for raw water quality standards/objectives since using *E. coli* independently is not adequate in indicating faecal contamination.

The literature suggests that the virus or protozoan (oocysts, cysts) group may be more appropriate as indicators for source water protection than the bacterial group because they generally require lower doses to infect the host, and survive longer in the environment. Viruses are smaller and in general have been observed to have the ability to move further into the soil column. In conjunction with source water monitoring and characterization, water utilities should engage in constant monitoring of water treatment performance parameters, such as turbidity, particle counting, free and residual chlorine and pH, as these measures offer a more preventative approach than intensive microbiological monitoring activities, as well as an additional barrier of protection.

The literature cites that there is an immense variation in the ranges of survivability and transport that can be attributable to the different environmental conditions that the microorganisms are exposed to in each study. The type of organisms used and how they were detected is also influential in producing a wide range of data. Bacteria have traditionally been the indicator of choice in determining water quality however, bacteria do not adequately represent the characteristics of viruses and protozoa, and thus, do not infer the same survivability and transport ranges for these groups. Therefore, using a single indicator to determine the quality of water would not be sufficient, and using a multi-indicator approach would be more accurate.

4.0 ALTERNATIVE APPROACHES TO PROTECTING SOURCE WATER FROM PATHOGENS

4.1 Effects-Based Approach

The effects-based approach is common and well established for treated drinking water. In general terms, the effects-based approach is defined or expressed as a numerical limit (standard or guideline) to which water system owners and operators must achieve. This numerical standard provides for the same level of protection of all treated drinking waters across a province or state. This concept is applicable also to source or ambient waters. In considering this approach as a viable option for source water protection, both the benefits and costs were examined. This approach is considered straightforward and would provide a municipality with flexibility on how the standard could be met; however, this approach could have significant cost implications to those source water locations that have significant contamination. An "effects-based" approach for Ontario would require research to establish a representative microbiological indicator or pathogen and to determine the maximum allowable or range of concentrations. This approach is easily enforceable from a regulatory standpoint, but would require time to create and implement. Laboratories would require lead in time to put new testing methods in place, and in the province of Ontario time would need to be allocated for licensing.

4.2 Process Based Approach

In the process-based approach, a process is specified on the steps needed to assess the risks to drinking water from source to tap, and to implement a plan to manage the risks. The risks are identified and evaluated by steps such as delineating and characterizing the drinking water sources, conducting contaminant source inventory, evaluating the water system, and evaluating the management, operation and maintenance practices of the water system. Then the risks to the water system are characterized in the context of a multi-barrier approach to drinking water protection. Following this, a plan or strategy to manage the risks is developed. Decisions are then made on how the plan will be implemented in terms of the responsible parties, and timelines. However the specific standards to be met are not mandated before the development of the plan.

The process-based approach provides flexibility and delegates ownership to municipalities or other responsible local agency in implementing the plan to manage risks for drinking water. The process-based approach can result in the development of cost-effective and efficient site-specific approaches, that accommodate a combination of best-practices, pre-treatment, and natural attenuation (equivalent travel-time) criteria based on knowledge of local conditions and practices. Technical guidance to support the process-based approach can be provided by the province to municipalities or other local agency on the following:

- provide guidance on drinking water hazards, information needed on source assessments, data elements and data sources, delineation options for assessment areas for streams, methods for estimating aquifer vulnerability, delineation methods for well capture zones, and potential sources of contamination for ground water and surface water sources.
- provide guidance on modelling of pathogens in ground water (e.g. by using steady-state flow and transport models), and on developing locally-based travel-time criteria (based on first-arrival times instead of the normally quoted average-arrival times) that supports the multi-barrier approach and ultimately achieves the desired health-based standard;
- establish a knowledge-sharing network on available hydrogeologic studies that municipalities can access and contribute to, and that helps municipalities identify or screen-out regions and conditions of concern (regions of hydrogeologic sensitivity).

The process-based approach can be joined to an approach where standards to be met for drinking water protection are specified upfront. The process will then be to develop a plan to meet the standards.

Implementation of a multi-barrier approach for protecting ground water from pathogens could include addressing:

- best practices in minimizing pathogen content by pre-treatment of manure prior to land application;
- best practices in managing and land application of controlled sources of pathogens;
- establishing time-of-travel criteria (to complement the multi-barrier approach) based on knowledge of local hydrogeology and conditions;
- well-water disinfection

- continuous monitoring.

Other factors include:

- sanitary survey of ground water systems (i.e. monitoring what is there now due to past loadings);
- triggered ground water quality monitoring;
- routine monitoring of sources that are sensitive to pathogen contamination. Wells in karst, fractured bedrock or gravel cobble aquifers are considered sensitive unless there was a hydrogeologic barrier present which prevents the movement of microbial contamination.
- land application standards for nutrients like biosolids and manure could be adopted for the plan.
    - The NMA Regulation has land application standards e.g. setbacks from wells. They may be modified in the future with more research done e.g. setback distances from pathogen sources specific to soil characteristics
- Improved water quality guidelines
    - improved guidelines & testing procedures of coliforms, viruses and protozoa
- Aquifer sensitivity analyses
- Improved septic system construction and maintenance standards
    - Inspection and enforcement programs
- Improved well construction and maintenance standards
    - Reg. 903 and future amendments
    - Inspection and enforcement programs
    - Well testing programs

4.3 Time of Travel Approach

The classical "time of travel" (TOT) approach is a common and well established method used to delineate wellhead protection areas (WHPA) for municipal wells and wellfields. Delineation of wellhead protection areas is not a new concept; the 1986 USA Federal Safe Drinking Water Act directed States to develop a wellhead protection plan for public and community water supply wells (NJDEP, 2003). In general terms, the WHPA defined using a TOT approach is the area from which a well draws its water within a specified time. These delineated areas become a priority for efforts to prevent and clean up ground water contamination. A TOT approach to source water protection can be applied to both ground water wells and surface water intakes; however, the methods of determination and goals are different for ground water and surface water systems.

4.3.1 Ground water Wells

The TOT approach, as applied to ground water systems, is based on the numerically modelled migration of tracer particles backward through the aquifer system for prescribed lengths of time (e.g., 2 years, 5 years). The location of these particles in the subsurface are projected vertically to the surface for the specified time period (e.g., 2 year TOT); the land area encompassed by these points defines the capture zone for that specified time period. The size of the well capture area or zone is influenced by many parameters, including well pumping rate, aquifer porosity, hydraulic conductivity, hydraulic gradient and flow direction.

The TOT approach specifically does not include the time of travel from the potential source down to the aquifer of concern. Exclusion of this time can be considered a form of conservatism in the approach. Two other factors not typically considered are the potential for preferential flow and differences in the transport characteristics of conservative, dissolved, contaminants and the contaminant of concern.

A pathogen protection zone for Ontario would result in a universal time of travel applied to all public water supply wells (not private wells). The area of land encompassed by the pathogen protection zone would be dependent upon the hydrogeologic conditions in the vicinity of the well. Activities that may impair ground water quality would generally be subject to restrictions in an effort to minimize potential pathogen loading to the source aquifer.

4.3.2 Surface Water Intakes

The TOT approach to surface water intakes is based on the amount of time it takes for a contaminant travelling at the same velocity as the stream and overland flow to reach the water intake point. The travel time method for surface water intakes does not define a protection zone; it is intended to directly protect water quality at the site of drinking water intake by providing an early warning system for contaminants deposited in or near upstream waters. The travel time between a surface water intake and an upstream location upstream monitor is dependent upon parameters such as stream discharge, overland flow discharge and contaminant characteristics. The intake-specific travel time, estimated through numerical modelling of stream and overland flow, would allow a drinking water treatment plant sufficient time (on the order of several hours) to take appropriate measures to avoid the intake of contaminated water or to bring additional treatment equipment on-line.

4.4 Setback Distance Approach

The Setback distance approach has been used historically in regulation (USEPA, Ontario Regulation 903, *Nutrient Management Act*, and the Ontario Building Code). The setback distance approach employs a standard distance to all water sources regardless of type or quality. The setback distance approach is not science or risk based and does not provide for flexibility to the municipality on how to ensure the standard is met. In addition, traditional setbacks may not consider or be based on protection from pathogens. More importantly this approach by itself will not provide for consistent source water quality across the province.

4.5 Combination Approach

The Pathogens Sub-Committee concluded none of the individual approaches described above would be adequate to address concerns with potential pathogens for all drinking water sources across Ontario. It was recognized that a desired model needs to be flexible to address the breadth of challenges that will be encountered and it was determined that the most effective model would be one that is based on a combination approach. The combination approach proposed uses elements of both the process and effects-based approaches. The combination approach provides municipalities or other water purveyors with the flexibility necessary to deal with site-specific issues (e.g., risks associated with local hydrogeologic conditions and land use activities).

The Sub-Committee recognized, however, that a full process/effects-based model requires significant additional work to develop and implement. It is proposed that while this model is under development a preliminary process/effects-based model should be used that incorporates standardized set-back distances.

5.0 SUMMARY

From the above review on the survivability and transport of pathogens it is clear that certain soil conditions which are conducive or inhibitive to one group or species of pathogen may be quite different for another pathogen of concern.

In addition, grouping wells and other source waters according to physical parameters, establishing a quantitative threshold limit for selected parameters and identifying them as low or high risk based on microbial occurrence data would seem a logical approach to determining time of travel, and zones of influence. The first step in developing a classification scheme would be to establish the criteria to separate each class. In addition, microbial data and information would be needed in order to assign a risk factor or level to the source water supply in question, this could be accomplished through the development of a screening protocol.

In conclusion, the information brought forward in this review with respect to pathogens provides enough information that a single zone of influence or time of travel value should not be uniformly applied across the province.

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APPENDIX 6Ba: TABLES

Table A1: Jurisdictional scan
See excel table attached

Table A2: Size classifications of the three primary particles of soil (Pepper, USDA definition)

Primary particle	Size range (diameter)
Sand	2 mm to 0.05 mm
Silt	0.05 mm to 0.002 mm
Clay	<0.002 mm (2 um)

APPENDIX 6Bb: EXPERT OPINIONS

Experts in the field of microbiology, hydrology and hydrogeology were contacted and asked to provide insight and opinion into microbial transport, survivability time of travel and zone of influence. They were also solicited for their interest and availability to speak to the Ontario Ministry of the Environment and the Technical Experts Committee on Source Water Protection on this particular issue. The proceedings to this working session can be found under a separate document entitled "The Ontario Ministry of the Environment's Source Water Protection Technical Experts Committee Presents the Proceedings on Determining Pathogen Management Zones for Source Water Protection" held July 23, 2004 at the Laboratory Auditorium at the Ministry of the Environment facility located at 125 Resources Road in Etobicoke, Ontario.

The following experts were consulted by conference call to discuss their current research relative to source water protection and provide insight to the questions noted below:

Dr. Joan Rose,

Dr. Peter Huck,

Dr. Pierre Payment,

Garry Palmateer,

Dr. Mark LeChevallier

Dr. Marylynn Yates

The following questions were asked of each of the scientific experts and a synopsis of the discussion that resulted from each question follows.

- What are the key microbial contaminants in ground water and source water?
    - Viruses and parasites
    - USEPA CCL list of pathogens
- What can we do to restrict contaminants from going into the rivers and lakes?
- Does an intake protection zone make sense?
    - yes
- What is your opinion of the TMDL approach?
    - good
- What is the current state of science (how much work has been done) in the area of transfer through the vadose zone, and un-saturated zone to ground water?
    - The USEPA performed an extensive literature review 10 years ago on saturated and unsaturated zones and identified that organisms behave differently in the two environments. Generally organisms inactivate quickly and readily removed in the

unsaturated zone. Once organisms enter the saturated zone we rely on natural die off where time of travel is the dominant factor. Gaps are in identifying the mechanistic level on fate of organisms in unsaturated zone.

- Parasites are larger therefore easy to remove in subsurface the exception being for GUDI situations. They are not usually found in gw.
- Bacteria intermediate in size can move through the soil and are metabolically active and the environment is harsh whereby nutrients are not readily available thus these organisms in general are not replicating.
- Viruses are the smallest and are readily transported and have been found in gw in the absence of bacterial indicators.
- AWWARF and USEPA study 2003. No relation between hydrogeology and occurrence of pathogens was observed. No relation between indicator and coliphage observed. Indicators identified something about vulnerability and risk.

- What are the current models available to determine separation or protective zones from ground water or well head protection areas? What is your opinion on these models and what are the gaps?
    - Two models are used in the USA for regulatory purposes, VIRALT and CANVAS
    - Relatively easy to model for *E. coli* and *Campylobacter* but more difficult for less common pathogens such as *Cryptosporidium*.
    - Research identified how difficult it is to model at a watershed level, adding on a pathogen transport model, trying to predict pathogen concentrations at surface water intakes and relating to level of treatment required.

- In your opinion, what approach should be used to determine or recommend well head protection, zones of influence or separation distances from ground water, and surface water?
    - Well head protection programs in the USA use 50-100 foot setbacks, but these focused on chemical contaminants and not pathogens.
    - The concept of setback distances may have limited use in certain situations, in some areas of high risk, unable to meet large setback distances.
    - First the goal of acceptable risk needs to be established (annual rate of infection for example 1/10 000- was derived based on 1/10^6 chance of dying of cancer which results in a 150 000 annual reduction in illness. This was based on the consumption rate of 2L of water per day.
    - TOT will not deliver consistent public health protection.

Appendix 6B. TEC Pathogens Discussion Paper

- In your opinion what key questions (concerns& issues) should we be focusing on in order to recommend well head protection zones?
    - Determine first what the target at the well head is
    - Determine if the approach will be prescriptive or flexible
    - Determine which indicator will be used in monitoring. A combination of bacteriophage and *E. coli* will capture 90% of the information.

- In your opinion who are the key experts in the area of surface water with respect to protective zones?
    - Surface water concerns are different than ground water
    - Indicators would include parasites because of their longevity

- In your opinion which organism should be used or combination of organisms should be used to determine TOT, zones of influence calculations *etc*.?
    - Primarily viral but also parasites.
    - Crypto 80-270 days from wetland to wells (gw temperature of 22-26C) >99% die-off
    - For surface water recommends E. coli only
    - Ground water use coliphage and E. coli with increased frequency of sampling

APPENDIX 6Bc: DETAILS ON LITERATURE SEARCH

LITERATURE SEARCH OVERVIEW

In developing its recommendations, the PSC carried out an extensive review of the literature, and conducted in depth consultations with international experts, to ensure that the most current scientific understanding of the epidemiology, and fate and transport of pathogens in the environment was known.

Results were obtained primarily from experimental studies, but also from limited field observations. The following identifies the sources and key words used to acquire relevant scientific information.

Method of literature review: Electronic searches of several electronic databases, primarily PubMed, Web of Science, Scholarsportal, Sciencedirect, and CISTI.

Search terms used: survival, fate, occurrence, inactivation, transport, pathogen, viruses, bacteria, protozoa, indicator, water, drinking water, source water, ground water, surface water, soil, Cryptosporidium, Giardia, *E. coli*, Escherichia coli, coliform, Streptococci, enterococci, Salmonella, Campylobacter, Shigella, Vibrio, Yersinia, Aeromonas, mycobacteria, poliovirus, hepatitis, adenovirus, Norwalk, norovirus, bacteriophage, coliphage, adenovirus, enteric viruses, rotavirus. These terms were searched individually as well as in a variety of combinations. Also, links to related articles were searched and the references of relevant articles were considered.

<u>Results:</u>
The searches considered relevant were retrieved and screened based on their “title” and then on “abstract”. These articles were reviewed for their quality and relevant information. Approximately 400 articles were acquired and information gathered from the literature review was used to populate a database of information on bacteria, viruses and protozoa with respect to survivability, lateral and vertical distance traveled in field and lab studies, indicator organisms, *etc*

The data was compiled by organism and the matrix in which it was studied, to determine the survivability (Table #) and transport ranges (Table ##).

Table C1: Survivability ranges in water and sediment or soil

Organism	Survivability Range	Survivability Range in Water	Survivability Range in Sediment or Soil
Bacteria:			
Arcobacter	16 days	16 days	
Bacillus	135 days		135 days
Campylobacter	9 hours - 4 months	9 hours - 4 months	
Total Coliform	> 106 weeks		
Escherichia coli	2 hours - > 1 year	11 days - > 1 year	< 7 days - 231 days
Helicobacter	> 24 days	> 24 days	
Klebsiella	215 hours	215 hours	
Leptospira	3 days		
Listeria	35.7 days		
Mycobacterium	9 - 55 weeks		55 weeks
Salmonella	0.7 day - 820 days		26 days - 820 days
Shigella	24 days		24 days
Streptococci	Few days - Several weeks		Few days - Several weeks
Yersinia	0.7 day - 35 weeks	> 4 weeks - > 13 weeks	> 15 weeks - > 35 weeks
Viruses:			
Adenovirus	28 weeks		28 weeks
Bacteriophage	5 days - < 1 year	5 - 175 days	< 1 year
Coxsackievirus	15 days - 28 weeks		15 days - 28 weeks
Echovirus	15 days - < 6 months		15 days - 90 days
Hepatitis	8 hours (Matrix not specified)		
Poliovirus	12 - 180 days	63 - > 175 days	12 - 180 days
Protozoa:			
Ascaris	24 hours - < 8 weeks		
Cryptosporidium	1 hour (Matrix not specified) - > 12 weeks	> 12 weeks	> 12 weeks
Giardia	1 - 11 weeks	1 week - 11 weeks	1 week - 7 weeks

Table ##: Transport ranges for

Organism	Transport Range	Transport Range in Water	Transport Range in Sediment
Bacteria:			
Bacillus	*Vert*: 18 m; *Horiz*: <40 (Matrix not specified) - 920 m	*Vert*: 18 (ground water); *Horiz*: 920 m (ground water)	
Fecal Coliform	*Vert*: 0.6 - 22 m; *Horiz*: 5 - 900 m	*Vert*: 0.6 (ground water) - 22 (ground water); *Horiz*: 5 (ground water) - 900 (ground water)	
Total Coliform	*Vert*: 0.6 m; *Horiz*: 15 m	*Vert*: 0.6 (ground water); *Horiz*: 15 (ground water)	
Escherichia coli	*Vert*: 0.75 - 18 m; *Horiz*: 0.23 - 16000 m	*Vert*: 0.75 (ground water) - 18 (ground water); *Horiz*: 5 (ground water) - 16000 (drain water)	
Klebsiella	*Vert*: 0.038 - 0.1 m		*Vert*: 0.038 (silica sand) - 0.1 (silica sand)
Pseudomonas	*Vert*: 0.6 m; *Horiz*: 15 m		*Vert*: 0.6 (ground water); *Horiz*: 15 (ground water)
Serratia	*Horiz*: 90 m	*Horiz*: 90 (ground water)	
Streptococci	*Vert*: 0.6 - 18.3 m; *Horiz*: 15 - 180 m	*Vert*: 0.6 (ground water) - 18.3 (ground water); *Horiz*: 15 (ground water) - 180 (ground water)	
Viruses:			
Adenovirus	*Vert*: 0.035 - 3 m		*Vert*: 0.035 (sandy loam (unsaturated conditions)) - 3 (Bassendean sand)
Bacteriophage	*Vert*: 0.038 - 28.9 m; *Horiz*: 7.6 - 1600 m	*Vert*: 0.24 (ground water); *Horiz*: 140 (ground water) - 911 (ground water)	*Vert*: 0.038 (low humic latersols) - 28.9 (silty sand and gravel); *Horiz*: 7.6 (alluvial sand) - 1600 (carbonate rock terrain)
Coxsackievirus	*Vert*: 0.035 - 18.3 m; *Horiz*: 3 - 250 m		*Vert*: 0.035 (sandy loam soil (unsaturated conditions)) - 18.3 (fine loamy sand over coarse

			sand and gravel); *Horiz*: 3 (fine loamy sand over coarse sand and gravel) - 250 (coarse sand and gravel)
Echovirus	*Vert*: 1-16.8 m; *Horiz*: 3 - 250 m		*Vert*: 1 (Bassendean sand) - 16.8 (coarse gravel and sand); *Hori*: 3 (coarse sand and fine gravel) - 250 (coarse gravel and sand)
Enterovirus	*Vert*: 1.4 - 27.5 m		*Vert*: 1.4 (loams to clays) - 27.5 (clay loams)
Poliovirus	*Vert*: 0.038 - 19.5 m; *Horiz*: 7 - 250 m		*Vert*: 0.038 (low humic latersols) - 19.5 (sandy forest soil); *Hori*: 7 (coarse sand and fine gravel) - 250 (coarse gravel and sand)
Reovirus	*Vert*: 1 m		*Vert*: 1 (Bassendean sand)
Protozoa:			
Cryptosporidium			
Other:			
Endotoxin	*Vert*: 1 - 30 m		*Vert*: 1 (loamy sand) - 30 (mixed loam soil)

APPENDIX 6C: TEC PATHOGENS SUBCOMMITTEE


The Ontario Ministry of the Environment's Source Water Protection Technical Experts Committee

Presents the Proceedings On

Determining Pathogen Management Zones for Source Water Protection

Friday July 23, 2004

Ontario Ministry of the Environment Laboratory Amphitheatre, 125 Resources Rd. Etobicoke, Ontario, Canada


Ontario

Ministry of Agriculture and Food — Ministry of the Environment

Ministry of Health and Long-Term Care

Table of Contents

Determining Pathogen Management Zones for Source Water Protection

A Workshop Held at the Ontario Ministry of the Environment Laboratory Amphitheatre, 125 Resources Rd. Etobicoke, July 23, 2004

Foreword:

These proceedings examine how appropriate protective areas can be established around source waters, intended for the purpose of a drinking water supply, to protect against contamination by pathogen and indicator organisms. The report was developed from a one day working session attended by about 60 people including microbiologists and other scientific experts, including those with regulatory and public health expertise, drawn from government, academia and private associations. The working session was convened by the Pathogen Sub-Committee of the Ontario Ministry of the Environment's Technical Experts Committee on Source Water Protection in Toronto Ontario on July 23, 2004. The session Chair and other selected participants in the symposium assembled in the working session to address the issue of determining protective areas for all source waters from potential pathogen contamination.

Disclaimer:

The opinions expressed in this publication are those of the individual presenters and do not necessarily reflect the views or policies of the province of Ontario.

Acknowledgements:

The Ontario Ministry of the Environment wishes to express its appreciation to all whose efforts made the production of these proceedings possible. The national and international group of experts and observers who attended the working session on Pathogen Management Zones in Toronto, Ontario, in July 2004 of whom contributed to the workshop and proceedings comprised the following:

Cassandra Lofranco, Ontario Ministry of the Environment, Symposium Chair

Technical Experts Committee on Source Water Protection: Pathogen Sub-Committee:

Michael Brodsky, Brodsky consulting
Dr. Doug Joy, University of Guelph
Dr. Michael Goss, University of Guelph
Dr. Ron Pushchak, Ryerson University
Hugh Simpson, Ontario Ministry of Agriculture and Food
Leslie Woodcock, Ontario Ministry of Agriculture and Food
Rosemary Ash, Ontario Ministry of the Environment
Shelly Bonte-Gelok, Ontario Ministry of the Environment
Karen Chan, Ontario Ministry of the Environment
Jennifer Young, Ontario Ministry of the Environment

Expert Speakers:

Dr. Joan Rose

Homer Nowlin Chair in Water Research, Department of Fisheries and Wildlife Michigan State University. Member of the Advisory Board for the Great Lakes International Joint Commission, and a Member of the Advisory Board for the USEPA Drinking Water Committee. Dr. Rose obtained her PhD. (Water Microbiology) in 1985 from the University of Arizona. She spent fourteen years at the University of South Florida.

Dr. Rose covered the topic of surface water indicators and evaluation of risk management strategies. Quantitative risk assessment is a tool used to estimate adverse health effects associated with specific hazards. It provides the frame work for science based assessment. Issues pertaining to risk management include the identification of acceptable risk. The USEPA suggested that 1/10,000 infection annually is an appropriate level of safety for drinking water. Benefit and cost are considered in risk management decisions. Dr. Rose also spoke to the sources and survivability of faecal coliforms, and specific coliphage types. In addition, she reviewed a number of studies that she had been involved in. Results from the Tampa Bay Healthy Beaches project, the Microbiological Characterization of ambient waters and proposed water sources for rehydration of a Floridan wetland project, and the results from the onsite sewage system setback distance to seasonally inundated areas project were presented to the audience.

Dr. Marylynn Yates

Professor of Environmental Microbiology, University of California

Dr. Yates obtained her M.Sc. (Chemistry) in 1982, and her Ph.D. (Microbiology) in 1984 from the University of Arizona. In 1985 she was a research Microbiologist with the U.S. Environmental Protection Agency, in Oklahoma. Since 1987, Dr. Yates has been a professor of Environmental Microbiology and Ground-Water Quality Specialist, with the Department of Environmental Sciences, University of California, where she served as Chair, for the Department of Environmental Sciences (1999), and more recently served as Associate Executive Vice Chancellor, University of California, Riverside (2001-2004).
Dr. Yates has been very active in research, teaching, and outreach in the area of the fate and transport of microorganisms in soils, water, and wastewater.

Dr. Yates spoke to the fate and transport of viruses in the subsurface. She spoke to results obtained from the AWWARF/EPA study on virus occurrence in ground water. US ground waters were found to be vulnerable when the multi-indicator approach in monitoring was used. Site specific conditions determined whether a well was contaminated and that well depth should not be assumed as a safety factor in determining water quality. Survival of many viruses was covered. Dr. Yates additionally spoke on using a 2 year time of travel illustrating various outcomes using models VIRAL T and HYDRUS-2D.

Dr. Pierre Payment

Professeur of microbiology, INRS Institut Armand-Frappier, Laval, QC
Dr. Payment obtained his M.Sc. (Microbiology and Immunology) in 1971 and his Ph.D. (Microbiology and Immunology) in 1974 from the University of Montreal. Since 1975, he has been a professor at INRS- Institut Armand-Frappier, a research institute part of the University of Québec. He has been very active both in clinical microbiology, veterinary virology and public health. He is knowledgeable on many aspects of water treatment and microbiology and his current research activities are centered on the health effects of drinking water. As an expert, he has participated to several activities of the USEPA, WHO, Health Canada, OECD, the Walkerton Commission (Ontario, Canada) and he is a member of the Consultative Scientific Committee of the Joint International Commission (IJC).

Dr. Payment covered the topic of Pathogen, Indicators and Survival. Dr. Payment's overview provided the required fundamentals on the key pathogens, selection of indicators and survival of enteric microbes in the environment. Pathogens of concern are those found in faecal matter that causes disease in humans. The list of pathogens is dynamic in that what we know today will surely change tomorrow as new and emerging pathogens emerge or are discovered. Natural and Human factors (point and non-point sources) affect source water quality. Temperature was identified as a significant factor for determining survivability. Colder temperatures allowed organisms to survive longer in the environment. Most pathogens can survive for months, desiccation rapidly inactivates most enteric pathogens, they can be transported long distances in surface or ground water and their presence is a function of input and environmental conditions. The relationship between indicators and pathogen presence is poor in diluted environments and predictivity value is poor if input is low or occasional.

Ms Susan Springthorpe

Director of Research, Centre for Research in Environmental Microbiology (CREM), Ottawa, On. Ms. Springthorphe received her formal training in the UK in biochemistry. She obtained her M.Sc. (Environmental Microbiology and toxicology) from the University of Ottawa. Ms. Springthorpe has over 30 years experience in the field of environmental microbiology and is currently the Director of Research for CREM.

Ms. Springthorpe spoke to water quality indicators and zones of influence. She identified that use of a single indicator would not be indicative of all types of contamination. Multi indicator approach would be more representative of recent and older contamination, and would give a better picture of bacterial viral and protozoan contamination. Transport and survivability was also discussed as part of her presentation, where it was noted that transport will be different for different classes and among species of organisms. Also noted were the effects of precipitation, preferential flow, and waste management practices. Ms. Springthorpe spoke about current research projects looking at preferential flow and identified preliminary results. Preferential flow is seen in all soil types, with silty clay showing more than other types. Microbial and particulate transport demonstrates spatial and temporal patterns. Zones of influence are not consistent in that no specific distances are suggested. Evaluation of sites should be done on a case by case bases taking into consideration hydraulic conductivities of soil. She recommends that the minimum distance be no less than 30m.

Dr. Peter M. Huck

Professor, University of Waterloo. NSERC Chairholder in Water Treatment, and appointed member to the Ontario provincial Advisory Council on Drinking-water Quality and Testing Standards.

Dr. Huck covered the topic of surface water indicators and zones of influence for rivers and lakes. Spoke of using the term robustness to evaluate a system and extending the multi-barrier approach. There are five basic elements to consider when evaluating the robustness of a system: Best possible source, adequate treatment, secure distribution, appropriate monitoring and response to an adverse result. A robust system has excellent performance under normal conditions and minimal deviation when challenged. The elements must be looked at as a cohesive overall unit that is a more robust source requires less robust treatment. Overall system must be robust because source water robustness impacts other components. No matter how robust the system is, treatment must always be provided. With surface Water, 'events' are the priority issue which means that the time for response is minimal in a robust system. Hydraulics/hydrology is also very important. When considering source water robustness (pathogens) is important as is considering the average, peak, and rapidity of the change and the quantification of the robustness through an index. It is also important to consider the type of pathogen management zone tied to index and the required treatment and monitoring robustness defined by this. This approach is a *Conceptual approach* that needs much further development.

Ministry of the Environment
Standards Development Branch

Ministère de l'Environnement
Direction de l'élaboration des normes

Ontario

<u>Agenda</u>

Source Water Protection Symposium on Pathogen Management Zones

Friday July 23, 2004
9:00 AM – 4:00 PM
Amphitheatre, Ontario Ministry of the Environment Laboratory, 125 Resources Road, Etobicoke, Ontario

9:00- 9:05 Welcome from MOE and symposium coordinator and chair,
Ms. **Cassandra Lofranco**, Senior Advisor Microbiology, Standards Development Branch, MOE

9:05-9:15 Opening remarks Overview on the relevance of the symposium to source water protection. **Dr. Michael Goss**, University of Guelph

9:15- 9:25 Overview: The impact of Source Water Protection Legislation in Ontario **Hugh Simpson**, Resource Management Policy Analyst, Ontario Ministry of Agriculture and

9:30- 10:15 Dr. Marylynn Yates, microbiological indicators, coliphage and ground water protection zones, Professor of Environmental Microbiology, University of California

10:15 – 10:30 REFRESHMENT BREAK

10:30-11:15 Dr. Pierre Payment, microbiological indicators, well head protection, Professeur of microbiology, INRS Institut Armand-Frappier, Laval, QC

11:15- 12:00 Dr. Joan Rose, surface water indicators and zones of influence for rivers and lakes, Homer Nowlin Chair in Water Research, Michigan State University

12:00-12:30 Panel Discussion

12:30-1:30 LUNCH BREAK

1:30 – 2:15 DR. Peter Huck, Professor of Civil Engineering and NSERC Chairholder, University of Waterloo, Waterloo, On. Along with **Dr. S.A. Andrews**, University of Waterloo and **Dr. Gayle Newcombe** Senior Research Scientist, Australian Water Quality Centre

2:15 to 3:15 Panel Discussion

3:15 – 3:30 REFRESHMENT BREAK

3:30- 4:15 Panel Discussion

4:15- 4:30 Thanks

Symposium – Morning Session

Participants were welcomed by **Cassandra Lofranco**, Senior Advisor Microbiology, Standards Development Branch, Ontario Ministry of the Environment.

Opening remarks with regard to the overview on the relevance of the symposium to source water protection were given by **Dr Michael Goss**, University of Guelph.
.

An overview on the impact of Source Water Protection Legislation in Ontario was given by **Hugh Simpson**, Resource Management Policy Analyst
Ontario Ministry of Agriculture and Food.

Presentations: Presentations made by the individual scientific experts can be found as attached PDF documents to these proceedings.

Synopsis of Panel Discussions and Questions:

The following questions were asked of the scientific experts and a synopsis of the discussion that resulted from each question follows.

Question #1: What can we do about protecting multiple well fields as opposed to municipal wells?

- Municipal wells in a communal/subdivision as opposed to private wells (owned by individual homeowner). In Ontario, private wells may not be treated; these water sources are under MOHLTC jurisdiction. Sample analysis and educational materials are provided by MOHLTC.
- Is the MOHLTC database accessible? Would need to speak with the MOHLTC regarding privacy issues.
- Data may be questionable, would have to know how and where sample was taken to ensure that the data was reliable and comparable to other data.
- Would the results be available by telephone? This would only be available in some regions.
- Plan would need to cite distances between individual lots, and then it would have to be determined whether these separation distances are appropriate.

- Setback distances are established in the USA, citing distances for septic systems based on rapid water infiltration into the soil column. They are not based on the ability of soil to remove contaminants.
- For a non disinfected system, no fixed distance that is set will protect the user, regardless of the distance. Zero risk is not an achievable goal.
- It may be possible to protect the well field via changes, such as limitations/restrictions in land-use.
- If home owners are on a private well, they are also likely to be on septic system located on the same property, therefore would any distance be protective?
- What is reasonable risk? Outbreak and survey data from the USA shows that ground water is not to be considered safe.
- Private well user could do tracer tests to determine risk from onsite septic systems.

Question #2: Is there a set back distance that you would recommend for Surface Waters (not associated with a well) where there could be agriculture discharge or septic discharge to surface water?

- Surface waters that interact with ground waters should be treated /considered separately.
- Due to flow and amount of input, there is no single answer that would be equal to really protecting water -New York.
- A 90 day buffer around drinking water reservoir may be an acceptable distance.
- River systems are more difficult because consideration would need to be given to looking upstream at loading. Some examples are Ohio and Kentucky who have different setback distances under Clean Water Act. A set distance between sewage discharge and drinking water uptake may also provide protection.
- Is TMDL the way to go? There was expert support for the concept of TMDL, however the process is not well conceived in the USA as the data on the source looks at loading over time. The approach to implementation has not been developed and it needs more data and work.

Question #3: If a pathogen capture zone was established, should the same distance be established for all pathogens?

- Although it is recognized that each pathogen may have a different capture zone, an “organism specific” capture zone is neither practical nor necessary.
- Ideally, the size of the capture or protection zone should be based on a worst case scenario that considers the source(s) of the contamination, the

nature of the pathogens and the hydrology/hydrogeology of the surrounding strata; however, how the distance would be determined needs to be resolved.

- Ideally a separate distance would need to be established for each pathogen.
- The same distance will not work and that how the distance would be determined needs more discussion.
- There would be a need to assess point/non point contributions and apply the science that determines how various factors interact to capture bacteria, virus and protozoa.

Question #4: What levels of well and source water protection are in place in the USA?

- USEPA's proposed Ground water Rule is not really source water protection, but a log reduction. Perhaps certain aquifer types would be identified as sensitive?
- Septic separation distances are site specific, thus varied.
- TMDL document is just a tool. It is not accessible to drinking water side legally.
- Guidance under well head protection program is provided, but is chemical risk based for volatiles *etc.*
- Watersheds are captured under the Clean Water Act: Boston (ozone and buy out), New York, Seattle, legally mandated…otherwise coalition approach trade reduction strategies.
- The USEPA may merge the Clean Water Act and Safe Drinking Water Act in the future
- Australia. Melbourne, protective catchments are government owned lands. There is no new development allowed in sensitive areas of these catchments.
- Queensland has allowed recreation in catchments and family owned grazing has been permitted historically, but this is now being looked in order to prevent

Question #5: If Time of Travel (TOT) is used is 200 days a good one?

- It would depend on which organism/indicator selected.
- Temperature + key pathogens + literature = enough data to look at die off for 200 days.
- – Which indicator would be used to monitor for those indicators that do not correlate to pathogens very well?
- There are risks associated with using TOT. Removal may not be enough to produce a desirable concentration at the end point (intake).

- Fixed TOT in areas with inputs already: Consideration would need to be given to dealing with the existing inputs into the system within the defined area, would you have to remove them? Or buy them out?
- The TOT would not apply to Surface water.

Log + 100 days die-off = removal 99%. Is this sufficient?

Appendix 7. TEC Data/GIS Sub-Committee

TEC Data/GIS Sub-Committee Members

TEC members:
Bob Clay
Steve Holysh
Bruce MacDonald
David Sharpe

Staff members:
Scott Duff (OMAF)
Charley Worte (CO)
Frank Kenny (MNR)
Scott Christilaw (MNR)
Bryce Matthews (MNR)
Hugh Simpson (OMAF)
Lorrie Minshall (GRCA)

Other staff who participated in subject specific data discussions included: Glenda Rodgers (LTCA), Mark Peacock and Chris Wilkinson (Ganaraska CA), Jennifer Chamberland, Gary Stronghill, Garry Flynn and Ian Parrish (MOE), Cam Baker and Ross Kelly (MNDM), Chris Harrington (CO), James Holland (DU), Bob Steiss and Jennifer Birchmore (OMAF) , Mike Robertson and Anne Trudel (MNR)

Data and Data Management Requirements in Support of Source Water Protection Draft Recommendations

Introduction

Source Protection Plans (SPP) will be undertaken over the next few years in Ontario. Underpinning the entire process is data. Underlying the source protection process is the assumption that data sets are available to Source Protection Committees and that these data sets can be relied upon to undertake the technical assessment and the source protection plan. The data sub-committee has built on a report by the Ganaraska, Lower Trent and Crowe Valley Conservation Authorities (Lower Trent Conservation Authority, Ganaraska Region Conservation Authority, Crowe Valley Conservation Authority, 2004) to make specific recommendations pertaining to a series of data sets within the Province of Ontario. This report, entitled Data Requirements and Availability for Source Protection Planning in Rural Ontario, was a source water protection plan pilot study to investigate which data sets would be required in moving through the source protection process. It provides an overall perspective on what needs to occur with specific data sets in order to make Ontario's source protection plan successful.

Given the importance of data to the source water protection process and the relative ease with which this fundamental aspect can be overlooked, the recommendations from this sub-committee should be the first phase in the roll out of the province's SPP.

This sub-committee report addresses three important aspects of data management. The first section addresses information management coordination. Section 2 addresses specific data management principles and protocols that must be adhered to by the province and the SPPC as source water protection process unfolds. Section 3 describes specific Provincial data sets required for Ontario's source water protection process.

Information Management Coordination
Because data and projects related to the SPP will include all levels of government, a strong coordinating body led by Water Resources Information Project (WRIP) must be put in place. Its functions will include identifying critical data, assisting in the establishment of data standards, ensuring agreements are in place to allow access to data, and liaison between Federal, Provincial, Municipal governments and Conservation Authorities.

Each SPP Team should have a Data/GIS team member who is responsible for local data management, data quality/integrity, data maintenance (including updates), and data access for the SPP team. These data professionals must be organizationally linked to the data coordination body.

<u>Discussion Item 1</u>
A provincial data coordination body is established for SPP.

<u>Discussion Item 2</u>
At least one member of each SPP team is a GIS professional focused on data management.

2.0 Data Management Principles and Protocols

2.1 Metadata

Metadata includes (but is not restricted to): source lineage of information, general description of content (with important keywords), relevant standards and manuals involved in managing the information, who is responsible for the information (ownership, maintenance, quality assurance, dissemination, storage), relevant standards governing content, use cautions, use restrictions and a detailed data dictionary for any tabular content. The advantage of provincially standardized information is that one set of metadata pertains to all of it; otherwise metadata needs to be recorded for each variant information set. The advantage of using the Ontario Land Information Infrastructure (OLII) is that the Ontario Land Information Directory (OLID) provides a free tool to record and maintain general metadata as defined by GO-ITS standard (GO-ITS 72.00 2004) and there is analysis support to build and maintain a detailed data dictionary.

Discussion Item 3
All provincial and local information used for Source Protection Planning must have a full set of metadata defined and available. As much as possible it is recommended that data sets take advantage of the Province's OLII

2.2 Custodial Responsibilities

An authoritative version of an information set is defined as an information set that has been endorsed by its owner as being the best quality and most current that the owner can provide *at this point of time*. It is the owner's responsibility to make the information available to stakeholders and publicly viewable, whether with its own staff and resources, or through OLII's exchange (Ontario Geographic Data Exchange (OGDE) – open to all municipalities and Conservation Authorities) and browser. Owners should accept feedback from stakeholders regarding the data, vet possible corrections, adopt them if accepted, and establish a new authoritative version. Date information must be kept with each authoritative version. Owners need to be familiar with Freedom of Information and Privacy Protection Act (FIPPA) and what data handling procedures need to be in place to adhere to it while providing access on a "need-to-know" basis to sensitive portions of their data.

Discussion Item 4
All provincial and local information used in Source Protection Planning should have accessible, authoritative versions.

2.3 Geo-referencing as an Integrator

Location is the major integration factor in Source Protection Planning. Information elements must be geo-referenced so that their interplay can be accurately identified and modelled. A standardized recording of those elements across the province facilitates data sharing, data integration and the use of common models.

Discussion Item 5
Where possible, all provincial and local information used and generated in Source Protection Planning should be geo-referenced to provincial standards.

3.0 Immediate Requirements of the Province

3.1 Specific Data Sets

Based on the previous provincially-funded ground water studies, as well as the pilot data study referenced earlier, expert opinion has determined that certain data sets are in need of special focused attention as the province rolls out the source water protection process. It is recognized that there will be time and resources required for the province to implement the following data-set specific recommendations, and as such, certain data sets may not be complete at the on-set of source water protection, but work needs to start as soon as possible.

Among the over 90 data sets analyzed by this sub-committee, the Water Well Information System (WWIS) stands out as being in the most critical need of work. These data are used extensively within hydrogeological modelling and form the backbone for hydrostratigraphic model development. Recent experience in the municipal ground water studies highlighted that individual studies utilized only between 55-85 percent of these records due to a lack of confidence in the data spatial quality. Even the vetting of such a high percentage of the database in many studies did not have the effect of instilling a high degree of spatial confidence in the remaining/utilized records.

The province can make a short-term investment in these data sets to ensure they can optimally support the first round of SPP. Since SPP is an iterative process, long term investment in these data sets will be required to meet the needs of future, more sophisticated models.

Discussion Item 6

The existing provincial data sets listed in Table 1, have been identified as critical to the success of SPP and in critical need of work. These data must be made accessible within the Ontario Land Information Warehouse (OLIW) by the end of 2005.

Table 1. Critically needed, existing provincial data sets identified as requiring work.

Existing Data Set	Lead Ministry	Scale	Relevance to SPP
Satellite Derived Land Cover Mapping – Northern Ontario.[1]	MNR	~1:50,000 28 m. resolution	Watershed Characterization, Water Budget, Vulnerable feature identification
Southern Ontario Land Resource Information (SOLRIS) [2]	MNR	1:10,000	Watershed Characterization, Water Budget, Vulnerable feature identification
Northern Ontario Engineering Geology and Terrain Series (NOEGTS) [3]	MNDM	1:100,000	Ground water and Surface Water Modelling, Watershed Characterization, Vulnerable area identification
Paleozoic geology compilation of Southern Ontario [4]	MNDM	~1:50,000	Ground water Modelling, Watershed Characterization, Water Quality, vulnerable area identification
Municipal and Tile Drains Mapping[5]	OMAF	1:50,000	Surface Water Modelling, Threats, Water Quality
Agricultural Soils [6]	OMAF	1:20,000 – 1:126,700	Watershed Characterization, Water Budget, vulnerable area identification
Water Well Information System (WWIS) [7]	MOE	Point data	Ground water Modelling, Subsurface geology, Threats, definition of WHPA, ISI *etc*.
Integrated Divisional System (IDS) [8]	MOE	1:10,000 Point/Polygon	Threats, Water Budget, Water Quality, Water Quantity
Bedrock Topography and Drift Thickness[9]	MNDM	1:50,000	Ground water Modelling, Water budget, vulnerable area identification

Notes:
1-9 See Appendix 1 for description of Data Sets.

The province has invested over 22 million dollars in developing municipal ground water studies. These were done with minimal data management coordination and minimally enforced standards (where defined). The products from the recently completed MOE municipal ground water studies should be catalogued with Ontario Land Information Directory (OLID) metadata records and stored in the Ontario Land Information Warehouse (OLIW) as packaged products. There should also be an effort now to extract true data value from these for the benefit of all SPP work.

<u>Discussion Item 7</u>
The municipal ground water studies should be mined for the unique, updated and refined information these reports contain about the base data used within the modelling. In particular previously unknown wells and data refinements to known wells must be captured within the Water Well Information System (WWIS).

3.2 Base Topographic Data

Source Protection Planning will be a long-term effort and will live through numerous more advanced and data intensive iterations. It is reasonable to expect the need for updated base data will go beyond the current provincial 1:10,000/20,000 scale base mapping.

The cost of developing a new larger-scale base for all of Ontario is cost prohibitive, but there is a clear need for an updated and larger scale base in certain areas to support SPP efforts. The province should coordinate large-scale topographic mapping (eg. DEMs, orthoimagery, infrastructure, hydrology *etc*.) acquisition by providing image acquisition standards, map compilation standards, letting and administrating contracts, monitoring products from contractors, ensuring developed data are aligned with other data sets, and providing open LIO access to the acquired data. This approach is very similar to USGS's new National Map compilation (www.nationalmap.usgs.gov).

In the absence of provincial coordination, twenty-six SPP teams will independently contract for and collect base data and then build/attribute additional data themes onto these data. This is not cost effective and will produce numerous data problems regarding standards, integration, access issues, and ownership.

<u>Discussion Item 8</u>
The province should coordinate and manage large-scale mapping acquisition as needed to support SPP efforts.

3.3 Expanded Data Sets

Understanding ground water and surface water systems, and the link between these systems, is key to successful source protection. Historically, Ontario has a record of temporarily starting and terminating various monitoring and data collection programs based on budget considerations at decision time. The adoption of source protection legislation further enhances the recognition of the importance of water resources to Ontario. The data sub-committee recognizes that it is the appropriate time to put in place long term, regionally extensive, and scientifically based monitoring networks. These networks must be developed in cooperation, and with the scientific input, from SPPCs. The province must budget accordingly and work in partnership with SPPCs to ensure that the data is cost-effectively collected and is reliable.

Discussion Item 9
The water monitoring data sets as listed in Table 2 have been identified as critical to the success of SPP.

A) **The province should strategically expand the collection of these key water monitoring data sets.**
B) **These data sets must be made accessible within the Ontario Land Information Warehouse (OLIW) by the end of 2005.**
C) **Where comparable data sets are held by local authorities, the province should assist these groups to ensure these data have recognized metadata, standards and can be made accessible.**

Table 2. Existing provincial data sets requiring expansion/densification.

Expanded Data Set	Lead Ministry	Scale	Relevance to SPP
Hydrology Data (HYDAT) [10]	MNR	Point Data	Water Budget, Surface Water Modelling, Water Quality
Provincial Ground water Monitoring Network [11]	MOE	Point Data	Water budget, Ground water Modelling
Provincial Water Quality Monitoring Network[12]	MOE	Point Data	Watershed Characterization, Water Quality Threats,

Notes:
10-12 See Appendix 1 for description of Data Set.

3.4 New Provincial Data Sets

Source water protection has specific data requirements and will develop specific products as the SPPC undertake their programs. The data sub-committee already recognizes at this point, four areas where the province should develop new datasets.

There are numerous data sets across our ministries that have useful information about Threats (eg MNR's old landfills, MNDM abandoned mines, MOE – HWIN, Waste Disposal Sites, MTO's Salt Storage Sites, *etc.*). Many of these data sets are out of date, most are incomplete, some are orphaned and none of these were collected with SPP in mind. The idea being that a new data set should be developed (a data model created) with SPP as the primary application (recommendation 11) – but also implies that this new data set when developed could be used for numerous other non SPP applications. A separate project should be developed to 1) examine these existing data/databases for their utility to support SPP, 2) identify gaps in Threats data required to support SPP, and 3) to develop a strategy to produce an authoritative and unified threats database. Several Ontario municipalities have developed threats data models for their information needs.

<u>Discussion Item 10</u>
The province should initiate the standardized collection of several new sets of provincial data as outlined in Table 3. These data sets must be made accessible within the Ontario Land Information Warehouse (OLIW).

<u>Discussion Item 11</u>
The province should build a threats data model to cover chronic and acute threats.

Table 3. New provincial data sets

New Data Set	Proposed Custodian	Scale	Relevance to SPP
Threats[13]	MOE	n/a	Threats Inventory, Water Quality
Private/Municipal Well Testing Data[14]	MOHLTC	n/a	Threats, Water Quality,
High-Quality (HQ) Subsurface Geological Mapping[15]	MNDM	n/a	Subsurface Characterization and Ground water/Surface water Modeling
Karst Compilation of Southern Ontario[16]	MNDM	1:50,000	Surface and Subsurface Characterization, Ground water and Surface water Modeling
SPP Newly Developed Information (eg. Well Head Protection Areas)[17]	To be determined	n/a	

Notes:
13-17 See Appendix 1 for description of Data Sets.

APPENDIX 7A: TEC Data Subcommittee

Notes pertaining to data sets discussed in report (Tables 1,2 and 3).

1. The ***Satellite Derived Land Cover Mapping for Northern Ontario*** is 28 metre pixel resolution, seamless land cover mapping for northern Ontario, interpreted from Landsat ETM imagery. Twenty eight distinct land cover units are mapped, including Forested (8 classes), Wetlands (9 classes), Agriculture, Urban, Burns, Cutovers and Mineral Extraction sites. These data are critical for many facets of source water protection planning, including watershed characterization, development of water budgets and identification of vulnerable features and areas.

2. The ***Southern Ontario Land Resource Information System (SOLRIS)*** is a regional scale land cover inventory based on MNR's Ecological Land Classification (ELC) for Southern Ontario (SCSS Field Guide FG-02). The land cover units captured include classes of wetlands, forested areas, natural areas, urban extents, and intensity of agriculture (high/medium/low). These data are critical for many facets of source water protection planning, including watershed characterization, development of water budgets and identification of vulnerable features and areas.

3. The ***Northern Ontario Engineering Geology and Terrain Series (NOEGTS)*** is largely a photo-interpreted classification of surficial material types and landforms/landscapes for mid-northern Ontario. This mapping contains basic information that will be used directly by all SPP teams for both surface water and ground water modeling across Northern Ontario.

4. ***Paleozoic Geology Compilation of Southern Ontario.*** This large-scale bedrock lithology mapping for Ontario captures the bedrock south of the Canadian Shield in a seamless map. These are critical data for any detailed analysis of ground water resources and modeling and will be needed for all source protection teams working in southern and eastern Ontario.

5. ***Municipal and Tile Drains Mapping.*** This mapping is conducted under a Provincial Act and captures at a minimum, fields that are tile drained (systematically or randomly) and engineering agricultural drainage works (Municipal Drains). These data are critical for SPP and will be used extensively in surface water modeling, and for watershed characterization.

6. ***Agricultural Soils.*** This mapping provides detailed information about the surface layer (the top meter) required to assess partitioning of water between surface runoff and infiltration. It also provides the basis of the

CLI land capability interpretation necessary for land use assessment and water budget modelling. The mapping which has been carried out over the last 50 years at various scales requires correlation to edge match soils between projects of differing scales and vintages to prepare a consistent provincial coverage registered to the base.

7. The ***Water Well Information System (WWIS)*** is a database containing over 500,000 water wells for across Ontario. This database contains a description of well geo-referencing, geological formations encountered during drilling, subsurface water characteristics, details of the well construction and testing and well yield results (Ontario Ministry of the Environment 1977). These data are extremely critical for ground water studies and in many parts of the province are the only source of hydrogeological knowledge.

8. The ***Integrated Divisional System (IDS)*** captures the workflow from the MOE's Operations Division. This systems is the point of data capture for many source water identified critical data sets including the Permit to Take Water (PTTW), Certificates of Approval (CofAs), Occurrence Reports, Biosolid Applications, Compliance Reports, Incident Reports and Control orders. The information captured by this system is identified as some of the most critical for SPP. The information is used extensively for water budgets, threats to drinking waters and water quality monitoring.

9. ***Bedrock Topography and Drift Thickness.*** This mapping, conducted by the Ontario Geological Survey over the last 40 years is a geological interpretation of the thickness of unconsolidated sediments and the topography of the bedrock surface. These are critical data for both surface and ground water studies. Many aquifer systems (eg buried paleo-channels) can be identified through this mapping. These data are a required input for almost all ground water modeling efforts.

10. ***Hydrology Data (HYDAT).*** The MNR and Conservation Authorities are currently collecting stream flow and level information on 358 HYDAT stations across Ontario. These data are owned jointly by Environment Canada, MNR and CAs. These data are absolutely indispensable for developing and calibrating water budgets. These data are also extensively used for ground water and surface water modeling.

11. ***Provincial Ground water Monitoring Network (PGMN)*** This network is designed to provide accurate data on geological/ stratigraphic, ground water level and ground water quality data for the province. PGMN is a recent initiative of the MOE and CA's (post – 2001). PGMN will be comprised of 380 wells in 36 CA's and municipalities. These wells are sampled every 6 months and the results stored at the MOE. These data

are used for the development of water budgets, drought monitoring, detection of threats and as high quality data within ground water models.

12. ***Provincial Water Quality Monitoring Network (PWQMN).*** The Provincial Water Quality Monitoring Network (PWQMN) is an on-going initiative of the MOE and CAs. Water quality sample collections are undertaken across the province at approx. 200 sites. Samples are currently collected at approx. monthly intervals from April through November. Samples are analyzed for a range of water quality indicators (including temperature, pH, conductivity, turbidity, suspended solids, major ions, nutrients, and metals) in order to screen overall water quality and identify potentially anomalous values. These data are very are critical within SPP for the indication of Threats and to provide an understanding of ambient values.

13. ***Threats.*** Numerous provincial databases such as MOE's -HWIN (Hazardous Waste Information Network), MOE's – IDS (Integrated Divisional System), MOE's Municipal Ground water Studies, MNR's-Waste Disposal Sites, MNDM's – Abandoned Mines Sites and MOT – Salt Domes *etc*. contain useful information about threats to drinking water sources. A separate project should be developed to 1) examine these existing data/databases for their utility to support SPP, 2) identify gaps in Threats data required to support SPP, and 3) to develop a strategy to produce an authoritative and unified threats database.

14. ***Private/Municipal Well Testing Data.*** Local Health Board routinely collect and analyze water well samples for health-related water quality involving microbiological organisms. The general public also bring private well samples to the health boards for testing. These data should be evaluated for their utility to contribute to SPP. Part of this evaluation must be an assessment of the FOI (Freedom of Information) issues associated with these data. These data are viewed as critical for identifying drinking water threats and to better understand ambient conditions.

15. ***High-Quality (HQ) Subsurface Geological Mapping.*** We recommend that high quality (HQ), subsurface (3-Dimensional) geological mapping be completed across southern Ontario and selected areas of northern Ontario, to identify potential new ground water resources, define properties of known aquifers (size and character) and assess their susceptibility to contamination. It is recommended that an integral component of the 3-D mapping is (HQ) data collection e.g. geophysical surveys and cored boreholes with geophysics (termed "golden spikes").
In Ontario, this approach has been used at selected landfill sites where intensive HQ data collection, hydraulic and geochemical monitoring and analysis have been employed at a local-scale. We recommend the use of this modern, enhanced science approach in support of SWP at the well-

head protection and watershed scales. Collection of HQ data has direct ties to the Provincial Ground water Monitoring Network, Provincial Water Quality Monitoring Network and the Permit to Take Water activities.

16. ***Karst Compilation of Southern Ontario*.** This is a proposed new layer that would outline karst features and describe their conditions in the Paleozoic areas of southern and eastern Ontario. The Ontario Geological Survey has numerous map and study sources to draw upon to develop this compilation. The understanding of where karst conditions (eg. Walkerton) exist and the degree of development are critical for understanding ground water flows and ground water/surface water interactions.

17. ***SPP Newly Developed Information***. Source Protection Planning will generate numerous new sets of provincial information. (eg. well-head protection areas, detailed LiDAR derived DEMs, *etc*). The collection methods and storage of these data must be provincially standardized across SPP areas. A long-term goal for these data is that they must be made accessible as a structured product within the Ontario Land Information Warehouse (OLIW).

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Data Requirements and Availability for Source Protection Planning in Rural Ontario. 2004. Draft Report by: Lower Trent Conservation Authority, Ganaraska Region Conservation Authority, Crowe Valley Conservation Authority. 103p.

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URL: http://www.gov.on.ca/mbs/techstan/tmp7200.htm

United States Geological Survey – The National Map.
URL: http://www.nationalmap.usgs.gov

Appendix 8. Details related to the process of developing a source protection plan

As a basis for making specific recommendations to the Minister, TEC understands that the general process for development and implementation of source protection plans will include the following steps.

First a technical assessment report that describes watershed characteristic, issues and risk assessment

- The technical assessment report should include watershed description, water budgets, delineation of protection areas and risk assessment and should be based on the best available scientific information and public input.

- The watershed description should cover information such as physical characteristics, population distribution, land use/cover that will be used as a context for assessment and management of risks and threats. The description should cover all sources including public, private and communal. The description should also include key areas to be protected including wellheads, surface water intake areas, hydrologically important areas, areas to be protected for future use.

- The water budgets should identify all uses and withdrawals, estimate consumption, and forecast future drinking water needs and the role of conservation in management of use. A water budget should include:
    - quantification of the components of the water balance equation (precipitation, evapo-transpiration, ground water inflow and outflow, surface water outflow, change in storage, water withdrawals and water returns)
    - characterization of the flow of water on and beneath the surface, using hydrologic and ground water models
    - identification of key hydrologic processes (e.g. major recharge & discharge areas) and,
    - quantification and projection of water uses and needs.

- In Southern Ontario and areas under CA jurisdiction, Source Protection Plans require water budgets at two levels of scale and detail:
    - Phase 1: A watershed level (based on available data & hydrologic modelling) that identifies areas with potential water issues (issues resulting from cumulative water taking)
    - Phase 2: In areas with potential water issues, a sub-watershed level (based on refined data & hydrologic/ground water modelling). Within the SPP program, potential water use issues that involve drinking water supplies will be most urgent.

- In Northern Ontario, however, outside CA jurisdiction, a Preliminary Water Budget should be undertaken to determine whether there is sufficient water use to warrant the development of a Phase 1 Water Budget.

- The information used to generate the Assessment Report is intended to provide sufficient knowledge to guide the understanding of the drinking water related issues, threats and risk and thereby guide risk management plans. Consideration of this information will result in a report of a drinking water source protection plan. This report should include the objectives for the plan and risk management actions that are designed to address the drinking water issues detected during the watershed assessment phase.

- Finally, the report should include delineation and prioritization watershed issues related to drinking water that have been discovered through data analyses or public consultation and assessment of risks posed by those issues.

Second, a source protection plan that builds on the assessment report and relates stated objectives and risk management actions to offset issues and reach the objectives will be prepared.

Third, approvals by the Minister of the Environment and implementation activities.

- Consistent with the TEC guiding principle dealing with the need for continuous improvement, the plans should be reviewed on a 5-year cycle and revised as appropriate.

Appendix 9. Naturally Vegetated Areas

Naturally Vegetated Areas Subcommittee Members

TEC members:
Bob Clay

Staff members:
Don Greer (MNR)
Brian Potter (MNR)

1. Introduction

Naturally vegetated areas including wetlands, riparian areas and woodlands are "hydrologic features" in that they influence both water quality and quantity. They form part of the pathway of surface water and ground water movement and therefore influence risks to sources of drinking water. As such, these areas are recognized as being vulnerable, for source protection planning purposes, and are an integral part of the watershed management planning process, and the emerging source water protection planning process.

Wetlands contribute to the quantity and quality of surface water and ground water (Gabor et al. 2004, Mitsch and Gosselink 2000, and Norman, 2004a, OMNR, 1999). The ecological functions and water-related services that they provide include:

- the recharge and discharge of ground water, ensuring a stable, long-term supply;
- flood damage reduction through the control and storage of surface water;
- stabilization of shorelines and reduction of erosion damage; and
- water quality improvement through the trapping of sediments, the removal and/or retention of excess nutrients, the immobilization and/or degradation of contaminants, and removal of bacteria.

Not all wetlands provide all of these benefits. The hydrologic functions of individual wetlands depend on local climate, location within the watershed, topography, and surficial geology. Examples of these functions and benefits are listed below.

Water quality*:* Wetlands can be effective "sinks" or traps for nitrates, phosphorus, sediments and contaminants found in surface waters (Gabor et al. 2004). Pathogens also are of particular concern in source water protection planning. Natural wetlands can be used, to a limited extent, for wastewater treatment without compromising their ecological integrity. Only limited volumes of wastewater and very low concentrations of contaminants can be introduced into these systems. Constructed or artificial wetlands can provide very effective treatment of contaminated waters. For example, concentrations of *Yersina enterocolitica, Pseudomonas aeruginosa, Clostridium perfringens,* and

Salmonella were significantly reduced by constructed wetlands at a pilot facility in Ontario. This occurred even at cold temperatures during the winter months (Herskowitz 1986). It is known that removal of viruses is associated with removal of suspended solids. Constructed wetlands that are effective at removing suspended solids are also likely to enhance virus removal (Kadlec and Knight 1996). Gersberg et al. (1989) concluded that wetland treatment followed by conventional disinfection can remove essentially all viruses.

Wetlands can also contribute to *improvements in the quality of ground water*. For example, high concentrations of nitrates can cause eutrophication of surface waters, contamination of ground water supplies and human health problems. The anaerobic conditions found in wetland soils facilitate reduction of nitrate levels in shallow ground water (Gabor et al 2004).

<u>Water quantity</u>: A number of studies of the *ground water recharge* function of wetlands have been conducted in Ontario. Irwin (1967) studied organic soils in the Holland Marsh, located at the southern end of Lake Simcoe. Water table measurements showed that:

- levels began to decline in early May as evapo-transpiration increased;
- depth of water table below optimum levels was greatest at the end of August; and
- recharge of the water table began at the end of October.

Whiteley (1975) studied the Garner Wetland, an 11-hectare wetland in the Blue Springs Creek watershed, east of Guelph. In each year of the study, ground water recharge occurred during the period August to November. Like some other wetlands, the Garner Wetland can alternate between being a discharge site and a recharge site. During the spring, large recharge amounts raise the regional GW level above the water level in the wetland - this is the period of significant lateral inflow into the wetland. By August the regional water table has dropped below the wetland, which becomes a site of recharge to ground water.

Isolated wetlands are those found in depressions on the landscape where there is no outlet overland flow. In southern Ontario, maximum possible evapo-transpiration rates are less than mean annual precipitation rates. In addition, these areas periodically receive overland runoff from adjacent lands. In most years, then, these wetlands receive more water than they lose to the atmosphere, and are considered as sites of recharge to the regional ground water (Whiteley and Irwin 1986). Similarly, the numerous small, ephemeral pools found in low-lying areas in agricultural and other landscapes that collect surface water in the spring may function to recharge ground water supplies.

Flood Attenuation: Woo and Valverde (1981) studied the hydrology of Beverly Swamp, a wetland located north of Hamilton. Two perennial streams enter the swamp and then join within it. The stream with the well-defined channel had a negligible impact on flood peaks, over a 2.5 km reach of the stream. The other stream branches out after entering the wetland and disappears underground for about 1 km. before re-emerging as a defined channel. In this portion of the wetland, passage of flood waves took 20 - 30 hours.

Surface Water Storage: In addition to temporarily impeding water flow and reducing overland flow, flooding and erosion, wetlands function to retain water. Water is stored in surface depressions and in the soil (Gabor et al 2004). The Norfolk Water Supply Enhancement Project is a multi-agency, cooperative undertaking in south western Ontario which is designed to develop a reliable supply of water away from sensitive streams, improve water storage capacity on the landscape and make more efficient use of existing water supplies. Initiatives include pond creation and expansion, and wetland drain restoration projects. The latter involve installation of water control structures in municipal drainage ditches to increase water storage capacity, water quality and other wetland functions. These wetland restoration projects have resulted in a measurable increase in the availability of water for agricultural uses (D. Richards, pers. comm.)

Shoreline Erosion Control: wetlands located on the shorelines of rivers and lakes help reduce shoreline erosion and water quality impairments. Wetland vegetation binds soil, dissipates wave and current energy, increases deposition of sediments by reducing current flow, and stabilizes banks (Carter et al 1978).

Riparian Areas are those lands adjacent to a river or stream that are influenced to some degree by flooding. They have a high water table, due to their proximity to flowing waters. Riparian areas can consist of riverine wetlands, or riverine wetlands plus the more transitional habitats located between aquatic and upland habitats.

Riparian areas can have a significant impact on water quality. They help control erosion from overland flow and limit the sedimentation of surface waters, and reduce the concentrations of nutrients, pathogens and pesticides. For example, forested riparian areas impede the movement of contaminants, including pathogens and toxins, to surface waters and increase opportunity for contaminants to become buried in sediments, adsorbed into clays or organic matter or transformed by microbial and chemical processes (Johnston et al. 1984).

Woodlands have a positive impact both on water quality and quantity. They act to reduce the velocity of overland water flow and hence erosion. Woodlands also function to intercept precipitation and increase infiltration to shallow ground water areas, and reduce the rate of snowmelt (Norman 2004b). Approximately one-third of the world's largest cities (33 of 105) obtain their drinking water primarily from protected natural areas, i.e., those with significant forest cover, wetlands and good best management practices ("BMPs") for land uses (Dudley and

Stolton 2003). Removal of woodlands results in a greater water yield, i.e., increased overland flow into surface waters, and reduced water quality.

Conservation of Natural Areas: Considerations for Watershed-based Source Protection Planning

Watershed Scale Considerations

Land development tends to result in losses of naturally vegetated areas, and an increase in the extent of impervious surfaces, which increases storm water runoff while decreasing ground water infiltration and evapo-transpiration. This, in turn decreases the travel time for runoff to reach surface waters, increasing the frequency and intensity of erosion and downstream flooding (Norman, 2004b). Water quantity and quality problems are more likely to occur in watersheds where there is little natural vegetative cover, and impervious surfaces are common.

“Healthy” watersheds have a good mix of naturally vegetated areas, well distributed across the landscape. These more naturally vegetated watersheds are better able to keep soil, nutrients, pathogens and contaminants on the landscape and out of ground water and surface waters. Properties of watersheds such as extent (% cover) of naturally vegetated areas, and impervious surfaces can be used as measures of watershed health. For example, watersheds with 10-15% of their surface area as wetlands exhibited flood peaks that are significantly lower than watersheds with no wetlands (Angus Norman, pers. comm). In a Minnesota study, Detenbeck et al (1993) demonstrated that lake water quality is high where wetlands are found in the surrounding landscape, and the watershed is forested. In an economic context, wetlands, riparian zones and woodlands can act as cost-effective barriers in a multi-barrier approach to source water protection. The water-related benefits of conserving natural areas on the landscape can be in the order of thousands of dollars per hectare per year (Hammer, 1992). These economic benefits accrue to communities on an on-going basis (Norman, 2004b).

The watershed characterization component of the Technical Assessments required under source protection planning would benefit from inclusion of an estimate of the total hectarage or percentage of landscape comprised of naturally vegetated areas (wetlands, riparian zones and forested lands). Over time, this basic characterization should be augmented with more detailed information on the relative hydrologic values of natural areas. Areas that perform a significant hydrologic function within the headwater, recharge and discharge zones of a watershed or sub watershed should be identified for protection.

Extent of Impervious Surfaces: Consider limiting hardened surfaces to a maximum of 10% of watershed area. Detrimental hydraulic and biological changes can occur in streams when 10 – 20 % of a watershed has impervious surfaces (Massachusetts Department of Environmental Protection and Massachusetts Office of Coastal Zone Management (DEP/CZM), 1997). In a watershed-scale study coastal watersheds in North Carolina (Mallin et al 2001), strong correlations were found between average fecal coliform counts and watershed population; percent developed area, and especially with % impervious surface coverage. This study concluded that:

- waterborne microbial pathogen abundance can be minimized in urbanizing coastal areas through reduced use of impervious surfaces and maximal use of natural and constructed wetlands for passive storm water runoff treatment; and

- in animal husbandry areas, retention of natural wetlands and management practices designed to minimize sediment runoff can likely reduce inputs of pathogenic microbes into streams.

Wetland Considerations

Per Cent Cover in Watersheds: Restoration guidelines for degraded areas within the Great Lakes basin (Environment Canada 2004) call for greater than 10% of each major watershed to be wetland cover. Similarly, the Ontario Ministry of Natural Resources (OMNR) suggests that that, in settled landscapes, 5 - 20% of the watershed area should be maintained as wetland area (Norman, 2004b). There is considerable natural variation in the amount of wetland habitat that was present in Ontario prior to European settlement. As a result, the ecological history of a watershed or other planning area needs to be taken into account when developing management guidelines. The pre-settlement characteristics of the landscape can be used to guide wetland protection/restoration goals.

Geographic distribution: Environment Canada guidelines call for greater than 6 % of each sub watershed as wetland habitat. This guideline is intended to complement the10% guideline for wetland cover, by encouraging a broad distribution of wetlands throughout watersheds.

Wetlands in headwater areas often contribute to recharge of ground water supplies. In particular, protection of isolated and palustrine headwater wetlands, which constitute focused recharge areas, can help ensure maintenance of ground water supplies.

In addition, headwater wetlands have the greatest impact on water quality. Protection of riparian zones and palustrine wetlands, where most of the water flow comes into contact with vegetation, are especially important in relation to water quality (Whigham et al. 1988).

In an ecological context, wetland protection in headwater areas helps maintain functions of coldwater streams. For example, swamps are commonly found in areas of ground water discharge, where they help protect water quality, and reduce warming of streams at their source. Many cold-water streams, and most brook trout streams, originate in swamps.

Riparian Areas: Environment Canada guidelines call for seventy-five percent of first and third order streams to be naturally vegetated with native plant species. This recommendation may be most relevant in headwater areas where permeable soils are present. Federal guidelines (Environment Canada 2004) for naturally vegetated areas call for a minimum width of 30 m on lands immediately adjacent to both sides of streams, recognizing that site-specific requirements can vary.

Ephemeral pools: The collective contribution of these areas to ground water recharge may be significant. Consideration should be given to investigating and documenting these contributions, and if relevant, appropriate conservation measures undertaken.

Woodlands: In areas with lower levels of forest coverage, (e.g., as found in many watersheds in southern Ontario), significant increases in runoff and flooding can occur. A forest cover target of 20% may be appropriate (Angus Norman, pers. comm).

<u>Restoration of Hydrologic Functions</u>

In areas where losses of natural areas are severe, habitat restoration is a cost-effective tool for re-establishing marshes, swamps, riparian areas and woodlands. In many cases, published restoration guidelines and training courses are available.

<u>Site-Specific Recommendations</u>

Surface water quality - Intake Protection Zones: existing riverine wetlands and riparian areas should be maintained and, where necessary, extended to minimize contamination of surface waters.

Ground water Quantity: as noted above, protection of isolated and palustrine headwater wetlands in areas of significant recharge will help ensure maintenance of ground water supplies.

<u>Use of Wetlands to Treat Wastewaters</u>

Natural wetlands and constructed wetlands designed to support natural heritage, wildlife and fisheries values should not be used as primary treatment for municipal, agricultural or industrial wastewaters.

Specifically within the Intake Protection Area 2 hour time of travel zone, artificial wetlands and/or buffer strips should be evaluated as a priority activity to reduce the vulnerability of the source water to point-source activities and/or potential discharges including storage of materials that may contain pathogens, application of pathogen-containing materials to tile-drained lands and stormwater discharges to surface water, the former as a component of farm water protection plans.

OMOE and OMNR should develop technical planning and implementation guidelines for the use of constructed wetlands to treat wastewaters for SPP purposes.

OMNR Information Management should ensure that Source Protection Planning (SPP) committees have access to hydrologic data for evaluated wetlands, via the ministry's Natural Resources Values Information System (NRVIS).

In addition, information on the wetland setting in the landscape (site type) and soils/ surficial geology can be used to indicate which unevaluated wetlands may have high hydrologic values.

Assessment of Regulatory/Policy Protection Mechanisms

A number of provincial statutes and policies provide mechanism for conserving wetlands, riparian areas and woodlands (the *Planning Act* and Provincial Policy Statement; *Conservation Authorities Act)*.

A review of the *Conservation Authorities Act*, and the statements of provincial interest in the PPS (Water, and Natural Heritage policies), is needed to ensure efficiency and consistency of approach in relation to the benefits of natural areas for source protection planning.

More specifically in relation to wetlands:

- where provincially significant and other wetland areas are currently managed and/or protected with regard to their hydrologic or ecological integrity this protection should be maintained;

- other wetland areas within watersheds should be evaluated as part of the water budgeting process to evaluate their contributions to the source water and regional aquifers, and where identified as important, be protected.

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Personal Communications

Dave Richards, Long Point Area Biologist, Aylmer District, Ontario Ministry of Natural Resources.

Angus Norman, Southern Region Science and Information Section, Ontario Ministry of Natural Resources.

Glossary

Conservation: Ensuring that loss or degradation of natural ecosystem functions does not occur and that, where ecologically and economically feasible, previously lost or damaged functions are recovered.

Ephemeral pools: small depressions in landscapes which collect surface water in late winter and early spring.

Isolated wetlands: those with no surface outflow.

Palustrine wetlands: those with no or intermittent inflow and either permanent or intermittent outflow.

Riparian areas: the lands adjacent to a river or stream that are influenced to some degree by flooding. These areas have a high water table, due to their proximity to flowing waters.

Riverine wetlands: those influenced by the waters of a river or permanent stream.

Wetlands: lands that are seasonally or permanently covered by shallow water, as well as lands where the water table is close to the surface. In either case the presence of abundant water has caused the formation of hydric soils and favoured the dominance of either hydrophytic plants or water tolerant plants. The four major types of wetlands are swamps, marshes, bogs and fens.

Woodlands: treed areas that provide environmental and economic benefits such as erosion prevention, water retention, and provision of habitat, recreation and the sustainable harvest of woodland products. Woodlands include treed areas, woodlots or forested areas.

Appendix 10. Recommendations made to the Minister of the Environment by TEC on April 26, 2004

Leona Dombrowsky
Minister of the Environment
135 St. Clair Ave. W.,
Toronto, ON
M4V 1P5

Dear Minister Dombrowsky:

On behalf of the Technical Experts Committee, we are pleased to provide you with comments on the White Paper released February 12th, 2003, on Watershed Based Source Protection Planning. The work of our Committee continues specifically on the Source Protection Planning framework, and we look forward to being able to provide you our report in the Fall. Therefore, the Committee has agreed to restrict its comments to the Permit To Take Water (PTTW) components of the White Paper.

The comments that are attached represent the general agreement of the Committee. We trust that these comments are helpful in both lifting the moratorium as well as refining the program longer-term. Some of the concepts as noted may well be suitable for integration into the development of the Source Protection program and ultimate plans. Some detailed materials have been provided to your staff under separate cover in support of the proposal to adopt a quantitative approach modelled after the approach in several other jurisdictions.

The membership of the Committee is grateful and enthusiastic to be engaged and involved in this initiative and appreciate the opportunity to comment at this time on the Permit program.

Yours:

Jim Smith
Assistant Deputy Minister,
Drinking Water Management Division

D. Gayle Wood
Chief Administrative Officer/Secretary-Treasurer
Lake Simcoe Region Conservation Authority

Attachment:
1. Comments from Technical Experts Committee

c: Technical Experts Committee
Joan Andrew, ADM, IEPD
Brian Nixon, Director, Water Policy Branch

Technical Experts Committee:
Comments on the White Paper - Permit To Take Water

Ontario's permit to take water program – overall intent:

In addition to the PTTW program, Ontario needs to have in place a robust, higher level and larger scale program to manage Ontario's overall water resources. The PTTW program that considers individual permit needs must be linked into a larger initiative that oversees the sustainability of Ontario's water resources. Source protection plans are part of this overall framework, but are not an adequate overall framework.

Charges for permit applications

It is suggested the permit fees only cover administrative costs, including maintenance of databases relevant to the permitting process. Examples of such administrative costs that would be built into the fee would include permit processing, technical review/third party dispute resolution, data maintenance and provision, and tracking of withdrawal rates. Fees from permitted takings could be one component of funding for low-water response programs. Funding for permit compliance audits and/or inspections could be an ongoing fee also. The database expenditures that should be funded by the application include provision of available Provincial data to the permit applicant upon request and the assimilation of the permit applicant generated information into a central data-repository, as well as the maintenance of the water usage/records.

Charging for water

It wasn't felt to be appropriate to charge for the water itself, unless those funds were allocated to protecting the water through the source protection planning process and committee; this latter consideration was felt to be outside the scope of the PTTW specifically. It was noted that should charges for direct takings get too high, large users may convert to municipal (lower cost) supplies and as such if the government wishes to consider water pricing, it was recommended that the price for private withdrawals should not exceed municipal water rates.

While it is recommended that water charges per se not be considered, a disincentive for "damaging" uses could be considered, such as the use of large quantities of water in such a way that it is returned to the system in a degraded fashion. An example of this could be deep-ground water high in salinity that is discharged to a stream, or applications leading to high evaporative losses when more efficient applications are possible.

Science in support of application

The permit application, review and approval process should include a "science assessment" so as to increase the level of confidence that the taking is a sustainable use. In this regard where the Ministry does not have adequate data already to review the application, the PTTW application process should generate sufficient information on the resource to facilitate review and approval. Such information will also be useful to other programs, such as the Source Protection Committees.

Current applications for municipal water takings are required to conduct major studies in support of their permits, and a similar level of study/assessment should be required for all large or potential water takings.

In support of a science-based approach and in recognition that substantial quantities of data may already exist that is relevant to a permit application it is strongly suggested that the government provide regional aquifer and/or surface water data to the applicant upon receipt of an "enquiry" for a Permit. In addition to providing this data to the applicant, the Province should ensure a regional context is available, particularly to aid applicants without the resources to generate and provide a regional assessment themselves. The Province cannot however undertake this without a program to update the Provincial well records database, and also to link the information on private wells to the Provincial ground water monitoring network.

If a PTTW is proposed for a wellhead protection zone, given it may impact upon the risk management strategies already determined for the wellhead zone, the application process should consider/address the presence of the zone and the potential implications for the withdrawal upon that zone. In recognition that large takings adjacent to a wellhead zone could alter flows and hence definition of the wellhead, the Province should establish some clear rules around "proximity".

Deciding whether to provide a permit

The overall goal for the review of permits should be a timely and efficient processing, which streamlines application review for simple submissions without potential for impacts, and ensures science-based reviews for more complex or larger submissions. Consideration to a third-party review process, such as through a requirement for an accredited (eg. P. Eng. or Geoscientist) individual to sign off on the application, may be an approach to providing for timely review without hiring additional government staff, though this may be a requirement also.

The issuance of permits needs to consider the "management" of the water being withdrawn as well as water allocation, conservation and also ecological needs.

Consideration should not be limited solely to quantity or sector of but to the impact of the taking.

It is important to document the real impacts of providing permitted takings (some may be ecologically beneficial) and so to ensure takings are not automatically construed in a negative manner. For example spring storage that can maintain low-water flows in the summer may be beneficial for low-flow maintenance, and the overall impact may be positive, provided the reduction in peak flows are not deleterious to some components of the ecosystem. The application process should consider the overall impacts.

It would be useful to document the “efficiency” of water use among applicants/permit holders, so as to develop “best practices” and to promote efficiency. For example sharing information on the ability of “leaders” to produce products (crops, golf courses, turf) with the most efficient use of water/unit of product would serve to identify the leaders in the field and promote water use efficiency and could be a component of educational programs. Under some circumstances a permit holder could be required to comply with such best practices as a condition of their permit.

The decision to provide a permit should consider the “consumption” or “water loss” rather than the actual volume of the taking. As such information on the fate of the water and hence the “impact” of the taking, rather than simply the event of the taking, needs to be considered, consistent with ensuring that a loss in water quality as well as quantity is considered an impact. Those requests that simply preserve water (storage) or alter flows (hydroelectric) could have less stringent conditions those that degrade or remove water and perhaps should be referred to as “permits for diversion/holding”.

In reviewing whether to grant a permit, a standardized approval process must assess the cumulative impacts of multiple takings from the same aquifer or waterbody; a risk-based process that includes quality, quantity, impacts and fate seems necessary.

The movement of large amounts of water within a watershed should be considered distinctly from exports and/or consumption. For example the movement of deep ground water to the surface water might be considered a trigger for a science assessment, but does not have the same implications as exporting the water to a different watershed or losing it from the cycle entirely.

<u>Other parties standing in the review and approval of permits:</u>

If a PTTW is proposed for a wellhead protection zone, given it may impact upon the risk management strategies already determined for the wellhead zone, the permit application should be reviewed by the SPPC or municipality. The objective of this review must be to understand the implications for the wellhead protection area and for those who will be required to manage activities within this area.

Length of permits

The default condition should be to make the length of the permits consistent with the anticipated impact and also the volume. New, large takings or large takings where uncertainty exists should receive an annual permit with seasonal considerations. The length of the permits could also be set as preliminary with a built in assessment at a specific time, when the permit could be finalized/updated. Permits having no implications could be extended while those impacting the resource can be amended/updated.

Trial periods before issuance of a full permit could also be considered, contingent upon monitoring information being collected. "Stepped permits" that allow incrementally more takings provided monitoring shows no issues or concerns could also be considered.

Conditions for permit

All permits that are issued should be conditional, with the inclusion of appropriate triggers. One example is to build into all permits a low-water response condition, such that when contacted by the government the permit holder would be required to abide by the condition upon receipt of notification. This would eliminate the current requirement for a "cease and desist" order to be prepared and issued, and could replace the current voluntary level 2 response (20% reduction) with a mandatory condition.

Classify permits and takings by season as well as total takings – more attention and conditions should be placed on takings during low-water periods for surface water permits or for zones adjacent to ground water discharge to sensitive streams than to those occurring during other periods of time.

A requirement for water quality testing (of the water as taken) should be considered in permits, such as testing for bacteria/pathogens, nitrates, salt and other common contaminants, in particular for those that may degrade water quality. This data would be useful in order to establish firstly if that water is safe to use, and secondly as a benchmark for assessing degradation. This data will also be essential if the Province wishes to maintain a comprehensive inventory of water quality, as private takings can fill in the gaps in Provincial monitoring. Where the quality of the discharged water cannot be assessed through a Certificate of Approval, the Permit may be a vehicle to obtain such information also. A Provincial data-base will obviously be essential for the maintenance and provision of this data.

Of special note is the requirement that operators who withdraw water are clearly informed of their obligations. An example would be where the Province requests bacterial and nitrate monitoring in a ground water well in order to address a data-gap; a finding of either bacteria or nitrate has health implications that the operator must be aware of, and be able to address. Discussions with the Ministry of Health and Long-Term Care regarding the implications for Medical Officers of Health may be required to assess the implications of collecting data such as is being suggested.

Auditing/compliance assurance would of course be required for any conditions, and could be funded as noted above through an appropriate fee.

Consideration should be given to mandatory reporting on actual water takings (even if estimated from pumping hours) so that water budgeting and consideration of additional or new permits can be undertaken with accurate information on current withdrawals. Another piece of information required to evaluate the long-term sustainability of ground water is the depth to the water table, which should be tracked over time to determine if the well is having an impact, and also to provide information relevant to the approval of other wells taking from the same aquifer.

Scope for permitting process:

It is recommended that no automatic exemptions be provided such as the current exemptions for agriculture (that may include large livestock operations) and domestic takings. However use of a graduated application and approval process can limit the paperwork/data considerations for smaller/low-impact takings whilst ensuring information on withdrawals is available for all such activities.

Technical basis for permit approval

Ontario should seriously consider following the leadership demonstrated by Alberta, Saskatchewan and New Brunswick in taking a quantitative approach to water allocation and permitting. The specific technical basis for the permit should be to restrict ground water permits to the Q20 and the R20. The Q20 is an estimate of amount that can be withdrawn for 20 years without changing aquifer head. The R20 is an estimate of the capture zone, and the permit application should have regard for land-use within the R20 zone so that the person(s) withdrawing the water understand and appreciate the land-use that might impinge upon their water taking.

The current analysis to determine if a permit may impact stream-flow or recharge must be continued.

<u>Current permits:</u>

Review current permits – do not allow grandfathering. Any existing permits should be re-issued based upon an evaluation synchronized with the provision of water budgets such as through the Source Protection Planning process or otherwise.

<u>Application process:</u>

It is suggested that a “scaled” permitting process be adopted so that small, simple takings (domestic) can be permitted simply, with the larger takings or those with potential negative implications required to submit more detailed applications.

Consider providing for different application processes for various types of applications – the example given was that an impoundment should not have the same type of application process as a bottler exporting water from the watershed or irrigation (with evaporation losses).

<u>Allocation:</u>

Where the amount of water is limited, either in total or seasonally, water allocation, in which the holder of a permit clearly understands how they must change their water use in the event of a shortage, should be practiced/considered. It was felt that the rule of prior acquisition as used in the Prairies wasn’t appropriate for Ontario, but it is recommended that Ministry of the Environment clearly establish through the permitting process a hierarchy of allocation as appropriate.

Appendix 11: Private Services

Private Services Sub-committee Members

TEC members:
Dr. Doug Joy, University of Guelph

Staff members:
Victor Castro, MOE
Mesmure Haile-Meskale, MOE
Brian Kaye, MOE
Tina Schankula, OFA

Drinking Water Source Protection: Protection of Private Services

Executive Summary

Development on Private Services involves the construction and use of individual, privately owned wells and septic systems. While some developments may also rely on partial services (eg, septic system and communal piped water), the best management recommendations presented here apply whether the development services are partially private or fully private.

While not nearly as common as development on water wells, developments on private individual surface water supplies also exist. For the most part, such developments tend to be seasonal residential in nature. The protection of these supplies depends not so much on the design of the intake (as with wells) but more so on the broader land use patterns and activities surrounding the surface water feature. The primary recommendation in the context of a private surface water supply is aimed at protecting the user through water treatment, as well as repeating the broader surface water source protection recommendations.

Although the scope of the problem is unclear, improperly constructed, maintained and/or decommissioned (abandoned) wells and septic systems pose a potentially significant risk to Ontario's groundwater and surface water resources and to the millions of Ontarians who rely on those resources for clean drinking water.

With regard to water wells, mandatory inspection programs for new well construction and existing wells are recommended for the purposes of protecting both the drinking water source and the health and safety of the water consumer. Programs are also recommended that will identify derelict or improperly abandoned wells as well as promoting the proper decommissioning (abandoning) of these wells. In addition, an inspection program specifically dealing with test wells, especially those located at contaminated sites, should also be considered.

With regard to private septic disposal systems a series of discussion items have been developed that also place an emphasis on inspection and maintenance. Small on-site septic systems are regulated through the Ontario Building Code (OBC), while larger systems are regulated by the Ministry of the Environment under the *Ontario Water Resources Act*.

As the Province moves forward with the implementation of Source Protection Plans, the Province should be addressing the broader planning issue of privately serviced development. The discussion items presented here are aimed primarily at the use and maintenance of individual systems with the intent of minimizing risk at the local scale. Additional time will be required for the Province to strengthen and fully develop broader planning policies (such as the establishment of minimum lot sizes and densities and stronger policies directing residential development into serviced areas), in support of Source Protection Planning.

DISCUSSION ITEMS

Private Water Wells

1. **A mandatory well inspection program be developed and implemented, ensuring compliance with water well regulations.**

2. **A mandatory inspection program be developed and implemented involving regular (eg. every three to five years) inspections and water quality monitoring of existing water wells.**

3. **Greater efforts at informing the public with regard to the risks associated with derelict wells and the regulatory requirement to decommission such wells be undertaken.**

4. **An abandoned well identification program be developed and implemented.**

5. **An incentive program be developed and implemented which aids the owners of derelict wells with the process and/or costs of properly decommissioning wells.**

6. **A well owner guide be developed that provides the well owner with clear information on maintaining or decommissioning their own well(s) at a reasonable cost. In addition, manuals for well construction, maintenance, and disinfection procedures should be developed.**

7. **A test well inspection program be developed and implemented.**

8. **Priorities for well inspection programs should be established, with initial phases to start with wellhead protection areas and other vulnerable areas.**

<u>Private Septic Systems</u>

1. **Clear authority for local re-inspection programs, targeted at small on-site septic systems, should be established through amendments to the *Building Code Act, 1992.* Such programs would be administered by enforcement bodies that currently have responsibility for septic enforcement under the Act, including municipalities, health units and conservation authorities.**

2. **The Province should establish standards for septics re-inspection through the OBC. There would be provision for enforcement bodies to allow mitigating measures where existing systems cannot meet the standards.**

3. **Priorities for septics re-inspection programs should be established locally. Such a program could be phased to start with older septic systems, systems with no permits on record, areas with a history of failed septics, and areas of high vulnerability. Source protection plans could provide direction in this regard. Several municipalities across the province have already developed septic inspection programs, including pump-outs, and these should be evaluated as potential working models.**

4. **Local septics re-inspections could enforce existing requirements for septic tank pump-out, and could also require pump-outs as a mitigation measure where septics re-inspection standards cannot be met.**

5. **Amendments to the OBC should be evaluated that would require a sampling devise to collect effluent below tile drains in all new Class 4 sewage systems for monitoring of septic performance at time of inspection. Operational parameters shall be established to provide guidance on treatment efficacy and performance standards.**

6. **With the phase-out of the land application of untreated septage, the MOE needs to finalize a waste management policy and implement an action plan to address treatment and disposal options for septage.**

7. **In conjunction with septic re-inspection programs (see Discussion Items 1-3), public education programs, aimed at implementing best management practices, should be formalized and delivered by provincial and/or local authorities.**

8. **The OBC should require the use of tertiary systems capable of treating the specific parameter(s) of concern (eg. nitrates, pathogens, phosphorus) in areas of high vulnerability and areas with known septic impacts.**

9. **Amendments to the OBC should be considered that would expand the scope of septics regulation and to set requirements related to nitrates and phosphorus, and determine the areas of application for such requirements. Further scientific work would be required to determine appropriate performance measures in this area.**

10. **The OBC should be reviewed to ensure that septic system design standards are consistent with Source Water Protection goals and current scientific understanding of environmental impacts. Changes to the OBC should be subject to stakeholder consultations and technical review to ensure efficacy, technical/economic feasibility and enforceability.**

11. **Lot sizing and densities for all new private services development should be based on hydrogeologic vulnerability of the area and proposed treatment technology. Other factors such as proximity between septic beds and domestic wells, and alignment of wells in the flow path of septic beds should also be considered.**

Private Surface Water Intakes

1. **That all private individual surface water supplies used for human consumption be treated for pathogens where the level of treatment is based on results of the source water risk assessment.**

Land Use Planning

1. **By 2008, the Province develop and implement private services development policies and guidelines that define best practices and designs that minimize threats to sources of drinking water.**

Drinking Water Source Protection: Protection of Private Services

Part A - A Well Management Program for Ontario

Introduction

Water wells in Ontario are regulated through Ontario Regulation 903 made under the *Ontario Water Resources Act* (OWRA), administered by the Ministry of the Environment. This regulation defines the construction methods, decommissioning methods and material standards used by the well construction industry. Improperly constructed wells, poorly maintained wells and abandoned (derelict) wells, pose a significant risk to public health and safety and to the protection of groundwater resources. Clearly defined construction standards, designed to ensure that wells do not represent a threat to the quality of groundwater, are essential to the protection of our drinking water sources.

The intent of Regulation 903 is to ensure that wells are constructed, maintained and decommissioned (abandoned) in such a way as to protect our groundwater resources against contaminants that might gain access to aquifers through poorly constructed or abandoned wells.

Current Situation

Under the OWRA, individuals and companies engaged in the business of constructing, repairing and decommissioning wells in Ontario, are required to be licensed. Regulation 903 sets out the educational and experience requirements for licensure. Well contractors and technicians are required to understand the standards imposed by Regulation 903 and are obligated to follow those standards.

The same strict minimum construction and material standards defined by the Regulation that apply to municipal water supply wells also apply to individual private water supply wells. In addition, the Regulation sets out design and construction standards for the groundwater consulting industry. Test wells, geotechnical boreholes, aquifer dewatering wells and other excavations used to acquire information regarding the state of aquifers and groundwater, must all comply with the requirements set out in Regulation 903.

Coupling the requirements of Regulation 903 with the provisions of the OWRA and its other regulations, the *Environmental Protection Act* (EPA) and its regulations, the *Environmental Assessment Act* (EAA) and other existing environmental legislation and policies, provide a framework that already ensures a high degree of protection for our groundwater resources. While the EPA, the EAA and other legislative tools deal with the sources of contamination, the role of Regulation 903 is to deal with one of the potential pathways between those sources and the groundwater resources.

What is the Risk?

New Wells

Thousands of new water wells are drilled every year in Ontario. These wells are drilled to supply drinking water for individual private, communal and public supplies. In addition, wells are drilled in support of hydrogeological, geotechnical and environmental investigations. Currently, there is no provincial permitting program associated with the drilling of new wells and as such no advance notice to any regulatory authority regarding the well's locations or intended use.

The *Ontario Water Resources Act* sets the framework for a permit system, but only in areas designated under the regulations. Currently, no areas in Ontario have been designated under regulation.

While the OWRA requires well contractors to be licensed and Regulation 903 sets the construction and material standards, a proactive inspection program is not universally in place across the province. Inspections conducted by the Ministry of the Environment do take place, but generally in response to complaints registered by the public. While well contractors have regard for the regulations and understand the importance of proper well construction, oversights (whether intentional or accidental) can be expected to occur.

An improperly constructed well located too close to a source of contamination can represent a real and significant risk to the local groundwater resource. More often however, an improperly constructed well will cause problems for the well owner rather than the aquifer. Because pumped wells induce groundwater flow towards the well, contaminants gaining access to the well's intake zone (through the annular space for instance) are often captured by the well and do not migrate very far into the aquifer.

In terms of the protection of sources of groundwater for drinking, be it the protection of the aquifer or the well itself, there is no alternative to proper well construction.

Existing Wells

There are literally millions of existing wells in use across Ontario. Ranging from large scale municipal production wells regulated through Certificates of Approval and Permits To Take Water, to individual private supply wells, from large scale aquifer dewatering wells to small diameter piezometers, each well represents a potential contaminant migration pathway. As with all infrastructure, wells are subject to the deteriorating effects of age and use. Contrary to popular belief, wells have a finite lifespan and must be properly maintained for that lifespan.

Regulation 903 contains one, and only one, simple requirement that all well owners must follow: they must maintain their well. Specifically, under section 20(3) of Regulation 903, well owners are required to "*maintain the well at all* *times after the completion date in a manner sufficient to prevent the entry into the well of surface water or other foreign materials*". While seemingly simple, this one requirement, if adhered to, will prevent the vast majority of groundwater contamination problems related to wells and their physical condition.

One significant impediment to the proper maintenance of wells is the desire of many well owners (and the result of certain well construction methods) to have the wellhead buried. It is not uncommon for a well owner to have little or no idea of where the well is actually located. Under such circumstances, routine visual inspection is impractical and regular maintenance is not undertaken. Rather than avoiding problems, problems are identified after the fact.

If wells are not maintained in the minimum manner required by the regulation and foreign materials are allowed access to the well, well contamination and possible aquifer contamination are potential results.

In addition to ensuring that proper methods and materials are used at the time a well is constructed, there is no substitute for ensuring that all wells are properly maintained at all times.

Abandoned (Derelict) Wells

The term *Abandoned Well* generally refers to a water supply or monitoring well that is no longer being used, is not being properly maintained for future use and one that has not been properly decommissioned. In Ontario and elsewhere, the term "abandoning" a well is often used synonymously with the term "decommissioning" a well. Within this document, "decommissioning" is the act of physically plugging and sealing an unused well while the term "abandoned" refers to a derelict well. Depending on their condition, abandoned wells have the potential to pose significant safety and environmental risks. In some parts of the province, abandoned oil and gas wells pose similar risks while the same can also be said for geotechnical and exploratory drill holes.

Within the context of Source Water Protection, the risk posed by abandoned wells is to the quality of our groundwater resources. When infiltrating water pass through the surficial layers of earth and rock on route to the water table, physical (e.g. filtration), chemical (e.g. oxidation) and biological (e.g. microbial metabolism) processes take place which help to remove unwanted organisms and contaminants from the water. An abandoned well bypasses this natural purification process by creating a direct and quick pathway between the ground's surface and the aquifer at depth. The presence of abandoned wells places the quality of groundwater, the drinking water source for millions of Ontarians, at risk.

There is no question that responsible environmental practices at the ground surface (waste management, nutrient management, integrated pest management and so on) reduce the likelihood of environmental impairment. Unfortunately, a single accident at the site of an abandoned well can undo the benefits of even the most precautionary environmental protection efforts. There is no substitute for the proper decommissioning of abandoned wells.

Even though the legal requirement exists to decommission abandoned or unused wells, such wells dot the countryside. There is no way of knowing exactly how many abandoned wells exist in Ontario but estimates place the number in the thousands. In many cases, while the well owner is aware of the presence of an abandoned well there is a lack of appreciation for the actual risk such wells pose to groundwater resources. In some cases, even where the well owner is aware of the legal obligation to decommission the well, the decommissioning cost is a significant deterrent. The end result is a well left in a state of disrepair, presenting both safety and environmental risks.

While abandoned wells in Ontario represent a significant threat to sources of drinking water, it is a threat that can be easily reduced through effective educational and incentive programs.

The actual risk to Source Water Protection posed by abandoned wells is difficult, if not impossible, to quantify. A single abandoned (or improperly maintained) well located in the wrong place at the wrong time relative to a spill of contaminants can lead to the irreversible contamination of an entire aquifer.

In many cases, the presence of the abandoned well, or the risk it represents, is not known until after a problem related to groundwater contamination has been identified.

The risk itself is a function of many things. An abandoned well in of itself may pose more of a safety risk than a contamination risk if no contaminants are present at or near the well head. However, the precautionary principle requires that the potential risk, rather than the probable risk, dictate how we deal with this threat.

In terms of priority, those abandoned wells located within a Well Head Protection Area (WHPA) pose the greatest risk and should be dealt with as the highest priority. Since all wells can potentially render an aquifer unusable, those wells located in areas not deemed vulnerable should be also dealt with as a potential risk.

Other Excavations

There are numerous other types of excavations that, like abandoned wells, can represent a risk to groundwater resources by providing a direct conduit between the surface and the aquifer. Included here are pits and quarries, foundation excavations, geotechnical boreholes not covered by the OWRA or Regulation 903, and any other excavation that encounters the water table or penetrates a protective layer.

While some of these excavations are dealt with in other legislation (*Aggregate Resources Act* for instance) many are not regulated in any form.

Past Efforts at Encouraging Well Management
From September 2001 through January 2004, the Ontario Federation of Agriculture (OFA) administered two water well projects: The Rural Well Decommissioning Project and the Rural Water Well Upgrades Project. These projects were funded through the Ministry of Agriculture and Food's Healthy Futures Program.

The funding formula provided well owners with the opportunity to receive funds offsetting the cost of upgrading a well by 67%. The cost of decommissioning a well could be offset by 64%. In both cases, there was no upper limit to the available funding per well.

During the life of the decommissioning program, 1,100 wells were decommissioned at an average actual total cost of $1,796. Despite the available funding and the regulatory requirement to decommission unused and un-maintained wells, participation was less than hoped. The average out of pocket expense of roughly $650 was enough to discourage participation. Clearly, in the absence of any funding, the regulatory requirement and the risk posed by these wells, will not be enough to encourage their owners to properly decommission them.

The Rural Water Well Upgrades Project was considerably more popular with 2635 wells upgraded at an average total cost of $1823 (remarkably close to cost of decommissioning a well). Funding for the project was exhausted prior to the completion of the project.

<u>Discussions Items</u>

A) <u>New Water Wells Inspection Program</u>
While the construction, maintenance and decommissioning of wells in Ontario is regulated, the regulation is not strongly enforced. Due to the significant number of new wells that are drilled each year, the inspection of all new wells would require significant resources, both fiscal and human. The Ministry of the Environment inspects new wells primarily on a complaint response basis. While wells associated with municipal drinking water systems and those associated with Permits to Take Water, may be inspected either regularly or intermittently on a proactive basis, there is no inspection program focusing on individual private wells.

In recognition of the potential risk associated with improperly constructed, poorly maintained, abandoned and improperly decommissioned wells, a comprehensive well inspection and outreach program is considered to be necessary.

An inspection program dealing with new private wells, is best delivered at the local level in a manner similar to the delivery of the septic system program. Consideration could be given to revising the Ontario Building Code to include provisions related to the construction methods and material standards related to private wells. The specific separation distance requirements between wells and septic systems, already defined by the Building Code, should be amended to establish *mandatory* minimums. Any provincial funding programs could be augmented through Municipalities Permit fees.

Discussion Item #1
A mandatory well inspection program be developed and implemented, ensuring compliance with current water well construction regulations.

B) Existing Well Inspection Program
Current regulations require that all well owners maintain their wells in such a manner as to prevent surface water or other foreign material from gaining access to the well. While the regulatory requirement exists, there is little in the way of provincial oversight to ensure that well owners actually implement a suitable inspection and maintenance program. In the absence of any oversight, there is a significant likelihood that wells will not be properly maintained. Improper maintenance increases the likelihood of water quality problems. Water quality monitoring would greatly help identify any maintenance issues.

Improperly maintained wells that remain in use, tend to be more of threat to the health and well being of the well owner than the groundwater resource. Ongoing pumping of the well, maintains groundwater flow towards the well thus preventing, or at least limiting, migration of contaminants away from the well. Perhaps this alone is the greatest incentive for well owners to maintain their wells in good working order. Well owners need to understand this however, placing importance on public education and outreach by the government.

Discussion Item #2
A mandatory inspection program be developed and implemented involving regular (eg. every three to five years) inspections and water quality monitoring of existing water wells.

C) Abandoned Well Inspection Program
An attempt needs to be made to determine the number and location of improperly decommissioned wells. While the current regulations require the proper decommissioning of abandoned wells, compliance is low due to the cost. Funding and educational programs as well as other incentives need to be established to encourage the decommissioning of existing abandoned wells.

Current regulations are complex and highly prescriptive, making it difficult for the owners of derelict wells to undertake low cost decommissioning projects as an alternative to hiring a licensed well contractor. Compounding this, as identified by the OFA decommissioning project, is a lack of licensed well contractors willing to take on decommissioning work.

Discussion Item #3
Greater efforts at informing the public with regard to the risks associated with derelict wells and the regulatory requirement to decommission such wells be undertaken.

Discussion Item #4
An abandoned well identification program be developed and implemented.

Discussion Item #5
An incentive program be developed and implemented which aids the owners of derelict wells with the process and/or costs of properly decommissioning wells.

Discussion Item #6
A well owner guide be developed that provides the well owner with clear information on maintaining or decommissioning their own well(s) at a reasonable cost. In addition, manuals for well construction, maintenance, and disinfection procedures should be developed.

D) Test Well Inspection Program

Inspection of test wells and monitoring wells associated with contaminated sites, brownfields, waste disposal sites, industrial facilities and other installations not intended to provide a private water supply, should be undertaken by the provincial government. While the proper abandonment of such wells is required under the regulation, there is no oversight to ensure that monitoring wells, exploratory wells, dewatering wells and other such installations are being properly maintained and decommissioned. The presence of such wells at landfill sites and other contaminated sites may pose a significant risk to groundwater resources.

Discussion Item #7
A test well inspection program be developed and implemented.

E) Program Priorities

Discussion Item #8
Priorities for well inspection programs should be established, with initial phases to start with wellhead protection areas and other vulnerable areas.

Drinking Source Water Protection: Protection of Private Services

Part B - Individual Subsurface Sewage Disposal Systems

Introduction
Individual wells and private septic systems (private services) are the primary method of servicing small communities and rural areas in the Province of Ontario.

This discussion paper will focus mainly on the issues around development serviced by private septic systems, particularly with respect to the current regulatory framework, scientific understanding of impacts to the natural environment, and potential risk management approaches to source water protection. A separate discussion paper has been prepared for individual wells.

With proper installation, care and maintenance, a septic tank and leaching bed system can provide many years of reliable service. However, there are numerous examples across the province where septic systems have contaminated neighbouring wells, impacted nearby streams and lakes, and rendered local aquifers unusable. Historic development patterns, usually characterized by clustered high-dense areas on small lots is a common factor associated with well-water complaints, degradation of shallow groundwater systems and impacts to surface water bodies. In addition, large areas of the province are vulnerable to aquifer contamination due to shallow or non-existent soil cover exposing fractured bedrock at or near surface. Other areas are vulnerable because of the coarse nature of the surface and subsurface soil deposits.

Poorly operating septic systems that do not provide adequate treatment of domestic or commercial wastewater can go undetected for years and result in contamination of local aquifers and streams. Often, it is only when a system fails completely by breaking-out at surface or backing-up into a house will remedial measures be undertaken. This is further compounded by the lack of any mandatory requirement for regular inspections, routine pump-out or periodic replacement.

Over the last 20 years, the province has spent tens of millions of dollars providing alternate sources of drinking water to replace contaminated groundwater wells servicing rural areas and small communities. Normally this is accomplished by piping water from a nearby urban centre or in some cases constructing a stand-alone centralized water treatment plant. Ironically, while the provision of a single-service, most often piped water to replace contaminated drinking water wells, can address the immediate public health concern, often the environmental impact related to contamination of the groundwater system or adjacent surface water body is worsened because of higher water loading rates and inadequate sewage treatment.

Current Regulatory Framework

The Ontario Building Code (OBC) sets out minimum design, construction, maintenance and operation requirements for small on-site subsurface sewage disposal systems, commonly referred to a septic tank systems. These systems have a design capacity of 10,000 litres per day or less and the Code requires that each system must be located on the same lot or parcel as the building(s) served by the system. Part 8 of the OBC sets out these requirements, and includes provisions related to separation distances between septic systems (and their components) and other features such as water bodies, structures, property lines or wells.

Specifically with respect to surface waters, the OBC requires that septic systems be located a minimum of 15 metres from water bodies such as lakes, rivers or streams. Section 8.2.1.4, Ontario Regulation 403/97 states:

> "1. Unless it can be shown to be unnecessary, where the percolation time is 10 minutes or greater, the location of all components within a sewage system shall be in conformance with the clearances listed in Tables 8.2.1.5 or 8.2.1.6."

The above section implies that a lower standard can be used, however, in practice for surface water features most Health Units and Building Officials apply the 15 metres as an absolute minimum setback for all new building lots. In situations where a replacement system is needed on an existing lot of record and the size of the lot precludes meeting the minimum 15 metre distance, the standard operating policy of most agencies issuing these Permits is to require a holding tank. No situations or examples could be found of where the above section has actually been applied to reduce the setback from a surface water feature."

Subsection 2 goes on to state:

> "2. Unless it can be shown to be unnecessary, where the percolation time is less than 10 minutes, the clearances listed in Tables 8.2.1.5 and 8.2.1.6 for wells, lakes, ponds, reservoirs, rivers, springs or streams shall be increased to compensate for the lower percolation time."

This subsection is designed to provide for increased separation distances to compensate for the more porous soil conditions. This is of greater importance when applied to the shoreline properties of sensitive lakes, where it is desired to prevent phosphates from entering the lakes.

Under the Planning Act, official plans can set out policies and zoning by-laws may prescribe increased setback distances for structures (including septic system) from lakes, rivers, *etc*. Since the Building Code Act (BCA) and the OBC supercede all municipal by-laws respecting the construction or demolition or buildings, municipalities may not, by means of a by-law, impose standards that are intended to regulate the construction of buildings, including septic systems. If the purpose of the by-law is to achieve a planning policy respecting land use planning matters covered by the Planning Act, but which may have a coincidental effect on construction options available under the OBC, then it will not be superceded by the OBC. It is important to have this purpose set out in the associated official plan policies.

There are several land use planning and Source Water Protection objectives which may be served by increasing building or septic system setbacks from surface waters. These might include:

-preventing destruction of vegetation along the shoreline;

-preventing destruction or disturbance of shoreline and beach habitat that may result from construction near the shore; and

-prohibiting, or requiring further setback of development with septic system services in some areas because of the risk of phosphorus, nitrate, pathogen loadings to sensitive surface waters.

With respect to this last planning objective, the underlying source water protection principle is the greater the distance between the leaching bed and the shore (also applies to wells), the greater the capacity of the intervening land base to address (the processes are physical, chemical, biological) contaminants of concern, and in so doing reduce the overall risk of contamination.

Current Scientific Understanding

The quality and quantity of domestic sewage discharging to a leaching bed from a typical residential dwelling is well documented and understood. The characteristics of typical wastewater are:

Parameter	Concentration (mg/L)
Suspended Solids	75 to 150
BOD_5	100 to 150
COD	300 to 450
Total Nitrogen	35 to 50
Ammonia-N	6 to 18
Nitrites and Nitrates	<1
Total Phosphorus	8 to 13
Total Coliforms	10^{10} to 10^{12} orgs/100 ml
Fecal Coliforms	10^{8} to 10^{10} org/100 ml

Source: Manual of Policy, Procedures and Guidelines for Onsite Sewage Systems, MOE, 1982.

The primary concern from a source water and ecological standpoint is the presence in sewage of disease causing bacteria, oxygen demanding compounds, and nutrients in the form of nitrogen and phosphates.

It is difficult to predict exactly when and if a septic system is going to become an active source of bacteriological contamination to a groundwater aquifer or to a surface water source. A properly functioning and maintained septic system can provide on the order of 4 log removal of Fecal Coliform via filtration/polishing through 600 mm of unsaturated sandy soil (reference excerpt from Canadian Institute of Public Health Inspectors, A Continuing Workshop On-Site Sewage Treatment, Richard J. Otis, P.E. et al., Design of Large Subsurface Wastewater Infiltration Systems). Also of note is the typical 3 to 4 log removal of Fecal Coliform at 300 mm below the bottom of a conventional leaching field trench (Wastewater Engineering Treatment and Reuse, 1991, Metcalfe and Eddy).

On the other hand, bacterial contamination from poorly operating septic systems can adversely impact local groundwater resources. Bacteria can survive for weeks in the subsurface and travel long distances through preferential pathways such as macro-pore zones in the subsoil, root networks, fractured bedrock, and via improperly cased or abandoned wells.

The breakdown, by microorganisms, of organic materials and compounds found in domestic sewage can place a high oxygen demand on soils. The re-aeration of soils is an important design consideration to prevent anaerobic conditions and extend the life of a septic system. The migration of sewage effluent with high levels of BOD_5 can adversely impair surface waters, where aquatic biota depend on well-oxygenated water to survive. Oxygen in the subsoil below leaching beds has been shown by numerous studies to be a critical factor impacting system performance (Otis, 1985). Without oxygen, oxidation of organic materials is incomplete, leading to soil clogging and hydraulic failure. Maintaining a well-oxygenated unsaturated zone is a key consideration in sewage system design. The OBC requires a minimum of 0.9 metres between the bottom of the distribution pipe and the high water table, impervious soils, or rock.

Domestic sewage contains high levels of ammonia-Nitrogen which in the un-ionized form can be highly toxic to fish and other aquatic organisms. In a proper functioning septic system the process of nitrification in the aerated zone below a leaching bed will convert most of the ammonia-N to nitrates. Nitrates in the subsurface environment are highly mobile and can migrate large distances. Elevated nitrates in drinking water are a public health concern. The Ontario Drinking Water Objective for nitrate is 10 mg/L.

The degree of attenuation of phosphorus in septic systems has been a topic of considerable debate over the past two decades. This issue is particularly relevant in areas of the province where development pressures adjacent to sensitive surface water bodies are significant (ie. cottage country). Due to the variability of soils/tills within and across watersheds, a large number of tests sites are required to estimate the amount of retention occurring. Migration rates of phosphorus-rich zones in watershed soils are variable, but commonly reported as less than one metre per year (Robertson et. al. 1993; Robertson 2003).

The attenuation of phosphorus is controlled by adsorption and precipitation onto insoluble minerals. Because these processes are controlled by soil type, depth, and chemistry, with retention increasing in acidic soils, considerable heterogeneity in phosphorus attenuation exists within and across watersheds. In general, phosphorus migration velocity in septic effluent is highly attenuated compared to the groundwater velocity of the overall plume. In calcareous sands, migration rates remain sufficiently fast (1 metre/year) to be a concern when considering long-term operation and the normal setback distance of septic systems from adjacent surface water bodies (Robertson et al. 1993). In non-calcareous sands, such as those found on the Canadian Shield, significant long-term retention has been documented at various sites, however, heterogeneity across watersheds is still a concern. The MOE is actively promoting monitoring and research, both directly and indirectly, on this issue to develop a long-term approach that is environmentally sustainable.

Risk Management Approaches

Discussion Item #1
Clear authority for local re-inspection programs, targeted at small on-site septic systems, should be established through amendments to the *Building Code Act, 1992.* Such programs would be administered by enforcement bodies that currently have responsibility for septic enforcement under the Act, including municipalities, health units and conservation authorities.

Discussion Item #2
The Province should establish standards for septics re-inspection through the OBC. There would be provision for enforcement bodies to allow mitigating measures where existing systems cannot meet the standards.

Discussion Item #3
Priorities for septics re-inspection programs should be established locally. Such a program could be phased to start with older septic systems, systems with no permits on record, areas with a history of failed septics, and areas of high vulnerability. Source protection plans could provide direction in this regard. Several municipalities across the province have already developed septic inspection programs, including pump-outs, and these should be evaluated as potential working models.

Rationale for #1 to #3
Historic cottage pollution surveys and septic inspection programs carried out by the Ministry of the Environment in the 1970's and 80's and by other agencies have documented high percentage rates of poorly designed, malfunctioning, and

failing septic systems. The main reasons identified are: age of systems; poor siting, sub-standard design and construction; and lack of routine maintenance. Compared to properly functioning septic systems, these systems are considered a high risk as sources of pollution loadings.

<u>Discussion Item #4</u>
Local septics re-inspections could enforce existing requirements for septic tank pump-out, and could also require pump-outs as a mitigation measure where septics re-inspection standards cannot be met.

<u>Rationale</u>
A new or replacement septic disposal system can cost anywhere from $8,000.00 to $18,000.00 depending on siting and access conditions, availability of well-drained granular soils, and method of wastewater application. At these costs most homeowners are reluctant to upgrade or replace a system until the existing system begins to show signs of complete failure. The lifespan of a properly functioning septic system can be significantly prolonged through routine maintenance, regular pump-out, and simple best-management practices (eg. control of surface drainage, use patterns, water conservation practices).

<u>Discussion Item #5</u>
Amendments to the OBC should be evaluated that would require a sampling devise to collect effluent below tile drains in all new Class 4 sewage systems for monitoring of septic performance at time of inspection. Operational parameters shall be established to provide guidance on treatment efficacy and performance standards.

<u>Rationale</u>
Current inspections of septic systems are based mainly on visual and qualitative assessments of the physical conditions of a septic tank and leaching bed. Although this type on inspection can provide valuable information regarding the existing conditions of the system and potential problems, it does not provide a direct measure of treatment performance. The inspection of a septic system and its performance could be significantly enhanced by the installation of a sampling devise to measure the quality of treated effluent directly below tile drains.

<u>Discussion Item #6</u>
With the phase-out of the land application of untreated septage, the MOE needs to finalize a waste management policy and implement an action plan to address treatment and disposal options for septage.

<u>Rationale</u>
Septage is unprocessed human sewage obtained from septic tanks, holding tanks and cesspools from domestic, commercial, institutional and industries sources. Under current practices, most septage is transported by licensed sewage haulers to approved storage/disposal sites for subsequent land

application. In some cases, septage is taken to a water pollution control plant for treatment. Under a mandatory septic pump-out system, as recommended above, much larger quantities of septage would be generated and require disposal. If the direction of the province is to ban the land application of septage, alternative forms of treatment and disposal are required.

Discussion Item #7
In conjunction with septic re-inspection programs (see Discussion Items 1-3), public education programs, aimed at implementing best management practices, should be formalized and delivered by provincial and/or local authorities.

Rationale
Given the sheer number of privately serviced homes in the province of Ontario, and the fact that most are located on private property, education and best management practices will form key elements of Source Water Protection for these systems. Programs for septic systems should focus on simple but effective means of maintaining and prolonging life-expectancy of sewage system.

Discussion Item #8
The OBC should require the use of tertiary systems capable of treating the specific parameter(s) of concern (eg. nitrates, pathogens, phosphorus) in areas of high vulnerability and areas with known septic impacts.

Discussion Item #9
Amendments to the OBC should be considered that would expand the scope of septics regulation and to set requirements related to nitrates and phosphorus, and determine the areas of application for such requirements. Further scientific work would be required to determine appropriate performance measures in this area.

Discussion Item #10
The OBC should be reviewed to ensure that septic system design standards are consistent with Source Water Protection goals and current scientific understanding of environmental impacts.

Rationale for #8 to #10
The OBC lists a number of aerobic treatment units capable of achieving enhanced treatment. These systems do not replace conventional septic systems but rather enhance and allow for alternative disposal systems. To be considered an alternative treatment system under the OBC, the effluent stream must meet tertiary criteria, defined as:

- BOD_5 15 mg/L
- $CBOD_5$ 10 mg/L
- Suspended Solids 10 mg/L

These proprietary units cost more than conventional systems, however, by providing such a high level of treatment they reduce the risk of impacts to the natural environment. Currently the use of these systems is voluntary. Areas where they should be considered include: where small lot sizes preclude conventional system; groundwater table is high; bedrock in proximity to surface; impermeable soils; high strength wastes; remediation of failed system.

Other parameters of concern to the environment such as nitrates, total phosphorus, and *E. Coli* should also be considered explicitly as design criteria for new technologies.

Discussion Item #11

Lot sizing and densities for all new private services development should be based on hydrogeologic vulnerability of the area and proposed treatment technology. Other factors such as proximity between septic beds and domestic wells, and alignment of wells in the flow path of septic beds should also be considered.

Rationale

To protect the environment and public health, development utilizing individual subsurface sewage systems should only proceed at a density and scale that will not cause degradation of groundwater and surface water resources. Historically, for new subdivision scale development the MOE has relied on a simple impact assessment technique to predict a development's cumulative nitrate impact on the groundwater resource at the down-gradient property boundary (MOE - Technical Guideline for Individual On-Site Sewage Systems: Water Quality Impact Risk Assessment,1996) . These impact assessments were required when the MOE was actively involved in reviewing new subdivision applications. Since the downloading of this technical review function to the local municipal planning departments, the use of the guideline is at the discretion of the municipality. In addition, impact assessments have never been applied at the individual lot consent scale, which is primary method of lot creation in rural Ontario. Further, this type of impact assessment is limited due to its focus on nitrates as the primary contaminant. There may be situations where the aquifer or surface water feature has been impacted by other contaminants such as pathogens or phosphorus.

Minimum lot sizes and densities for all new private services development should be based on hydrogeologic conditions/vulnerability of area and type of technology proposed for use.

Drinking Source Water Protection: Protection of Private Services

Part C - Private Individual Surface Water Intakes

Introduction

Thousands of individual residences across the province rely on private surface water intakes as their primary source of drinking water. These systems are not captured or regulated under the Ontario Water Resources Act or the Safe Drinking Water Act. Nonetheless, many of these systems serve as primary drinking water supplies and should be considered under the Source Water Protection initiatives.

Most of these systems are located in unserviced areas of the province where naturally poor groundwater conditions (quality and/or quantity) or the high cost of installing a groundwater supply (eg. seasonal residences) force residents to surface water sources. In many cases these systems do not provide the primary source of drinking water, but rather serve as a source supply for other household needs. In other cases, however, surface water systems provide the primary source of drinking water.

Unlike homeowners on wells, individual property owners using surface water supplies do not qualify for analytical services (bacteriological tests) provided by local health units, as these systems are not considered groundwater supplies. All surface water bodies are considered open natural systems and are presumed to have ambient levels of pathogens, even under pristine conditions. As such, they are not part of any drinking water surveillance system and are not normally captured by adverse drinking water quality notifications.

Most individual surface water intakes are located beyond the municipal intake protection zone areas in the broader watershed. Under the risk management approach for Source Water Protection, an issues identification process will be the primary method of addressing threats to water quality at this scale. This process along with other recommendations pertaining to septic inspection programs, pump-outs, riparian zones and education will reduce risk to individual surface water intakes.

Discussion Item #1

That all private individual surface water supplies used for human consumption be treated for pathogens where the level of treatment is based on results of the source water risk assessment.

Appendix 12. TEC Sub-committee on Water Quantity

Water Quantity Subcommittee Members

TEC members:
Bob Clay

Staff members:
Cynthia Carr (MOE)
Victor Castro (MOE)
Scott Christilaw (MNR)
Scott Duff (OMAF)
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Frank Kenny (MNR)
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Water Quantity Management for Protection of Drinking Water Sources

Introduction
The Water Quantity Subcommittee has undertaken to develop a practical approach for characterizing the water resources that are or may be the source for drinking water, and for identifying threats and evaluating risks from a quantity perspective.

In making its recommendations, the subcommittee has taken the view that protecting the sustainability of water resources that may be the source for drinking water requires landscape level consideration of the hydrologic cycle and the cumulative impacts of human activities on it. The water cycle or "hydrologic cycle" is dynamic. Precipitation that falls onto the ground surface can either evapotranspirate back to the atmosphere, runoff to surface water bodies (e.g. streams, lakes and wetlands); or move downwards to the saturated zone. In turn, water that moves to the saturated zone can evapotranspirate back to the atmosphere or move in the groundwater system and eventually discharge into a surface water body. How, and in what proportion, these things happen depends on many factors including geology, soil characteristics, land cover, drainage, and where and how humans take water for water supply purposes. As various stresses are imposed on the system, the system will change and ultimately reach a different state of dynamic equilibrium. A water budget is a tool that will allow us to understand how water moves throughout the flow system.

Water Budgets

Water budgets compare all current and forecasted water uses and withdrawals to the amount of water in the watershed. Water resources, uses, and withdrawals are compared to identify where cumulative water withdrawals, current or future, pose a risk to the sustainability of drinking water supplies. Conservation measures that "make water go farther" are encouraged and realistic estimates are taken into account in scenarios of future water use. In addition, water budgets characterize the flow of water and identify key hydrologic processes required to sustain the water resource, including where and how ground water resources are recharged from the surface, how ground water sustains surface water, and the role of physical features such as wetlands and riparian zones along rivers and streams.

Traditionally, water budgets may only have quantified the components of the water balance. The Subcommittee felt strongly that a good understanding of the spatial and temporal dynamics of water movement and storage is also needed to support science-based decision-making and sustainable water management.

A water budget should ultimately include:

- quantification of the components of the water balance equation (precipitation, evapotranspiration, ground water inflow and outflow, surface water outflow, change in storage, water withdrawals and water returns)
- characterization of the flow of water on and beneath the surface, using hydrologic and ground water models
- identification of key hydrologic processes (e.g. major recharge & discharge areas),
- quantification and projection of water uses and needs.

This water budget definition is consistent with the technical guidance being provided for the Oak Ridges Moraine Conservation studies.

Since water budgets that satisfy this definition require large amounts of good information and significant modelling effort, it is practical to carry out water budget studies in phases and focus efforts on those areas with significant water taking and/or shortages.

In Northern Ontario outside Conservation Authority jurisdiction, a simple (preliminary) water budget, such as that carried out in preparation for the lifting of the Permit to Take Water moritorium, should be done to determine whether there is sufficient water use to warrant further work.

In Southern Ontario and areas in Northern Ontario that are under Conservation Authority jurisdiction, Source Protection Plans should ultimately include water budgets at two levels of scale and detail:

- Phase 1 water budget completed across the watershed area:
  A watershed level water budget, based on available data and hydrologic modelling, that identifies areas with potential water use issues resulting from cumulative water takings.

- Phase 2 water budget completed in areas with potential water use issues:
  A subwatershed level water budget, based on refined data and hydrologic/ground water modelling.

Water quantity issues should be identified (as a deliverable of the Phase 1 water budget) by comparing estimated actual water use and permitted use in a subwatershed area with supply. Potential water quantity/water use issues are indicated when estimated annual water use exceeds 10% of supply annually or seasonal water use exceeds 25% of mean seasonal discharge. Initial estimates of supply should be based on recharge potential (infiltration net of evapotranspiration) and discharge from the subwatershed.

Potential water quantity/water use issues trigger Phase 2 (finer scale) investigations. For Source Protection Planning, potential water use issues that involve drinking water supplies are the most urgent. Other water use issues can be referred to parallel programs.

The steps in the development of a water budget are summarized as follows:

Phase 1

1. Develop a watershed scale water budget using a hydrologic model and accessible water use data (with water budget catchment size 300-500 km^2, not entire tertiary watershed)
2. Identify key processes e.g. major recharge and discharge areas, role of permanent land cover.
3. Project water use based on municipal water supply plans.
4. Identify areas with potential water use issues, current and future.
5. Screen potential water use issues for those that may affect drinking water supplies. Refer other issues to parallel programs

Phase 2

6. In issue areas that may affect drinking water supplies, refine subwatershed scale water budget using hydrologic and ground water models, and field-verified water use and ecological water needs data.
7. If Phase 2 investigation concludes that there is a water use issue and that drinking water supplies may be affected now or in the future, identify what needs to be achieved to reconcile the demand for water with the water resource.

There are at least four Ontario programs (Drinking Water Source Protection, Permit to Take Water, Oak Ridges Moraine Conservation, and Ontario Water

Response) that will rely on water budgets. The subcommittee felt strongly that there should be only one water budget for a watershed and it should inform all of the Ontario programs that need or rely on water budget information.

Future Water Supplies

The planning to meet future drinking water needs should be an integral part of the municipal land use planning and growth management process. Large parts of Ontario are growing and changing rapidly. The provincial government regularly provides 25-year population projections to municipalities, and municipalities are required, under the Planning Act, to provide for growth through their land use planning processes. As such, all municipalities should maintain a long-term water supply strategy that sets out their water supply needs, including conservation plans, and the planned sources for meeting those needs. In particular, those municipalities that do not have water supply capacity to meet their 25-year needs, or a water supply strategy that shows how their 25-year needs will be met, should prepare a long-term water supply plan as part of developing a Source Protection Plan. Municipalities preparing a new long-range water supply strategy should look to the 50-year planning horizon.

In order to protect the quantity of future municipal water supplies, the future municipal water supplies identified in the long-term water supply strategy should be considered when Permits to Take Water for other new or expanding uses are considered. Similarly, municipalities should consider the availability of water when zone changes for water-intensive land uses are considered.

Future drinking water wells and intakes identified in the municipal long-term water supply strategy should be protected, from a quality perspective, in the same way that current water supplies are protected. Where it is too costly or too early to pinpoint future municipal wells and intakes, it will be necessary to rely on protection afforded to vulnerable areas; future water supplies that are vulnerable can be given priority when determining risk management actions to be taken in vulnerable areas.

Protecting Sources from a Water Quantity Perspective

Water quantity protection involves managing water withdrawals and maintaining the recharge that replenishes ground water and sustains ground water discharge to surface water.

Managing Water Withdrawals

Water takings that change the hydrologic regime (i.e. consume water or return water to another place) are threats because, cumulatively, they may pose significant risks to current and future drinking water sources by depleting the drinking water supply available.

In determining whether water is being over-used, or the sustainability of future supplies, it is necessary to determine how much water must remain in the environment. Changes in ground water, whether from withdrawals or interference with the recharge processes, are ultimately reflected in ground water discharge to surface water features and cumulatively affect surface water flows and levels. Environmental water needs should be defined as a regime of water flows, levels and quality that is required to sustain a healthy ecosystem. The regime of water flows and levels that is required to sustain a healthy ecosystem and the tolerance of the ecosystem to changes should be determined based on hydrology, water quality, geomorphology, connectivity, and biology.

The science for determining environmental water needs is in its infancy and evolving rapidly. Building upon existing pilot projects for defining ecological water needs, research should be undertaken to evaluate methodologies for determining the regime of water flows, levels and quality required to sustain a healthy ecosystem and for determining the tolerance of the ecosystem to changes in the hydrologic regime.

Options for managing water taking (i.e. demand management) include managing new and expanding water taking, implementing water efficiency and water conservation programs and practices, and maintaining drought contingency plans.

Where water use issues involve drinking water supplies, the SPP Committee should coordinate the development of a collaborative water conservation plan among the affected water users that will reconcile water demands with the available resource. The conservation plan may include operational limits on water taking as part of that plan. If the conservation plan cannot be completed in the time frame of a first plan, the Committee should direct how a plan will be developed and by whom. It is expected that a water conservation plan developed as part of a Source Protection Plan will inform Permit to Take Water decisions.

The development of a water conservation plan among water users is recommended so that the economic and social costs of reducing water use can be balanced among the affected water use sectors. If across-the-board reductions in water use were expected (e.g. all users were expected to reduce water use by 40%), the impact may be a nuisance for some sectors and devastating for others.

The development of a water conservation plan is also recommended so that the opportunities to enhance supply can be considered along with the opportunities to reduce demand.

Areas Sensitive to Water Taking

Justice O'Connor made reference to the need to define "areas vulnerable to water taking". Using the risk assessment definitions recommended by the

Technical Experts Committee, these areas are referred to here as "areas sensitive to water taking".

The subcommittee recommends that "areas sensitive to water taking" include:

- Areas of high water use, where total water taking is already at or nearing the sustainable limit;
- Areas where the ecosystem has a low tolerance for changes in the hydrologic regime that may be caused by the cumulative effects of water withdrawals; and
- Areas with reduced capacity for water taking based on the water needed to maintain assimilative capacity and water quality.

Sustaining Water Supplies

Land uses and activities that reduce infiltration at source may, cumulatively, pose significant long-term risks to drinking water supplies by reducing recharge to ground water aquifers and reducing ground water discharge to surface water. Examples of threats that reduce recharge potential include:

- Activities which increase surface runoff resulting in a loss of recharge potential at source, including paving, grading to remove surface depressions, and improving surface drainage (e.g. storm sewer systems, surface drainage), and
- Activities which speed up the flow of surface water resulting in a loss of recharge potential, including the loss of wetlands and loss of riparian vegetation along streams.

Similarly, all land uses and activities that interfere along the recharge pathway to a drinking water supply aquifer are threats to water quantity and cumulatively may be significant long-term risks to drinking water supplies. The major recharge contribution areas and pathways should be identified and steps taken to manage the risks. The quality of water infiltrated in major recharge areas is also a concern because of the potential for long-term water quality impairment of aquifers.

Defining and Protecting Vulnerable Areas

Recharge mechanisms describe the "pathways" to drinking water supplies for quantity purposes, for both ground water and surface water supplies. Major recharge areas and other important hydrologic areas sustaining drinking water sources should be identified as vulnerable areas and steps be taken to manage the risks for depletion and impairment. The vulnerable areas for quantity management should include:

- Areas of major recharge potential that contribute 80% of the total recharge potential in the watershed, including those areas generally infiltrating more than 250 mm of precipitation per unit area per year (i.e. focused recharge areas such as hummocky terrain in moraine areas, sink hole terrain in karst topography, gravel and sand terraces, and outwash gravel and sand plains),

- Contributing areas sustaining at least 80% of the recharge supplying drinking water wells, and areas providing the source for at least 80% of the ground water discharge that is sustaining surface water supplies.

Management options for maintaining or enhancing recharge (i.e. supply management) include:

- Avoiding paving, re-grading, and drainage improvements in major recharge areas;
- Mitigating the effects of paving, regarding, draining using engineered measures;
- Protecting natural areas, such as wetlands and riparian zones, that promote infiltration and recharge.
- Enhancing the opportunities for recharge across the landscape through restoration of wetlands and riparian zones

TEC discussed the advisability of protecting, in particular, those areas where very large amounts of water are infiltrated and, in general, 80% of the potential recharge. There was concern, however, that in areas that are already impacted, protection of 80% of the recharge potential may not be enough to sustain the resource. TEC felt that, instead, the hydrologic regime should be characterized through modelling, the key processes identified, and the tolerance of the hydrologic system to changes determined.

The following summarizes the recommendations of the Water Quantity Subcommittee:

<u>Discussion Item 1</u>
Drinking water source protection needs to consider threats and risk to water quantity in the context of the hydrologic cycle.

<u>Discussion Item 2</u>
Source protection plans should be based on a watershed water budget that includes both ground and surface water dynamics. The water budget should be sufficiently accurate so that withdrawals can, cumulatively, be assessed as a threat to drinking water.

<u>Discussion Item 3</u>
A water budget should be developed on a watershed basis for each watershed area in Ontario, to quantify cumulative water taking and projected future water demand relative to available water resources, and

<u>Discussion Item 4</u>
The water budget so developed should be used to support Ontario's various water management programs (Drinking Water Source Protection, Permit to Take Water, Oak Ridges Moraine Conservation, Ontario Water Response), rather than having a different water budget for each program.

<u>Discussion Item 5</u>
Future drinking water needs should be identified so that they can be protected.

<u>Discussion Item 6</u>
Those municipalities that do not have water supply capacity to meet their 25-year needs, or a water supply strategy that shows how their 25-year needs will be met, should prepare a long-term water supply plan as part of developing a Source Protection Plan. Municipalities preparing a new long-range water supply strategy should look to the 50-year planning horizon.

<u>Discussion Item 7</u>
Where water use issues involve drinking water supplies, water conservation plans should be developed collectively among the water users in the area to show how water demand will be reduced and managed to ensure sustainability. The plans may recommend operational limits on water taking.

<u>Discussion Item 8</u>
The tolerance of the ecosystem to changes in water flows and levels should be considered in assessing the sustainability of water supplies.

<u>Discussion Item 9</u>
Further research should be undertaken to evaluate methodologies for determining:

a. **the regime of flows, levels, and water quality needed to sustain a healthy ecosystem and the tolerance of the ecosystem to changes caused by the cumulative effects of water withdrawals; and**
b. **what reductions in aquifer recharge and discharge are sustainable or acceptable over the long-term and for establishing baseline recharge rates for monitoring and future planning.**

<u>Discussion Item 10</u>
As part of developing water budgets, vulnerable aquifers and aquifer recharge must be identified, in recognition of the importance of recharge in sustaining aquifers and also the connections between ground water discharge and the maintenance of surface water. Source protection plans should protect the quality and quantity of these water supplies.

<u>Discussion Item 11</u>
As part of preparing a water budget, source protection planning committees should evaluate what reductions in aquifer recharge and discharge are

sustainable over the long term and establish baseline recharge rates for monitoring and future planning