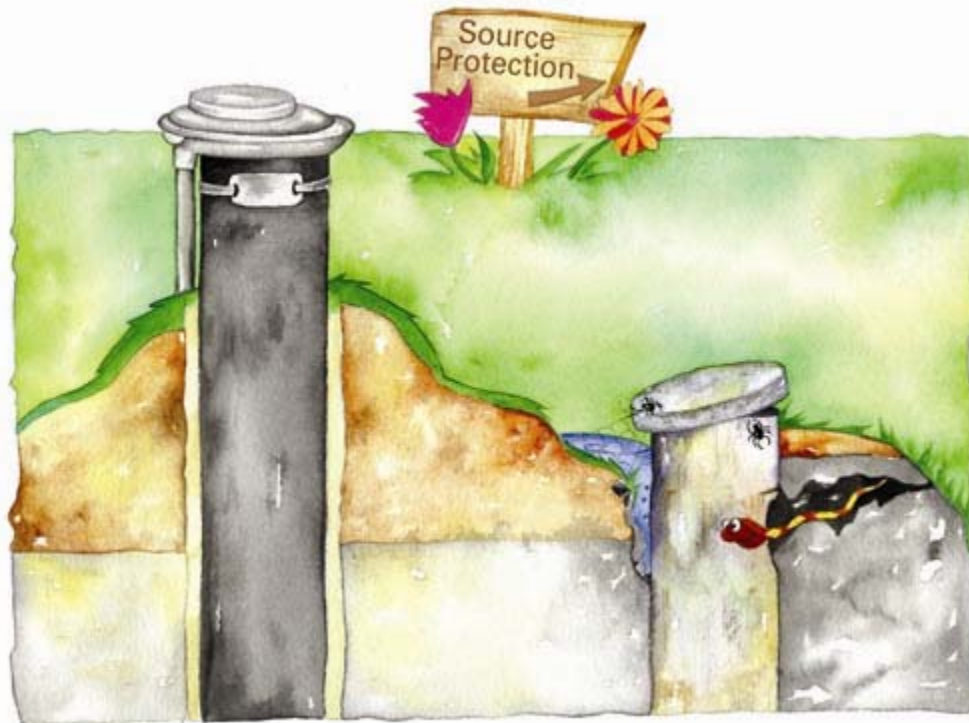


# **WATER WELL SUSTAINABILITY IN ONTARIO**

## **Expert Panel Report**



**Prepared for the Ontario Ministry of the Environment  
Sustainable Water Well Initiative**

**Final Report**

**January 30, 2006**

## Expert Panel Members

The Sustainable Water Well Infrastructure (SWWI) Expert Panel was conducted according to the guidelines for Expert Panels developed by the Royal Society of Canada. These guidelines specify the formation of three different assemblies to carry out the duties of expert review, panel facilitation and report preparation support, and co-ordination of panel selection and peer review. These assemblies and their members are listed below:

### Panel Members:

**Kent Novakowski**, Panel Chair, P.Geo., PhD (Hydrogeology), MSc (Hydrogeology), BSc (Geological Sciences), Associate Professor, Department of Civil Engineering, Queens University. *Panel Specialty: well hydraulics, regional groundwater flow in fractured rocks*

**Brian Beatty**, P.Eng., BSc (Water Resources Engineering), President, WB Beatty & Associates Limited. *Panel Specialty: hydrogeology/groundwater resources*

**Mary Jane Conboy**, P.Geo., PhD (Land Resource Science), MSc (Geology), BSc (Biology and Geology), Water Resources Researcher, Ontario Federation of Agriculture. *Panel Specialty: rural water wells, bacterial transport*

**John Lebedin**, P.Eng., MSc (Hydrogeology), BSc (Geological Engineering), Manager, Earth Sciences Unit for PFRA (Prairie Farm Rehabilitation Administration) of the Department of Agriculture and Agri-Food Canada. *Panel Specialty: sustainability of water well infrastructure*

### Technical Secretariat & Expert Panel Advisory Committee:

Dan McGillivray, PhD, Unit Director for the SWWI Expert Panel, Member of SWWI Expert Panel Advisory Committee, Ontario Centres of Excellence, Earth and Environmental Technologies (formerly CRESTech)

Deborah Brooker, Member of the SWWI Expert Panel Advisory Committee, Ontario Ministry of the Environment

Michael Rich, P.Eng. Member of SWWI Expert Panel Advisory Committee, Director, Centre for the Advancement of Trenchless Technologies (CATT)

Leanne Gelsthorpe, Ontario Centres of Excellence, Earth and Environmental Technologies (formerly CRESTech)

Don Lewis, Ontario Centres of Excellence, Earth and Environmental Technologies (formerly CRESTech)

Lorraine Craig, Technical Writer

## Table of Contents

|   |      |
|---|------|
| List of Figures .....   | vi   |
| List of Tables .....  | vii  |
| Acknowledgements .....  | viii |
| Executive Summary .....   | ix   |
| 1.0 Introduction.....   | 1    |
| 1.1 Operation Clean Water .....   | 1    |
| 1.2 Terms of Reference.....   | 2    |
| 1.3 Nature of the Problem.....  | 2    |
| 1.4 Sustainable Life Cycle of a Well: The Panel’s Approach .....                      | 3    |
| 1.5 The Process .....   | 4    |
| 1.6 Organization of the Final Report .....  | 5    |
| 2.0 Life Cycle of a Well.....   | 7    |
| 2.1 Smaller Capacity versus Municipal Wells.....                                      | 7    |
| 2.2 Well Life Cycle Components.....   | 10   |
| 2.3 Wells in Ontario.....   | 13   |
| 2.4 Well Infrastructure Management: The Sustainable Asset Management<br>Approach..... | 16   |
| 2.5 Conclusions.....  | 18   |
| 2.6 Recommendations.....  | 18   |
| 2.7 References.....   | 19   |
| 3.0 Groundwater Resources in Ontario.....   | 20   |
| 3.1 Groundwater and Climate.....  | 20   |
| 3.2 Groundwater and Geology.....  | 21   |
| 3.3 Groundwater Distribution in Ontario.....  | 22   |
| 3.4 Groundwater in Overburden.....  | 25   |
| 3.5 Groundwater Studies.....  | 27   |
| 3.6 Natural Groundwater Water Quality.....  | 28   |
| 3.7 Development and Sustainability .....  | 30   |
| 3.8 Future Groundwater Demand .....   | 31   |
| 3.9 Water Takings.....  | 32   |
| 3.10 Conclusions.....   | 36   |
| 3.11 Recommendations.....   | 36   |
| 3.12 References.....  | 37   |
| 4.0 Present Status of Water Quality in Wells in Ontario .....                         | 40   |
| 4.1 Private Well Water Quality.....   | 40   |
| 4.1.1 Bacteria .....  | 40   |
| 4.1.2 Nitrate .....   | 44   |
| 4.1.3 Pesticides.....   | 45   |
| 4.1.4 Road Salt.....  | 46   |
| 4.1.5 Other Rural Water Quality Surveys.....  | 47   |
| 4.2 Municipal Well Water Quality.....   | 48   |
| 4.3 Groundwater Under Direct Influence of Surface Water .....                         | 49   |
| 4.4 Conclusions.....  | 50   |
| 4.5 Recommendations.....  | 50   |

|         |   |    |
|---------|---|----|
| 4.6     | References.....   | 51 |
| 5.0     | Regulatory Framework in Ontario and other Jurisdictions.....                      | 55 |
| 5.1     | Roles of the Ontario Ministry of Environment.....                                 | 55 |
| 5.1.1   | Operations Division.....  | 56 |
| 5.1.2   | Environmental Science and Standards Division.....                                 | 56 |
| 5.1.3   | Drinking Water Management Division.....   | 60 |
| 5.2     | Provincial Regulation of Wells – Regulation 903.....                              | 60 |
| 5.2.1   | Summary of the Regulation.....  | 60 |
| 5.2.1.1 | Well Types Permitted.....   | 61 |
| 5.2.1.2 | Decommissioning.....  | 61 |
| 5.3     | Legislative Requirements in Ontario Compared to Other Jurisdictions.....          | 62 |
| 5.3.1   | Construction of Water Wells.....  | 62 |
| 5.3.2   | Set backs.....  | 63 |
| 5.3.3   | Disinfection.....   | 66 |
| 5.3.4   | Training for Well Drillers/ Technicians.....                                      | 66 |
| 5.3.5   | Well Decommissioning.....   | 67 |
| 5.3.6   | Inspection.....   | 68 |
| 5.3.7   | Water Testing.....  | 68 |
| 5.4     | Legislation in Ontario Impacting Municipal Wells.....                             | 69 |
| 5.5     | Role of Associations.....   | 70 |
| 5.6     | Conclusions.....  | 71 |
| 5.7     | Recommendations.....  | 71 |
| 5.8     | References.....   | 72 |
| 6.0     | Evolving and Other Important Legislation Affecting Water Well Sustainability..... | 73 |
| 6.1     | Source Protection Planning.....   | 73 |
| 6.2     | Nutrient Management Act.....  | 75 |
| 6.3     | Other Water Quality Legislation.....  | 77 |
| 6.4.1   | Ontario Water Resources and Environmental Protection Acts.....                    | 77 |
| 6.4.2   | Local Programs.....   | 78 |
| 6.4.3   | Groundwater Protection in Other Jurisdictions.....                                | 78 |
| 6.4     | Water Quantity Legislation.....   | 79 |
| 6.5.1   | Other Influences on Water Taking.....   | 80 |
| 6.5.2   | Proposed Changes to the Permit to Take Water Program.....                         | 81 |
| 6.5.3   | Water Quantity Protection in Other Jurisdictions.....                             | 83 |
| 6.5     | Conclusions.....  | 85 |
| 6.6     | Recommendations.....  | 85 |
| 6.7     | References.....   | 86 |
| 7.0     | Location and Construction of Wells.....   | 88 |
| 7.1     | Locating Water Wells.....   | 88 |
| 7.1.1   | Practices in Ontario.....   | 88 |
| 7.1.2   | Historical Perspective on Well Construction Practices.....                        | 89 |
| 7.1.3   | Dug Wells.....  | 90 |
| 7.1.4   | Cable Tool Drill Rigs.....  | 91 |
| 7.1.5   | Rotary Drilling Rigs.....   | 91 |
| 7.2     | Current Well Construction Practices.....  | 91 |
| 7.2.1   | Dug or Bored Wells.....   | 91 |

|       |   |     |
|-------|---|-----|
| 7.2.2 | Driven or Jetted Sand Points.....   | 93  |
| 7.2.3 | Drilled Wells.....  | 93  |
| 7.3   | Issues in Well Construction.....  | 95  |
| 7.3.1 | Variation in Hydrogeology.....  | 95  |
| 7.3.2 | Well Location.....  | 96  |
| 7.3.3 | Annular Space.....  | 96  |
| 7.3.4 | Pump Installation.....  | 96  |
| 7.3.5 | Altering Wells After Construction.....                                    | 97  |
| 7.4   | Well Inspection Pilot Project.....  | 97  |
| 7.5   | Sustainability of Well Construction.....                                  | 97  |
| 7.6   | Conclusions.....  | 98  |
| 7.7   | Recommendations.....  | 98  |
| 7.8   | References.....   | 98  |
| 8.0   | Operation and Maintenance of Wells.....                                   | 100 |
| 8.1   | Aspects of Well Maintenance.....  | 100 |
| 8.1.1 | Casing Integrity and Adherence to Best Practices.....                     | 100 |
| 8.1.2 | Preventive Operating Procedures.....                                      | 102 |
| 8.2   | Biofouling.....   | 103 |
| 8.2.1 | Diagnostic Procedures.....  | 105 |
| 8.2.2 | Iron Related Bacteria.....  | 106 |
| 8.2.3 | Sulphate Reducing Bacteria.....   | 107 |
| 8.2.4 | Emerging Microbiological Considerations: Biofouling and Hygiene Risk..... | 107 |
| 8.3   | Well Rehabilitation.....  | 109 |
| 8.4   | Well Maintenance and Awareness in Ontario.....                            | 111 |
| 8.5   | Implications for Sustainability.....                                      | 116 |
| 8.6   | Conclusions.....  | 117 |
| 8.7   | Recommendations.....  | 117 |
| 8.8   | References.....   | 119 |
| 9.0   | Decommissioning and Abandonment.....                                      | 121 |
| 9.1   | Decommissioning Practices.....  | 123 |
| 9.2   | Decommissioning Requirements.....   | 124 |
| 9.2.1 | Decommissioning Large Diameter Wells.....                                 | 125 |
| 9.2.2 | Decommissioning Drilled Wells.....  | 126 |
| 9.3   | Difficult Cases.....  | 127 |
| 9.3.1 | Well Pit Decommissioning.....   | 127 |
| 9.3.2 | Flowing Well.....   | 128 |
| 9.3.3 | Well Containing Existing Material.....                                    | 129 |
| 9.3.4 | Well with Hydrocarbon Contamination.....                                  | 130 |
| 9.4   | Implications for Sustainability.....                                      | 130 |
| 9.5   | Conclusions.....  | 131 |
| 9.6   | Recommendations.....  | 131 |
| 9.7   | References.....   | 133 |
| 10.0  | Emerging Issues in Water Well Infrastructure Sustainability.....          | 134 |
| 11.0  | Review of the Water Well Infrastructure Think-Tank Process.....           | 139 |
| 11.1  | Think-Tank Process and Outcomes.....                                      | 139 |
| 11.2  | Panel Assessment.....   | 142 |

|      |                                       |     |
|------|---------------------------------------|-----|
| 11.3 | Recommendations.....                  | 142 |
| 12.0 | Conclusions and Recommendations ..... | 143 |

Appendix A Panel Terms of Reference.

Appendix B List of the Panel consultations.

Appendix C Source protection examples in New York City, Oxford County and Waterloo Region.

Appendix D Well drilling procedures.

Appendix E Further resources on best practices for water well decommissioning.

Appendix F Glossary

Appendix G Acronyms

Appendix H Regulation 903 - Wells

## List of Figures

|   |     |
|---|-----|
| Figure 1.1 Sustainable Water Well Infrastructure Life Cycle .....   | 3   |
| Figure 2.1 Well Properly Fitted with Water Level Monitoring and Sampling Ports.....                       | 8   |
| Figure 2.2 Distribution of MOE Well Water Records in Southern Ontario .....                               | 10  |
| Figure 2.3 Sustainable Water Well Infrastructure Life Cycle .....   | 11  |
| Figure 2.4 Wells Constructed in Ontario in 1950.....  | 13  |
| Figure 2.5 Water Wells in Ontario (to June 2002).....   | 14  |
| Figure 2.6 Distribution of Well Type in Ontario .....   | 15  |
| Figure 2.7 Distribution of Well Age in Ontario.....   | 16  |
| Figure 3.1 Four Major Bedrock Regions in Ontario.....   | 23  |
| Figure 3.2 Major Bedrock Aquifers in Southern Ontario .....   | 24  |
| Figure 3.3 Provincial Water Quality Monitoring Network.....   | 30  |
| Figure 3.4 Precipitation in Ontario 2001. ....  | 33  |
| Figure 3.5 Stream Flow in Ontario 2001 .....  | 34  |
| Figure 3.6 Key Areas Facing Water Constraints in Ontario.....   | 35  |
| Figure 4.1 High vs. Low Risk Wells.....   | 44  |
| Figure 4.2 Results of Ontario Federation of Agriculture Rural Water Quality Testing<br>Program.....       | 48  |
| Figure 5.1 Ontario's Responsibility for Water by Ministry .....   | 56  |
| Figure 5.2 Ontario Ministry of Environment Organizational Chart .....                                     | 57  |
| Figure 6.1 Answering Key Sustainable Asset Management Questions for Private Wells                         | 76  |
| Figure 8.1 Biofouling on Water Well and in Adjacent Environment.....                                      | 104 |
| Figure 8.2 Biofouling on Pumping Equipment.....   | 105 |
| Figure 8.3 Standard Biological Activity Reaction Tests: Presence-Absence Monitoring<br>Technology .....   | 106 |
| Figure 8.4 Staircase Effect – Treatment and Operational Trends Typically Observed in<br>Water Wells ..... | 110 |
| Figure 9.1 Fieldstone Lined Well Receiving Contaminants.....  | 122 |
| Figure 12.1 Summary of Key Recommendations for Water Well Sustainability.....                             | 143 |

## List of Tables

|   |     |
|---|-----|
| Table 2.1 Summary of Well Type Observed in Ontario .....                            | 15  |
| Table 4.1 Comparison of Private Well Water Quality Surveys.....                     | 42  |
| Table 5.1 Minimum Casing Depths and Set Backs for Various Jurisdictions.....        | 64  |
| Table 8.1 Summary of Healthy Futures Well Upgrade Audits.....                       | 101 |
| Table 8.2 Evaluation of Well Aware Phase II (GCA, 2004) .....                       | 114 |
| Table 9.1 Possible Indicators of an Unused Well (based on AGWT, 2000) .....         | 122 |
| Table 9.2 Number of Audited Decommissioning Projects by Well and Project Type ...   | 124 |
| Table 10.1 Example of Key Issues Affecting Water Well Infrastructure Sustainability | 135 |
| Table 11.1 Think-Tank Research Priorities .....                                     | 140 |

## Acknowledgements

The Expert Panel gratefully acknowledges the following individuals for their contribution to the report:

- Simon Smith, S.D. Smith Well Drilling for providing information on well construction and decommissioning
- Deborah Conrod, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment for providing data and maps from the provincial water well records database
- Dan Dobrin for providing a powerpoint presentation on GUDI
- Brian Stratton for providing the preliminary report on the Ottawa Well Inspection Pilot Project
- Green Communities for providing the Well Aware Phase 1 and II reports and the Well Discovery Report
- Ontario Federation of Agriculture for providing the Healthy Futures Well Upgrading and Decommissioning reports
- Dave Neufeld and Deborah Brooker, Ontario Ministry of the Environment for providing information on legislative and policy issues
- Michael Convery, Minnesota Department of Health for providing information on the Minnesota Well Management program
- Rob de Loe and Reid Kreutzwiser, University of Guelph for providing information on water taking
- Earl Morwood, Ontario Ground Water Association for providing information on water well industry initiatives
- Bonnie Lemaire of Bonniella for creating the illustrations for many of the Figures

## **Executive Summary**

### Background

In the years following the Walkerton Inquiry, there have been several governmental regulatory and policy initiatives aimed at improving the health and safety of Ontario's water supply. Although many of these have focused on larger water supply and distribution systems, a project initiated in 2002 by the Ontario Ministry of the Environment (MOE) was directed at the most fundamental of water sources, that being the water well.

The project was identified as the "Sustainable Water Well Infrastructure (SWWI)" initiative and has the general objective to investigate, plan, and implement innovative approaches to water well maintenance and monitoring in order to extend and improve the integrity of water well infrastructure in Ontario. As part of the SWWI initiative, an Expert Panel was established to investigate the state of wells in Ontario and determine the prognosis for improving well longevity. The Panel consists of four scientists and engineers who have expertise in a variety of areas related to the water well industry.

### Terms of Reference

The Panel was struck in September of 2003 and given Terms of Reference that had been initially established by the MOE and CRESTech (now the Centre for Earth and Environmental Technologies, Ontario Centres of Excellence), which were then vetted during the first public meeting held by the Panel. The finalized Terms of Reference held three principal objectives for the Panel: 1) to produce a "state of knowledge" document on Ontario's water well infrastructure, 2) to identify emerging threats to water well infrastructure and assess Ontario's ability to mitigate these, and 3) to provide peer review of the findings of two "Think-Tanks" conducted previously on the topic. The "Think-Tanks" were conducted as a highly interactive process involving approximately 25 professionals and academics in which the principal issues and research needs related to the longevity of water well infrastructure were identified.

In order to meet the first two objectives, a considerable amount of information was gathered from a variety of sources. The Panel was interested in obtaining information not only from established governmental and academic sources, but also from practitioners and professionals who deal with the water well industry in Ontario on a daily basis. As such, interviews were conducted with numerous stakeholders including water well contractors, hydrogeologists and consulting engineers who work in the industry, managers of municipal water supplies, and representatives from conservation authorities in Ontario, and the MOE. The Panel also obtained information from jurisdictions outside Ontario, including most provinces in Canada, and particularly the state of Minnesota.

The general focus of the information collected falls into two categories: 1) water well construction, operation, maintenance, and decommissioning, and 2) the regulatory framework protecting wells, particularly Regulation 903 (the revised regulation covering

the construction and maintenance of all wells). Information gaps and research needs were also identified and compiled during the data gathering phase.

### Scope of Study

In early Panel deliberations, the need to differentiate between municipal and private wells was debated. The Panel concluded that all wells would be considered, and recognised that substantially different issues may arise in regulations, operation, and maintenance between these two. For the purpose of this report, the Panel defines a “private well” as any water supply well not utilized to support a municipal water distribution system. This includes domestic drilled wells; domestic dug or bored wells; water supply wells for agriculture, commercial, institutional and industrial uses; and wells that support small waterworks. Geotechnical wells and monitoring wells used in environmental studies were not considered in detail since most of them have a limited life-span and they are almost always designed and installed under the direction of expert professionals.

The Panel’s assessment included the following aspects of sustainable water well infrastructure: well infrastructure management; groundwater resources in Ontario; well water quality; the regulatory framework; construction, maintenance and decommissioning practices; and current and emerging issues that might threaten the sustainability of wells over the long term. The latter topic had the potential to dominate the document and was thus summarised in an abbreviated tabular format. Conclusions and recommendations are presented at the end of each of the main chapters. A summary of the Panel’s conclusions and most pressing recommendations to promote water well sustainability in Ontario is presented below.

## CONCLUSIONS

### Design Life of a Water Well

All water wells have a limited design life. The design life depends on factors such as the construction materials, installation methods, hydrogeological setting and groundwater quality. A large percentage of the recorded and unrecorded wells that currently provide potable supplies are beginning to reach the end of their useful design life.

The lack of attention to the aging water well infrastructure in Ontario means that the period ahead will require more demanding and challenging solutions than the Province has experienced in the past. The pathway forward demands innovative new approaches to sustain and manage both the existing and growth-generated water well infrastructure.

### Groundwater Resources in Ontario

The Panel recognizes the gap between what is commonly referred to as aquifer management and infrastructure management. The latter was felt to require much greater and more dedicated institutional attention. In general, the Panel concluded that the health of the groundwater drawn to wells is excellent, with abundant supply of good quality

groundwater in most parts of Ontario. The geological and climatic conditions of Ontario, however, are very diverse which presents unique challenges for well life cycle management. The MOE has been proactive in mapping groundwater resources via a network of monitoring wells and the funding of groundwater studies conducted in almost all regional jurisdictions in the Province. Despite these efforts, the Panel found that public concerns about both groundwater quality and quantity remain an issue, particularly in more densely populated parts of the Province and local areas with limited or naturally poor groundwater quality.

### Water Well Infrastructure in Ontario

Approximately 10,000 - 20,000 new wells are constructed in Ontario on an annual basis. The Panel found that it was difficult to ascertain from the number of new wells, those that were replacements for failed, low yield or abandoned wells. The number of wells abandoned or properly decommissioned per year is also uncertain. In fact, the present condition, age, and life expectancy of most private wells are largely unknown. As a consequence, an estimate of the typical lifetime of a private well is highly uncertain. Municipal wells, conversely, are much more proactively managed and considerably more is known about the performance and longevity of this water supply.

### Water Well Quality in Ontario

The Panel found that a comprehensive province-wide survey of private wells has never been conducted by the MOE. Although a few water well surveys by the MOE and other researchers have focussed on water quality, none have concentrated on the water well infrastructure. As a result, little is known about the vulnerability of wells to surface contamination or the risks of aquifer contamination from abandoned wells throughout the Province.

### Water Well Records

In the early 1950s, Ontario became one of the first jurisdictions in North America to require mandatory submission of water well records for inclusion in a publicly accessible database. The records contain valuable information on the well construction and hydrogeologic conditions and have been updated to enhance the well database. In spite of Ontario's leadership in developing a public water well database, the Panel found two major shortcomings to the current system: 1) there is no legal requirement for well owners to transfer the well record to new owners, and 2) the MOE's aging water well data management system is not up-to-date or readily accessible by the general public. The lack of readily accessible well records has contributed to a general lack of understanding by the majority of well owners about their own water supply wells.

### Public Education and Outreach

The efforts by the MOE to educate well owners in the benefits of proper well maintenance and well rehabilitation are applauded. The 2003 "Well Aware" publication

by the Green Communities Association and Ontario Ground Water Association, filled a major gap in public education on water wells; however, MOE financial support for the document was withdrawn in 2004.

### Well Maintenance and Disinfection

In many cases, wells that are discovered to perform poorly or have poor water quality can be rehabilitated through upgrading and proper maintenance. The Panel found two barriers to this: 1) a lack of understanding among well owners of the importance of regular maintenance and disinfection, and 2) the limited supply of qualified contractors to conduct rehabilitation and upgrade work. Biofouling of wells was recognised to be one of the most significant contributors to the degradation of well performance, although the methods for prevention are usually not understood by the well owner.

### Well Decommissioning

Once a well has reached the end of its life, the well should be properly decommissioned, as is now ensconced in law (Reg. 903). It is speculated that there are at least 500,000 abandoned wells distributed throughout the Province. The Panel considers that abandoned wells present a significant risk of contamination of aquifers, since they provide a direct conduit from the surface to the aquifer. Where abandoned wells are located in close proximity to newly constructed wells, the safety of the new well may also be questioned. Unfortunately, the location of abandoned wells is often unknown, and the Panel recognises this to be a significant challenge in eliminating this contaminant pathway.

### Water Well Legislation

In reviewing existing regulation and policy pertaining to wells in Ontario, the Panel determined that the principal regulatory instrument for the construction and decommissioning of wells (Reg. 903) is a comprehensive article of legislation for water supply wells. Based on interviews with stakeholders, however, implementation and enforcement of Reg. 903 is inconsistent and incomplete. The MOE is commended for utilising outreach programs to promote the proper implementation of the regulation; although, without inspection and enforcement, the Panel believes that the objectives of the regulation (i.e. improvement in the safety of the water well infrastructure) will not be achieved. In contrast, the construction, operation, maintenance and disinfection of municipal wells in Ontario are well regulated and monitored with rigorous surveillance.

At present there are several recently enacted or proposed regulations and policies which may impact both municipal and private water well infrastructure in Ontario. In comparison to jurisdictions elsewhere in North America and Europe, these initiatives are bringing the province to the international forefront of proactive water supply protection. In particular, the Panel commends the proposed Source Protection Planning program and the recent revisions to the Permit to Take Water (PTTW) legislation (O. Reg. 387/04); both of which will lead to more sustainable use of the groundwater supply. The Panel,

however, also recognises that although private wells should not be a principal focus of the proposed source protection legislation, this infrastructure may provide potential pathways for contamination within source protection areas for municipal wells and could in some cases require their own wellhead protection.

### Research Needs

The Panel identified a number of research needs that will help to develop sustainable water well infrastructure over the longer term. In particular, research is required in the areas of well biofouling and rehabilitation; pathogen transport to wells or aquifers; decommissioning of large-diameter wells; and methods for locating abandoned wells. These research needs are similar to those identified during the 2002 “Think-Tank” process, which was conducted to initiate research in those areas identified to be of highest priority. By 2005, only one funded project was spawned from the process, and the Panel concluded that the process be revisited following the publication of this report in order to initiate more research in this area.

### Sustainable Asset Management

The Panel recognizes that there is significant investment in private water well infrastructure in Ontario. Sustainable Asset Management (SAM) is a possible means to protect this significant investment. The SAM approach integrates quality and risk management principles and provides a comprehensive flexible and proactive means of optimizing drinking water quality and protecting human health. It is a preventative management approach that encompasses all steps in water production from catchment to the well user. It has become an integral part of managing Ontario’s municipal systems and many of the municipal actions taken to support this approach could be applied to private wells.

## RECOMMENDATIONS

After considerable deliberation, the Panel identified 44 recommendations addressing all aspects of water well sustainability of which 10 recommendations were emphasized as critical initiatives to promote the longevity of water wells in Ontario. These high priority recommendations are as follows:

### 1. Province-wide Well Water Quality Survey

A comprehensive province-wide survey of water quality in all private wells should be undertaken immediately. This should include all unregulated wells including rural wells, cottage wells, and private wells in urban areas, in addition to farm wells. This survey should be repeated at least every ten years, allowing for ample time between surveys to investigate trends and findings in more detail.

## 2. Public Groundwater/Well Water Website

The MOE should make available to the public a comprehensive, user-friendly, interactive groundwater website containing information such as the results of comprehensive groundwater studies; water taking; groundwater monitoring network data; Water Well records data; and Ministry of Health and Long Term Care well water quality data.

## 3. Skilled Groundwater Workforce

Mandatory membership in an accredited professional groundwater association should be required for all workers engaged in water well activities. This action is needed to facilitate the transfer of knowledge from those on the cutting edge to the broader water well industry and to ensure that a highly skilled workforce is sustained throughout the Province.

## 4. Industry Outreach and Education

To ensure due diligence and compliance with Reg. 903, a third party organization should be engaged to develop an outreach and education program for the drilling industry.

## 5. Third Party Enforcement of Well Regulation

To support the objectives of Reg. 903, enforcement of the regulation should be provided by a third party organization who has qualified, experienced staff that are knowledgeable about the water well industry.

## 6. Water Well Database Initiative

To build upon MOE's source protection and water taking permit initiatives, a stakeholder group should be established immediately to explore alternatives for managing the Water Well database. This stakeholder group should report to the Minister within 12 months of its formation.

## 7. Expand Well Aware Program

The Well Aware program, a provincial government funded province-wide effort to educate rural residents about well safety, is an effective tool for promoting well stewardship and should receive continued funding and support. Indeed, consideration should be given to expansion of this program into additional Ontario communities.

## 8. Subsidy Program for Well Upgrades and Decommissioning

The Ontario government should continue to fund a subsidy program similar or equivalent to the Ontario Ministry of Agriculture and Food (OMAF) Healthy Futures Upgrade and Decommissioning program. The Panel recommends that such programs provide greater than two-thirds cost-sharing and include an educational component.

## 9. A New Water Well Service Industry

The Ontario government should support and fund a new sustainable asset management training program at Sir Sanford Fleming College. The program should focus on the practices, tools and techniques necessary to develop life-cycle management strategies that will sustain the water well infrastructure in Ontario, and beyond. The program would spawn a badly needed service industry aimed at maintaining, rehabilitating and decommissioning water wells. The new industry would meet the growing needs of the millions of Ontarians who rely on high quality groundwater supplies.

## 10. Disclosure of Water Well Status

The MOE should introduce legislation aimed at disclosing the status of all used and unused water wells by the owner at the sale or transfer of property where they are located. The disclosure records should include well performance and quality of all operating water wells and the status and condition of all unused wells. The new legislation should include a phase-in schedule to allow time for trained water-well service companies to develop across the Province.

## **1.0 Introduction**

### **1.1 Operation Clean Water**

In August 2000, the Ontario government launched Operation Clean Water, a comprehensive strategy to protect drinking water public health. The broad objectives of Operation Clean Water are: i) the development of standards and regulations to improve and protect the quality of drinking water, ii) the development and improvement of effective inspection and enforcement capacity to identify and punish non-compliant activities that threaten water quality, and iii) to invest in efficient delivery practices that assist in complying with the new regulations.

To date several initiatives have developed from Operation Clean Water. These include the Drinking Water Systems Regulation (O. Reg. 170/03) under the Safe Drinking Water Act, 2002 which replaced the Drinking Water Protection Regulation for Larger Waterworks (O. Reg. 459/00) and the Drinking Water Protection Regulation for Smaller Waterworks Serving Designated Facilities (O. Reg. 505/01); the Groundwater Studies Program and the Nutrient Management Act and Regulation 267/03 which are intended to develop capacity for the protection of water supplies in the Province; and the Ontario Small Town and Rural Development (OSTAR) Infrastructure Program to help smaller towns, and rural areas to upgrade health and safety infrastructure, including waterworks.

In 2002, a program focused on the health of water wells in Ontario was initiated as part of Operation Clean Water. The program is entitled Sustainable Water Well Infrastructure (SWWI) and the general objective is to investigate, plan and execute innovative approaches to well maintenance and monitoring in order to extend the integrity of water well infrastructure in Ontario. As a component of the SWWI initiative, an Expert Panel was established to determine the present condition of private and municipal water wells with the specific goal to provide recommendations that will help to extend and improve integrity of the infrastructure over time. Prior to the establishment of the Expert Panel, two "Think-Tank" meetings were conducted by CRESTech (now the Centre for Earth and Environmental Technologies, Ontario Centres of Excellence) in the Summer of 2002 to explore the issue of "making Ontario's water well infrastructure sustainable". The Think-Tank meetings were attended by a wide variety of stakeholders including drillers, hydrogeologists, academics, and government officials.

## **1.2 Terms of Reference**

The first act undertaken by the Panel was to establish a Terms of Reference. These were initially formulated by the Ontario Ministry of the Environment (MOE) and CRESTech (the functionary entity supporting the Panel) and then vetted through public consultation at the 2003 Grand River Conservation Authority Water Forum. The Terms of Reference were formulated as an assignment, which is given as follows:

- To produce a “state of knowledge” document on the life cycle of a water well in Ontario, including the identification of knowledge gaps and opportunities to improve the quality of the life cycle in Ontario.
- To identify emerging threats to well water sustainability and assess Ontario’s capacity to mitigate these threats.
- To provide peer review of the findings of the Think-Tank Process.

The primary product of the Expert Panel is the present report. The Terms of Reference were used as the governing principles in completing the report. A more detailed version of the Terms of Reference is provided in Appendix A.

## **1.3 Nature of the Problem**

Municipal or private water wells and associated infrastructure including pumps and water distribution systems are the primary source of drinking water for more than three million Ontarians. In the case of municipal wells, many have been in place for several decades and are well maintained, where withdrawal is managed in an optimal manner. In the case of private wells, this is often not the case. Based on experience with the Well Discovery Program (a provincially-funded program to locate domestic wells), many homeowners were unaware of their well history when contacted. For older properties, there may be one or more abandoned dug or drilled well in addition to the operational well. Some wells are located in poor hydrogeological settings where the potential for contamination is high. The Panel found that well inspection and maintenance is rarely done.

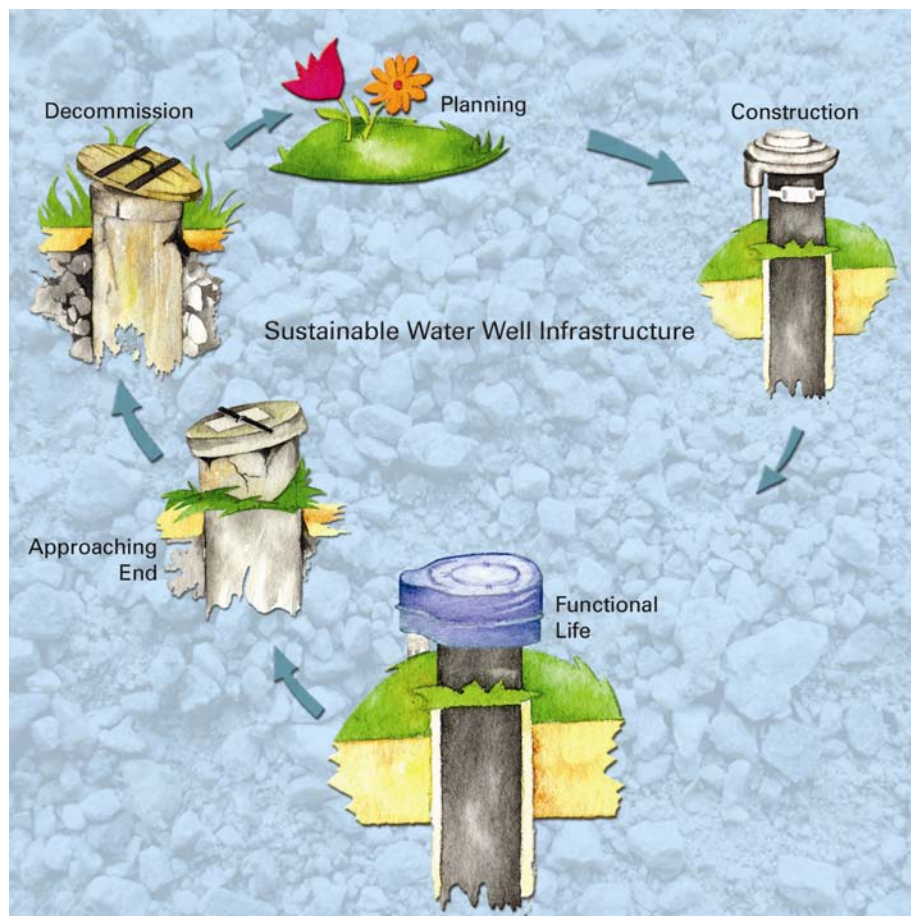
Clearly, the longevity of private well installations is an unknown. At what point in a well’s lifecycle should there be scheduled maintenance or replacement? Do private and municipal wells have similar life cycles? Are there maintenance methods or programs that can improve the life cycle of a well? In cases where attention is brought to the well as a result of failure or a requirement to decommission, positive intervention that might lead to improved longevity of the well is likely too late. Thus, the Panel is sensitive to the need to compile good documentation on the processes that might impact the life cycle of a well in addition to identifying some interventions that might help extend the life cycle.

The Panel recognizes that the provincial government is identified by the public as the principal regulator and safe keeper of water wells in Ontario. This is despite the fact that once a well is constructed, the well is the owner’s responsibility. We also recognize that the Province, through

the MOE, has initiated a number of programs and regulations supporting the improvement and safety of drinking water from water wells. The revised Regulation 903 (see Appendix H) governs the construction and decommissioning of water wells and training of well technicians. The Panel has assessed the Regulation in some detail, including the comprehensiveness of the regulation and issues related to its implementation.

#### 1.4 Sustainable Life Cycle of a Well: The Panel's Approach

In the Terms of Reference, the Panel was provided with a preliminary conceptual model which describes the life cycle of a typical water well. This conceptual model was adapted by the Panel to help guide our process of deliberation. This model for understanding sustainable water well infrastructure is illustrated in Fig. 1.1 in which the typical life cycle is shown. The Figure illustrates current practice for well construction which now includes well tagging. Further along the life cycle, some of the typical well scenarios which eventually lead to decommissioning and abandonment are shown.



**Figure 1.1 Sustainable Water Well Infrastructure Life Cycle**

This illustration demonstrates how the degradation of the well condition is dissimilar to the condition of a new well. The conditions illustrated in the later part of the life cycle were the driving impetus behind the process to improve sustainability. The Panel also recognized that the

processes leading to well aging and deterioration are complex and are a function of the well location, design and method of construction.

## **1.5 The Process**

The sponsor for this Expert Panel is the MOE who utilized CRESTech (now the Centre for Earth and Environmental Technologies, Ontario Centres of Excellence) as the facilitator and technical secretariat. The sponsor requested that the Panel follow the Royal Society of Canada procedural guidelines for expert panels published in 1996. As such, the prescribed process is approximately as follows:

- Select the Panel
- Propose a Terms of Reference
- Publicly introduce the Panel and vet the Terms of Reference
- Produce a report
- Peer review the report
- Publicly present the final report

During the process, the opportunities for non-solicited public input to the Panel were limited to the first public meeting. The Panel Chair solicited all other public input at the behest of individual panel members or the Panel as a whole.

At the beginning of the process, the Panel determined that the final report should be a guidance document founded on an accurate representation of the present condition of the water well infrastructure and the regulations that pertain to water wells in Ontario. In order to evaluate the current state of water wells in Ontario, the Panel used information from published sources, personal experience in the field, and key informant interviews. The Panel selected the interviewees and representation was sought from as many of the stakeholders as possible. This included representatives from the MOE, Conservation Ontario, individual conservation authorities, municipalities, other regulatory jurisdictions outside Ontario, and the drilling industry (see Appendix B for list of consultations).

The Panel notes that in the years following the Walkerton Inquiry, there have been several governmental regulatory and policy initiatives aimed at improving the health and safety of Ontario's water supply. These initiatives continue to evolve. The Panel considered documentation published up to mid-2005 in relation to these evolving initiatives.

The Panel deliberated over the definition of a "water well" with respect to a specific definition for the purpose of this report. For this report, we define the term "water well" to mean any groundwater supply well not utilized to support a municipal water distribution system. This includes domestic drilled wells; domestic dug or bored wells; supply wells for agriculture; commercial, institutional and industrial uses; and wells that support small waterworks.

Geotechnical wells and monitoring wells used in environmental studies were not considered in detail. The Panel also deliberated over the distinction between the life cycles of municipal and private wells. Management of the two systems is very different (see Chapter 2), with the municipal system being highly regulated; therefore, the Panel felt the focus of this Report should be on private wells.

Panel members agreed to undertake specific writing assignments by topic, based on their areas of expertise and experience. Each member prepared a draft version of their material for review and discussion during face to face meetings of the entire Panel.

The writing assignments were as follows: Kent Novakowski (Executive Summary; Chapter 1: Introduction); Brian Beatty (Chapter 3: Groundwater Resources in Ontario; Section 5.5: Role of Associations; Section 7.1.2 Historical Perspective on Well Construction Practices); John Lebedin (Chapter 2: Life Cycle of a Well (with Mary Jane Conboy); Section 8.1: Aspects of Well Maintenance; Section 8.2: Biofouling- an Emerging Issue; Section 8.3: Rehabilitation); and Mary Jane Conboy (Section 2.3: Wells in Ontario; Chapter 4: Present Status of Water Wells in Ontario; Chapter 5: Regulatory Framework in Ontario and other Jurisdictions; Chapter 6: Other Important Legislation Affecting Water Well Sustainability; Chapter 7: Location and Construction of Wells (with Simon Smith); Section 8.4: Well Maintenance and Awareness); Chapter 9: Decommissioning and Abandonment (with Simon Smith)).

In addition to the report conclusions and recommendations, the following chapters were prepared collectively by the Panel: Chapter 10: Emerging Issues in Water Well Infrastructure and Chapter 11: Review of the Water Well Infrastructure Think-Tank Process.

The draft report was externally reviewed by five peer reviewers. In finalizing the document, the Panel formulated a response to the individual comments. The Panel deliberated over the reviews individually and the Chair drafted appropriate actions which were discussed by teleconference followed by a two day face-to-face meeting. This report represents the consensus view of the Panel members and addresses the peer review comments.

## **1.6 Organization of the Final Report**

This report discusses water well sustainability in Ontario within the framework of the water well life cycle and according to key legislative and non-legislative tools for management of water well sustainability (see Figure 1.1). The Panel's conclusions and recommendations are provided at the end of each chapter and are also summarized in Chapter 12, which is ultimately the product of this expert panel process.

The report is organized as follows:

The Executive Summary provides an overview of the task of the Panel, the scope and approach to its assessment, and the main findings and recommendations.

Chapters 2, 3, and 4 discuss current knowledge of wells in Ontario and the hydrogeology of Ontario. This information is important to understanding the "asset".

- Chapter 2 summarizes our current understanding of the life cycle of a water well. This includes locating, constructing, operating and maintaining, rehabilitating, and decommissioning a well. The chapter describes what is known about the current status of water wells in Ontario in terms of numbers of wells, well age and well depth.
- Chapter 3 provides an overview of groundwater resources in Ontario. Present development, usage and future demand are described.
- Chapter 4 describes the present status of wells in Ontario based on the findings of water quality studies.

Chapter 5 provides a description of the provincial regulatory framework in Ontario from both a water quantity and water quality perspective. It also contrasts and compares how other jurisdictions in Canada and the United States regulate the construction and management of wells.

Chapter 6 highlights other legislation specific to Ontario that could support the water well regulation to ensure a sustainable resource. These chapters help the reader to understand the legislative framework underlying Ontario's capacity to manage water well infrastructure.

Chapters 7, 8, and 9 walk the reader through the life cycle of the well and provide recommendations to enhance the sustainability of wells at different points of the life cycle.

- Chapter 7 describes the present methods used to locate and construct wells in Ontario.
- Chapter 8 describes the operation and maintenance of wells in Ontario and discusses initiatives to promote well stewardship in Ontario.
- Chapter 9 describes the regulatory requirements for well decommissioning and abandonment and discusses barriers to adherence to best practices.

Chapter 10 discusses current and future issues in water well sustainability in Ontario. The purpose of the chapter is to identify the various risk elements; their jurisdictional/regulatory aspects; and provide insight as to the manner in which these risks are related to sustaining present and developing future water well infrastructure. This chapter is not intended to provide a detailed review of each risk, but rather an assessment of the relative threat posed by each.

Chapter 11 presents a summary of the outcomes of CRESTech's Think-Tank process on Sustainable Water Well Infrastructure. The Think-Tank results were placed here to support the Panel conclusions and recommendations.

Chapter 12 provides the Panel conclusions and recommendation and identifies ten key recommendations for promoting water well sustainability in Ontario.

The Appendices provide additional information to supplement the report and are identified in the Table of Contents.

## **2.0 Life Cycle of a Well**

In this chapter we discuss the life cycle of a well from the perspective of a sustainable asset management approach. Sustainable Asset Management (SAM) is a way to manage a system holistically for continuous improvement, including a process to measure success. This is a preventative management approach that encompasses all steps in water production from catchment to consumer and has become an integral part of managing Ontario's municipal systems. Many of the steps to develop a Sustainable Asset Management approach, and actions to be taken, could be applied to private wells.

### **2.1 Smaller Capacity versus Municipal Wells**

Over three million Ontarians depend on groundwater as their main source of domestic water and it is used extensively for irrigating crops, and for livestock; commercial; and industrial facilities including golf courses, aggregate pits, water bottling plants. Groundwater provides about 30% of all water requirements in Ontario, but in rural areas of Ontario, closer to 95% are dependent on private wells.

A water well can be defined as a constructed conduit comprised of casing, intake, pump and ancillary components designed to extract water from an aquifer and discharge the water to some point of use. This description is common and applies to all wells and their components regardless of size or purpose.

There is a growing appreciation that water wells and aquifers must be regarded as integrated components of a complete delivery system and that well infrastructure is made up of not only the well but also the aquifer environment directly around the well through which groundwater flows. Accordingly, this also should include the distribution line from the well to the water delivery point.

In Ontario, there is a fairly widespread availability of local long-yielding aquifers at depths in the range of 20 to 50 m. In these areas, private wells are often shallow and some may be of large diameter (i.e. dug or bored). In comparison, municipal wells are usually drilled to greater depths into regional aquifers and have a larger production capacity than private wells. Accordingly, they are typically expertly located, designed, constructed and operated to distribute water to a treatment plant and then to multiple users. All municipal groundwater is treated for disinfection purposes prior to distribution and most systems remove nuisance compounds (commonly iron and manganese). Municipal wells are proactively managed by trained and qualified personnel.

The majority of private wells are used to deliver water to a single user or purpose. They are typically of a smaller capacity than municipal wells and the water that they produce is not usually disinfected. Many are constructed in poorly protected settings. Management is typically not undertaken in a dedicated way and intervention to correct well problems is usually carried out reactively. Much of this situation can be attributed to a general lack of awareness about water wells, water quality issues and well maintenance procedures by the well owner. This lack of awareness is reinforced by the situation that wells, in general, are not "user-friendly". The access to the interior and subsurface well components is difficult, and usually requires special

equipment to remove contractor-installed well components such as pumps, discharge lines and electrical cables.

Proactive evaluation of conditions inside the well, particularly below the water level is a daunting task and often set aside. Even basic management issues such as water level monitoring or collecting water samples nearest the well head for chemical/biological evaluation are compounded by the access problem to the hidden interior portions of a typical drilled well. In addition, there is seldom a sampling port at the well head (i.e. closest to the pump) as shown in the diagram of a typical drilled well in Figure 2.1).

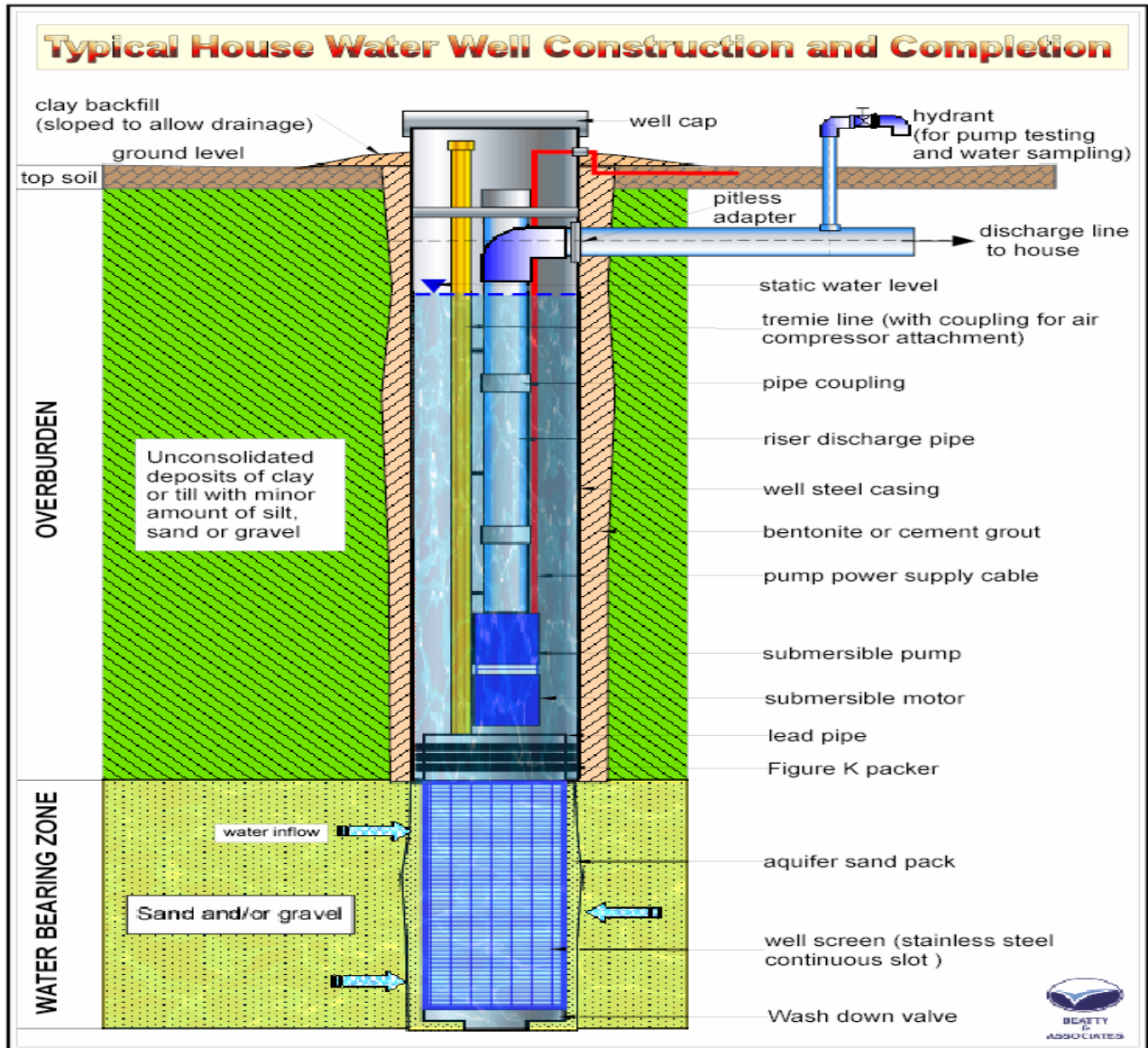


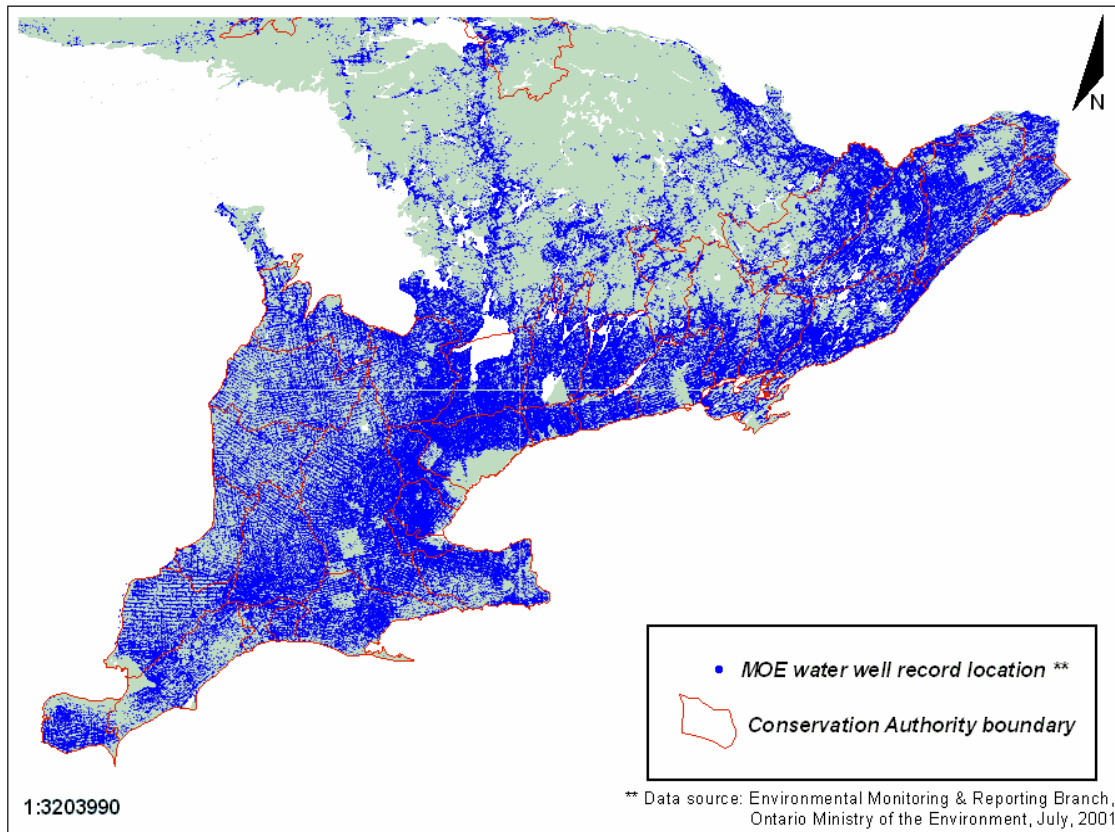
Figure 2.1 Well Properly Fitted with Water Level Monitoring and Sampling Ports

The preceding suggests why many water wells have been treated and operated as “turn key” operations and fixed as a last resort only when broken. In the specific case of private wells, an “install and forget” attitude understandably appears to prevail on the parts of well owners. This is particularly significant for the life cycle management and the sustainability of water wells, which are most numerous and most heavily relied upon in support of rural life and enterprise.

Little is known about the life cycle of private water well infrastructure in Canada, as a whole - rehabilitation and/or decommissioning data is rarely, if ever, available in established provincial data collection systems. The present condition; age at failure; and life expectancy of private water wells remain knowledge gaps in most jurisdictions. The newly developed well tagging system in Ontario developed in 2004, however, represents a significant step in correcting this situation in the future.

In Western Canada, several field surveys performed suggest that the average useful life of water wells before failure ranges between 10 to 25 years (Lebedin et al., 2000). While the age variance at failure in these surveys can be attributed to factors such as well maintenance, construction materials, aquifer characteristics and groundwater chemistry, it remains that many of the wells appear to be significantly affected by biofouling, - a condition that was recognized to be pervasive and a significant contributor to shortened well life by creating either a water quality problem or reduced productivity or both.

What has emerged perhaps most significantly in such studies, is that the investment in private water well infrastructure is substantial. For example, it is estimated that \$2 billion has been spent in the Prairie Provinces alone to construct approximately 400,000 wells since 1961 to the present. Ontario, with a reported construction estimated to be 750,000 wells since the 1950s, would easily be of similar order with respect to infrastructure investment (Figure 2.2). This does not include the economic value of the enterprise that this water well infrastructure supports by way of providing a secure groundwater supply. Knowledge about the condition of this infrastructure or how to extend the operational life of these wells is lacking despite the very heavy reliance on it.



**Distribution of MOE water well records in southern Ontario**

**Figure 2.2 Distribution of MOE Well Water Records in Southern Ontario**

Source: EMRB, MOE (2001).

## **2.2 Well Life Cycle Components**

The life cycle of all wells is comprised of five parts: 1) planning (locating/siting); 2) construction; 3) functional life (operating and maintaining); 4) approaching end (rehabilitating); and 5) decommissioning (see Figure 2.3). Each part has a bearing on the useful life span of the water well and from a utilitarian perspective, its life cycle cost. A more detailed discussion of each of the life cycle components is provided in Chapter 7 (Location and Construction); Chapter 8 (Operation, Maintenance and Rehabilitation); and Chapter 9 (Decommissioning).

### ***2.2.1 Location***

Wells typically are installed in an aquifer that will produce an adequate supply to meet the well owner's needs. In addition, they are located a safe distance from other infrastructure (e.g. waste fields, holding tanks etc.) and are accessible for pump installation and maintenance. In Ontario,

this requires adherence to Regulation 903 which has very specific requirements for setback distances and well construction details. Reg. 903 was originally enacted in the early 1960s, revised first in 1985 and again in August, 2003 (see Appendix H). Locating a well properly requires consideration of the historical, present, and planned future land uses. Identifying the location of the well accurately and detailing its construction data, also facilitates its proper decommissioning and contributes to the management of knowledge of the water well life cycle.

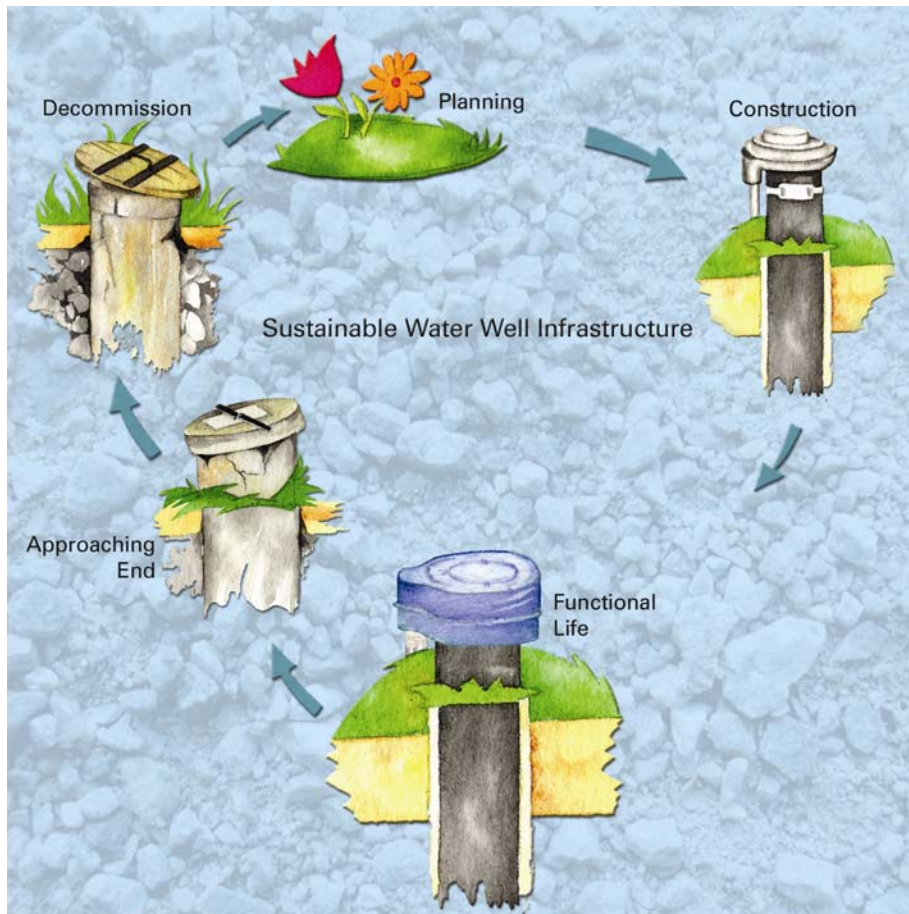


Figure 2.3 Sustainable Water Well Infrastructure Life Cycle

### 2.2.2 Construction

Well construction consists of drilling, boring or excavating to a suitable depth into an aquifer and setting casing, screening and pumping equipment in compliance with MOE regulations governing well siting, use of approved materials and completion methods. Reg. 903 requires the water well contractor to conduct a 60 minute pumping test to determine well yield and to benchmark well performance characteristics. A well record of geological materials encountered, GPS coordinates, construction and owner details is submitted to MOE and archived for management information purposes.

### **2.2.3 Operation and Maintenance**

All water wells require attention to the operation of principal components including well intakes (i.e. screens, slots, open sections exposed to fracture zones in bedrock etc.) and casing, pumping equipment, surrounding land uses) and the distribution line. Common maintenance practices should include periodic inspection of water quality; measurement of specific capacity; inspection of components for corrosion and or structural integrity; disinfection by chlorination; and well treatment if required to restore the well yield. In more recent years, microbiological conditions have been recognized that cause biofouling of well intake areas, pumps and casings. Special chemical treatment with a biocidal effect may be applied in restoring lost production capacity, to control taste and odour problems and to minimize hygiene risk.

### **2.2.4 Rehabilitation**

Lost production capacity, poor quality water or inadequate well design are the dominant reasons for rehabilitative efforts. These can be attributed to any one or combination of four factors:

- 1) loss in casing/screen integrity or pump failure - In such cases corrosion or faulty construction may cause interior components to be exposed to sand production/screen blockage, casing leakage, premature wear on pump parts and turbidity and discoloration;
- 2) chemical incrustation - This is caused by precipitation of dissolved minerals on screen surface that impede flow;
- 3) biofouling - This is created through prolonged well operation and the growth of naturally occurring groundwater bacteria in and around well screens and immediately adjacent aquifer environments; or
- 4) well interference – This occurs when nearby supply wells pump sufficient groundwater to cause a lowering of the water level in wells within the zone of influence.

Biofouling may also accelerate chemical precipitation processes and promote bio-corrosion of metallic well components. In the case of mechanical or structural problems, well rehabilitation can range from efforts as basic as redevelopment or as extreme as outright abandonment and replacement of the entire well. Chemical or biological difficulties require chemical and biocidal treatments to clean interior well surfaces and, as necessary, the adjacent aquifer environment and distribution line from the well. Refurbishing wells installed in pits or retrofitting wells with improved connections and well caps etc. are also considered rehabilitative measures and such measures are often structural improvements performed to enhance well safety and reliability, but not necessarily well performance.

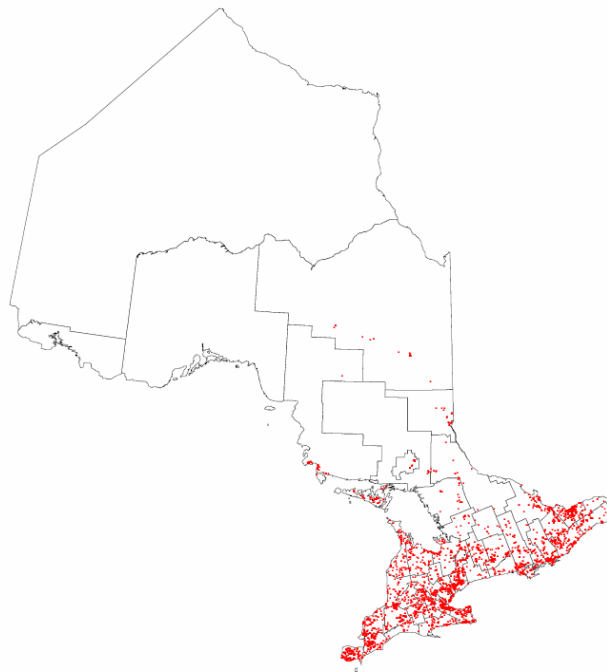
### **2.2.5 Decommissioning**

Wells which have lost required production capacity, show signs of damaged casing or screen or are simply no longer needed, have completed their life cycle and should be decommissioned. A replacement well is often required. The recently developed well tagging system in Ontario allows such events to be tracked and ensures that important life cycle data is archived and information concerning construction details is available and considered in the proper closure of the well.

### 2.3 Wells in Ontario

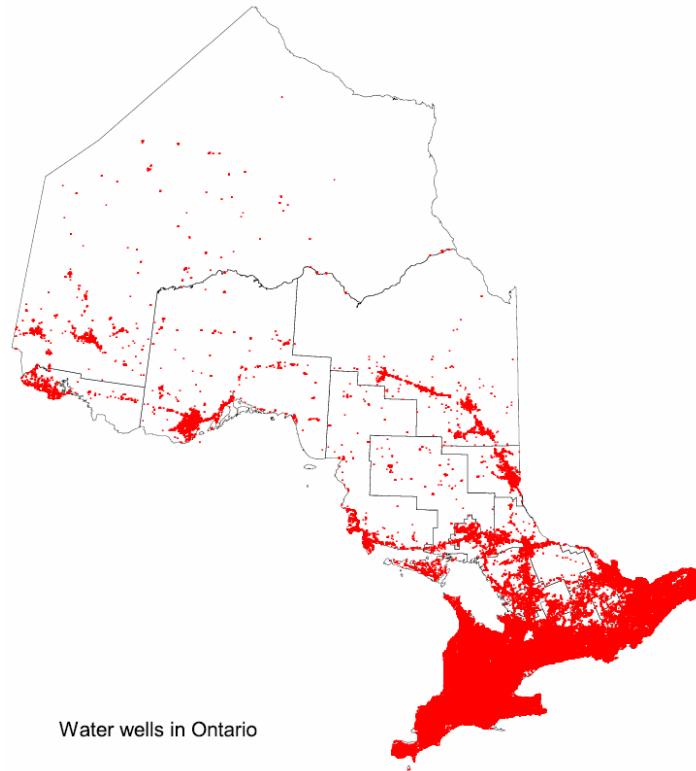
Figure 2.4 and 2.5 show the distribution of water wells in Ontario in 1950 and up to June 2002. The actual number of wells in Ontario is unknown, as not all wells are registered in the Ministry of Environment Well Driller logs. Estimates indicate that there may be 750,000 wells in Ontario with close to 500,000 abandoned wells. To get an idea of number of wells represented in Figure 2.5, the Oak Ridges Moraine has conducted a number of investigations including efforts to compile a well inventory. These studies show approximately 200,000 wells of which 135,000 are private wells.

Approximately 10,000 - 20,000 new wells are drilled each year in Ontario.



**Figure 2.4 Wells Constructed in Ontario in 1950**

Source: EMRB, MOE (2004).



**Figure 2.5 Water Wells in Ontario (to June 2002)**

Source: EMRB, MOE (2004).

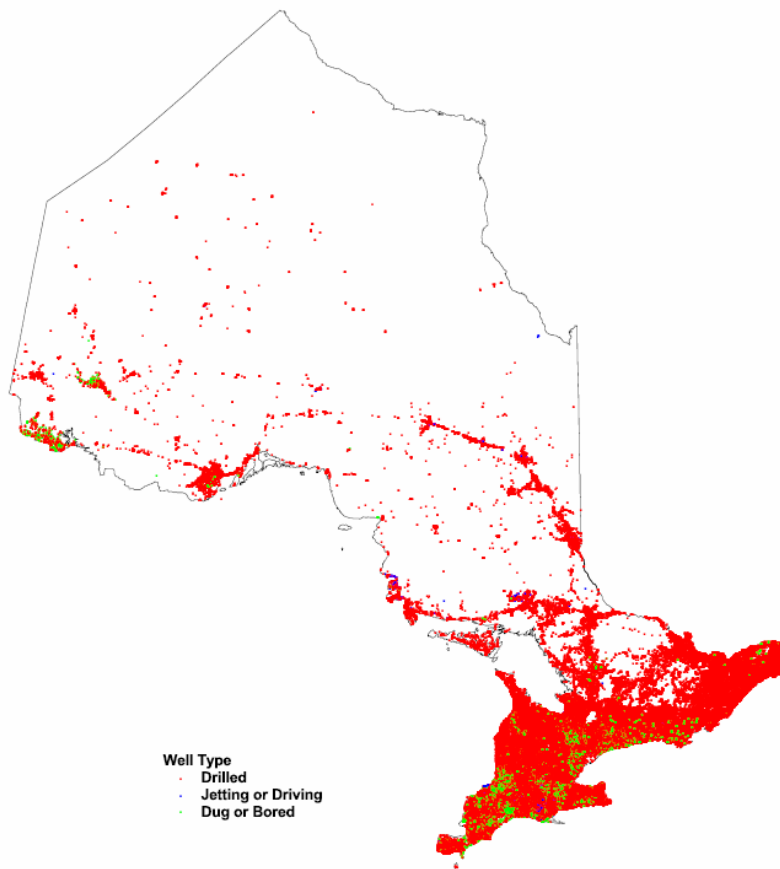
There are three predominant types of well construction in Ontario. Dug or bored wells, generally have a much larger diameter, up to 1 - 1.5 m or more for older wells. The casing may not remain water tight over long periods of time. Drilled wells are of smaller diameter, generally 0.10 – 0.15 m, and have a metal or polyvinyl chloride (PVC) casing. A sub-group of drilled wells are finished below ground, either alone or in a well pit. These drilled wells tend to be less secure than a drilled well finished above-grade as the pits can fill with water, debris and other materials. This condition contributes to premature corrosion of the casing and cap and may eventually allow surface water to find a path into the well water supply.

Table 2.1 summarizes information from inspections of wells in selected areas of Ontario. The results were obtained from a limited number of studies and cannot be considered representative of Ontario as a whole. Drilled wells are the most common type (45 – 71%), but more than half the drilled wells observed in some studies were finished below ground. Drilled wells finished inside a dug well are not common (1 – 6%) but represent a risk to deeper aquifers because of the construction. The well is drilled through the base of the older well which is not decommissioned. An average of 27 % of the wells observed in these various initiatives were dug or bored wells with the vast majority under 15 m in depth. Shallow dug or bored wells, located in sites where there is a shallow soil profile and/or a high water table, can be very vulnerable to contamination. Further discussion of well construction is presented in Chapter 7.

**Table 2.1 Summary of Well Type Observed in Ontario**

| Well type                            | Frank et al., 1990 | Goss et al., 1998 | Conboy and Goss, 2000 | Well Discovery (2002) | Well Aware GSA (2003) | Rural water testing program |
|--------------------------------------|--------------------|-------------------|-----------------------|-----------------------|-----------------------|-----------------------------|
| Dug or Bored                         | 27%                | 34%               | 33%                   | 10%*                  | 30%                   |                             |
| Drilled                              | 71%                | 58%               | 45%                   | 59%                   | 58%                   |                             |
| Well Pit**                           |                    |                   |                       | 33%                   | 30%                   |                             |
| Sandpoint                            |                    | 6%                | 12%                   |                       | <1%                   |                             |
| Drilled inside dug                   | 1%                 | 4%                |                       | 6%                    |                       |                             |
| % linked to MOE well record database |                    |                   | 54%                   | 49 (24%)              |                       | >30%                        |
| # of wells                           | 179                | 1237              | 300                   | 202                   | 423                   | 1046                        |

\*16% did not know their well type \*\* well pit is a type of drilled well, percent represents percent of total number of wells, not just percentage of drilled wells.



**Figure 2.6 Distribution of Well Type in Ontario**

Source: EMRB, MOE (2004).

Wells in Ontario are aging as shown in Figure 2.7. The figure shows that the majority of wells surveyed in 1992 through the Ontario Farm Groundwater Quality (OFGWQ) survey and also

those inspected during the summer of 2003 through the Well Aware Guided Self Assessment (GSA), were constructed prior to the 1985 revisions of Regulation 903. The OFGWQ survey was conducted in 1991-92, thus only the first column in the chart reflects wells that would be constructed according to the 1985 revisions; although, the first two columns capture the majority of the wells observed through GSA that were constructed since the 1985 revisions. In addition to the age of the wells, the condition of the wells was often found to be deteriorating. The Well Aware Guides indicated the need for a repair in 89% of the visits conducted.

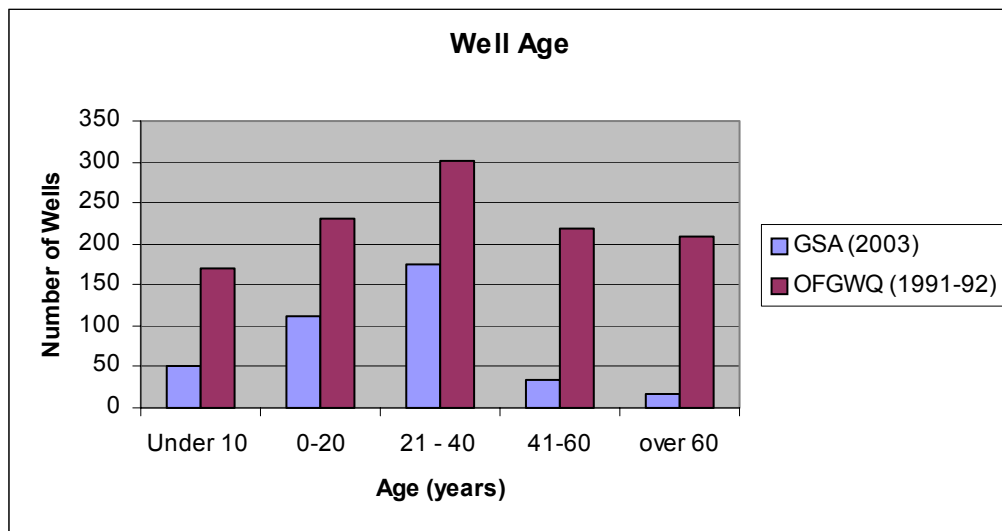


Figure 2.7 Distribution of Well Age in Ontario

An Environics survey of 400 well owners (GCA, 2002) showed that most (89.5%) respondents thought their well was in good condition. However, most also reported not doing any kind of maintenance and were unaware of how to properly inspect their well or improve its longevity. In addition, only 5.5% indicated that they understood that septic systems could affect their water quality. Lack of knowledge was identified as a key barrier and again from this survey, 75% of respondents reported that they never received any information pertaining to their wells.

## 2.4 Well Infrastructure Management: The Sustainable Asset Management Approach

It is clearly advantageous to develop knowledge, practices, techniques and technologies that will extend the life cycle of water wells and render them safe and reliable. Premature well failure presents increased cost because of well decommissioning, or where abandonment or non use presents contamination risk by way of the connection to an underlying aquifer.

In Ontario, knowledge of groundwater resources is a work in progress. Several major aquifers (Oak Ridges Moraine, Waterloo, Oxford) are now under exemplary management plans that are intended to sustain the quantity and quality of the groundwater. Completion of groundwater studies in most regions of Ontario has provided a greater awareness of groundwater resources at the municipal level. Commensurate with this is the knowledge required to manage and sustain individual wells. Continuing effort must be directed toward understanding water well

infrastructure and how to extend well life and enable wells to function safely and reliably in their respective aquifer environments.

Of the well life cycle components outlined previously, there is consensus that greater attention is required on well operation, particularly on maintenance and rehabilitation. These components are regarded as presenting the greatest potential for sustaining well infrastructure and ensuring the longevity of wells and investment in them. Presently there are new diagnostic techniques for evaluating well problems and promising new technologies designed and now fairly well accepted to either prevent well problems or rehabilitate them which need to be broadly disseminated (Smith, 1995; Borch et al., 1993).

The management of water wells in Ontario has been largely a complaint-driven, crisis management approach for a decade or more. This type of system is not proactive and does not create sustainable water supplies. Sustainable Asset Management (SAM) is a way to manage a system holistically for continuous improvement, including a process to measure improvement. It ensures the latest techniques, the best science, the most appropriate engineering and the most effective human and financial resource management be universally available to systems of all sizes in all communities. Asset management can be defined as “*managing capital assets to minimize the total cost of owning and operating them while delivering the level of service demanded by the customer and the regulator*” (Allbee, 2005). This is a preventative management approach that encompasses all steps in water production from catchment to consumer.

The asset management approach has become an integral part of managing Ontario municipal systems through the *Sustainable Water and Sewage Systems Act*, Bill 175. It is designed to move municipalities towards full-cost accounting, asset management and full-cost recovery of water and wastewater services. Proficiency in the SAM approach requires analysis of tradeoffs and their implications for economics, environmental protection and the users. The asset management solution for municipal wells is a comprehensive source-to-tap approach with heavy reliance on water treatment to deliver safe drinking water.

There are many examples where poor well maintenance causes serious problems that could have been prevented through a proactive approach to avoid environmental problems and significant costs. Deferring well maintenance and replacement leads to higher capital costs in the future. This is complicated by the fact that the longevity and causes for failure of wells are not well understood.

Many of the steps to develop a SAM approach and actions to be taken to support a SAM approach could be applied to water wells. Examples include: evaluation and analysis of resource; implementation of training programs; conduct of Centre of Excellence multi-jurisdictional research; establishment of core research programs; and ensuring consistency in approach across province. The asset management approach integrates quality and risk management principles. It does not eliminate the requirement for monitoring but provides verification that preventative measures are effective.

Achieving excellence in asset management practices will only come about through the hard work and mastery of specific tools and techniques. Bringing about excellence in the execution of particular processes, procedures, techniques and tasks is above all a function of hard work, training, coaching, peer-to-peer exchange, mentoring and benchmarking. These new approaches will produce significant cost savings over the long-term and make meeting the infrastructure challenge more manageable.

## **2.5 Conclusions**

1. Management of private water wells is usually not carried out in a proactive manner, due to limited operator knowledge, and an “install and forget” attitude among well owners. This attitude is reinforced by a non user-friendly well design.
2. Municipal wells are generally much better managed, although the longevity of these wells may also be at risk in some cases. Municipal wells are usually tested for chemical or biological parameters and yield on a relatively regular basis.
3. The present condition, age and life expectancy of private wells remains largely unknown as are the reasons for well failure.
4. The Panel recognizes that there is significant investment in water well infrastructure in Ontario. Sustainable asset management (SAM) is recognized as a possible means to protect this significant investment. The effort involved to investigate this approach in more detail was beyond the resources of the Panel.

## **2.6 Recommendations**

1. Collaborative research is required into the development of user-friendly well designs for new installations and retrofits on existing wells.
2. Continuing effort must be directed toward understanding water well infrastructure and how to extend well life and enable wells to function safely and reliably in their respective aquifer environments.
3. A technical consumer’s guide for private well owners should be developed to focus on improving technical knowledge of well construction and maintenance.
4. The Panel recommends that SAM (sustainable asset management) be investigated more thoroughly as a potentially cost-effective approach to extending the sustainability of private water wells. Therefore there is a requirement for data gathering that will support SAM. In addition, an affordable service program that provides for routine well maintenance should be set up similar to those available for furnaces or air conditioning systems.

## 2.7 References

Allbee, Steve 2005. America's pathway to sustainable water and wastewater systems, The United States Environmental Protection Agency, USA, © IWA Publishing 2005

Fleming, R.J. 1992. Rural well water survey. Huron County 1991: Final report to the Ontario Ministry of Agriculture and Food. Huron Park, ON, Centralia College of Agriculture Technology.

GCA (Green Communities Association). 2002. Well Aware Phase 1 Report. including Environics survey results. Prepared for Ontario Ministry of the Environment..

Gohier, L. F. 2005 Sustainable asset management, presentation made Washington DC, May 2005, Canuck update.

Goss, M.J., and Rudolph, D.L. 1992. Ontario Farm Groundwater Quality Survey -Winter 1991/92. Agriculture Canada, September 1992.

Goss, M.S., Barry, D.A.J., and Rudolph, D.L. 1998. Contamination in Ontario Farmstead Domestic Wells and its Association with Agriculture: 1: Results from Drinking Water Wells. Journal of Contaminant Hydrology, 32, 267-293.

Hrudey, S. E. Drinking Water Risk Management Principles for a Total Quality Management Framework

Lebedin J., Rohde H., Jaques D., and Hammer M., 2000. Rural Water Well Infrastructure Assessment on the Prairies: An Overview of Groundwater Development and Reliance Trends. March 31, 2000. Agriculture and Agri-Food Canada -PFRA. 14 p.

Lee-Han, H., Hatton, B. Editors. 1991. Regional municipality of Waterloo: survey of bacteriological and nitrate contamination of private well water. Waterloo, ON, The Municipality.

Powell, G. 2004. Sustainable Water and Waste Water Utility Management, An Engineer's Perspective. Presented to OMEC, Kingston, September 16, 2004, CH2M HILL Canada

Sinclair, M. Drinking Water Quality Management: The Australian Framework.

Smith S. A., 1995. Monitoring and Remediation Wells. Problem Prevention, Maintenance and Rehabilitation, Lewis Publishers. 182 p.

### **3.0 Groundwater Resources in Ontario**

Groundwater is the primary source of supply for virtually all rural water users in Ontario and about half of the Provinces' municipalities. The distribution and sustainability of the resource, however, depends on the unique geology and climate in the Province. The distribution of groundwater is complex due to the diverse and widely varying geologic conditions found throughout the Province. The sustainability of groundwater is largely a function of the unique climatic conditions. Areas where groundwater is abundant have been able to sustain urban growth and expansions of villages, towns and cities. Areas with limited groundwater resources have largely remained rural, with the exception of communities on major rivers or those bordering the Great Lakes.

The pattern of rural growth in the Province has been strongly influenced by the availability of groundwater supplies. While pioneer communities usually developed around mill sites or streams and rivers, their growth depended mostly on the existence of good aquifers. The largest groundwater-based growth has occurred in the Kitchener-Waterloo area due to extensive aquifer systems in the area. In contrast, communities with limited groundwater resources have experienced little growth over the past century.

The diverse geological and climatic conditions in Ontario require a variety of approaches to well design, location, and construction. This presents unique challenges for well life cycle management. Where overburden materials are thin, the choices are limited to dug wells sitting on bedrock or wells drilled into bedrock. In contrast, where ample granular sediments are available, drilled wells are the most common. Similarly, in areas of the Province where rainfall is less or more abundant, specific well designs are dictated by the potential for recharge, or lack thereof, to that well.

Although a comprehensive province-wide mapping of the groundwater resources in Ontario has never been conducted, the Ministry of the Environment has recently undertaken regional scale investigations using existing data that cover most of the populated areas (see Section 3.6). An overview of groundwater in Ontario was produced in 1994 by the National Hydrology Research Institute of Environment Canada (MacRitchie et al., 1994) and this document provides a useful addendum to the information provided in this chapter.

#### **3.1 Groundwater and Climate**

The sustainability of groundwater in Ontario is closely related to the Province's unique climatic conditions. With a semi-humid climate and close to a metre of precipitation every year, there is an abundance of water available to recharge the aquifers.

Although the annual precipitation in Ontario is distributed uniformly throughout the year, the climatic conditions have a major influence on groundwater recharge patterns. For example, over half of the annual groundwater recharge usually occurs over a two-month period each spring. This is the period when an accumulation of snowmelt water and lack of water losses to growing

vegetation allows peak recharge to occur. The annual spring recharge event is largely responsible for the long-term sustainability of the groundwater resources in the Province.

Under average climatic conditions in Ontario, minimal groundwater recharge occurs in the winter and summer months. During the winter, frozen ground conditions significantly reduces recharge. During the summer, evapotranspiration losses from growing vegetation usually reduces recharge to negligible amounts.

The unique climatic conditions in the Province sustains an annual groundwater recharge of 30 to 300 mm in non-urbanized areas. This range of annual recharge provides Ontario with major renewable groundwater resources.

### **3.2 Groundwater and Geology**

The flow patterns and availability of groundwater in Ontario are mostly dependent on the geologic conditions, which vary widely throughout the Province. The sustainability and quality of the groundwater supplies depends primarily on local geologic conditions. For example, the yield of wells depends on the hydraulic conductivity and thickness of the water-bearing materials; the quality of groundwater depends on the length of the flow paths and the mineralogy of the geological materials. The sustainability of the supply depends on the annual volume of recharge that migrates from the surface down to the aquifer.

Ontario has two principal geologic materials, which can be tapped for groundwater supply: fractured bedrock and sand and/or gravel overburden deposits. Bedrock is found throughout the Province and is the result of several billion years of geologic activity. The sand and gravel deposits, which are less than 100,000 years old, are associated with advances and recessions of continental ice sheets that covered the Province. Together, these two geologic formations form aquifers which provide storage for groundwater resources and a perpetual water supply to wells.

There are dozens of bedrock formations throughout Ontario, and for the most part, they have been accurately mapped. Potable bedrock aquifers, however, are limited to a relatively small percentage of the Province due to variable fracture patterns and the mineral composition of the rock. Sand and gravel aquifers are widespread throughout the Province, but range in size from small, isolated lenses in glacial till sheets to massive formations that are several hundred square kilometers in area. Overburden aquifers in general, are much more complex than bedrock aquifers and as a result, are more difficult to delineate. Mapping of aquifers requires knowledge of the subsurface conditions which is provided mainly by water well records. As a result, the accuracy of overburden aquifer maps is largely dependent on the depth and density of water supply wells.

Adequate groundwater for domestic supplies of up to 5 m<sup>3</sup> /day can usually be obtained by drilling wells a few tens of metres into most of the bedrock or overburden materials found in Ontario. In some isolated areas, where groundwater supplies are marginal, residences utilize storage facilities to provide sufficient capacity for the peak periods of daily use. Non-domestic uses, such as livestock watering, irrigation and fire fighting can be supplemented in areas of low well yields by the use of storage facilities.

Many of the geologic formations in the Province are very permeable and can support high capacity wells. The most productive aquifers are found in glacial outwash deposits of sand and in fractured sedimentary bedrock. The most productive sand and gravel aquifers are usually associated with buried bedrock valleys, glacial outwash channels, eskers and moraines.

The high-yielding sand and gravel and sedimentary bedrock aquifers are the primary source of groundwater for municipal supplies, irrigation, geothermal energy, and major industrial/commercial uses. Only a fraction of the major aquifers in Ontario, however, have actually been developed for water supply. Large groundwater resources remain undeveloped and available for future uses.

### **3.3 Groundwater Distribution in Ontario**

As noted in the previous section, adequate groundwater supplies for domestic use can be found almost anywhere in Ontario. A brief overview of the general distribution of groundwater in bedrock and sand and gravel aquifers throughout the Province is presented in the following sections. To simplify the discussion, bedrock and overburden deposits will be reviewed separately.

#### **3.3.1 *Groundwater in Bedrock***

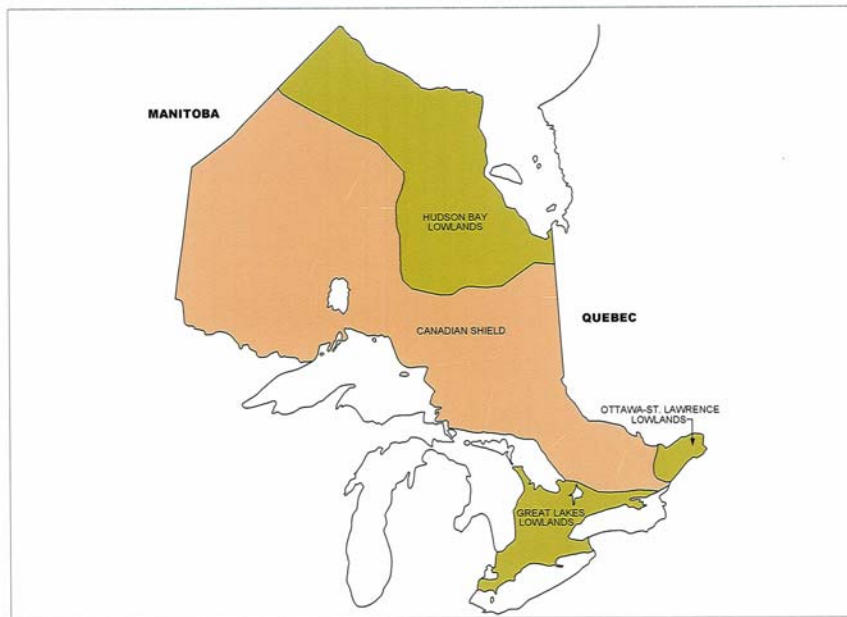
Groundwater movement in bedrock is limited to cracks, joints and fractures in the various formations. As a result, the fracture density and width of the openings control the occurrence and availability of groundwater. In areas where the rock mass is largely unfractured, significant groundwater can only be obtained from local discontinuities such as faults and zones of highly weathered rock.

There are over two dozen distinctly different bedrock formations in the Province. In terms of groundwater, each formation has two distinct characteristics: 1) the hydraulic conductivity of the fracture network; and 2) the water quality. In general terms, most of the bedrock in Ontario produces low well yields due to poorly developed or closed fractures. In addition, some bedrock formations produce good supplies, but soluble minerals in the rock render the groundwater unpotable.

The lowest well yields are generally found in igneous and shale rocks. The highest yields are obtained from sedimentary rocks such as sandstone, limestone and dolostone. These rocks tend to have a dense network of fractures that are sometimes opened by chemical dissolution of soluble minerals (e.g. – gypsum).

The distribution of groundwater bedrock will be examined in the four major bedrock regions of Ontario. The four areas are shown on Figure 3.1 and include:

- 1) the Canadian Shield – igneous rock,
- 2) Hudson Bay lowlands – sedimentary rock,
- 3) Ottawa – St. Lawrence lowlands – sedimentary rock, and
- 4) Great Lakes lowlands – sedimentary rock.



Major physiographic and hydrogeological regions of Ontario

FIGURE 3.1

**Figure 3.1 Four Major Bedrock Regions in Ontario**

Where possible, examples of high capacity municipal wells will be given to indicate the range of yields that are available from bedrock water wells. The best quality and highest capacity bedrock aquifers are indicated in Figure 3.2.

1. Canadian Shield

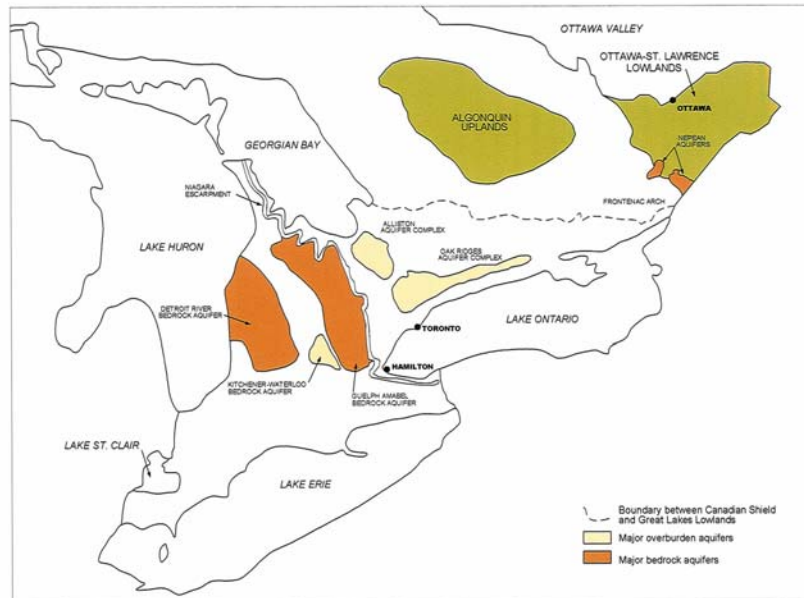
The Canadian Shield consists of a variety of 1 billion-year old Precambrian rocks including granite, gneiss, metasedimentary and metavolcanic rocks. Most of the igneous rocks have poorly defined fracture patterns and as a result, the majority of wells in the Shield supply less than ½ L/s. Locally, large well yields are available in discontinuities such as faults, dykes, fracture zones, etc.

Groundwater quality is relatively good in the upper few hundred metres of the Shield rocks. Calcium and sodium bicarbonate water is generally found in the shallow strata. Iron and manganese are widespread in igneous rock. Occasionally, heavy metals and radionuclides may also be present.

Examples of a few isolated high capacity wells in the Shield rock include the municipal wells at Deloro, Madoc and Tweed.

2. Hudson Bay Lowlands

The Hudson Bay lowlands are a sparsely populated area, which covers about one quarter of the Province. The area forms a 250 to 280 km wide band along the shore of Hudson Bay and James Bay. These lowland areas are mostly covered with frozen muskeg.



Major physiographic and hydrogeological features of southern Ontario

FIGURE 3.2

### Figure 3.2 Major Bedrock Aquifers in Southern Ontario

Bedrock in the Hudson Bay lowland consists of Paleozoic rocks, which are divided into 16 different formations. The rocks consist mainly of limestone and dolomite. High well yields, in the order of 10 to 16 L/s (MacRitchie et al., 1994) are possible from these rocks. Little data, however, is available on water quality in the Hudson Bay Lowland bedrock.

### 3. Ottawa – St. Lawrence Lowlands

The Ottawa – St. Lawrence lowlands are located in south-eastern Ontario, between the Precambrian Frontenac Arch, a ridge in the Canadian Shield, and the Ottawa and St. Lawrence Rivers. The bedrock in this area consists of Paleozoic sedimentary rocks, which are divided into four different formations. The rocks are mainly limestone, dolostone and sandstone.

The most important feature of the bedrock in the Ottawa – St. Lawrence Lowland is the faulting that has occurred (MacRitchie et al., 1994). The faulting has a significant influence on groundwater flow patterns, especially where permeable, fractured rocks have been placed next to less fractured rocks.

Groundwater supplies are variable in the Ottawa – St. Lawrence Lowland sedimentary bedrock and depend on the fracture patterns in the various formations and the proximity to the fault zones. Well yields of 0.5 to 1 L/s are available in most of the area, however the best aquifers in the region are found in the Nepean, March and Oxford Formations which outcrop along the boundary of the Canadian Shield. High capacity wells, with yields up to 50 L/s, have been developed in these sandstones and dolostones.

### 4. Great Lakes Lowlands

The Great Lakes lowlands area is bordered by the Canadian Shield, Georgian Bay, and Lakes Huron, Erie and Ontario. This area includes the most densely populated part of the Province. The bedrock consists of Paleozoic sedimentary rocks, which are divided into about 18 formations. The Niagara Escarpment is the most prominent topographic feature of the area and separates the low-yielding rocks to the east from the high-yielding rocks to the west.

### **East of the Niagara Escarpment**

Rocks to the east of the Niagara Escarpment consist of shale and limestone. Both formations are poor aquifers and the groundwater is highly mineralized. In addition, the shales frequently contain low levels of methane gas. Private wells in these bedrock formations usually obtain groundwater from the upper few metres of the rock. Of the few municipal wells completed in the bedrock, in the region, the Cannington well (east of Lake Simcoe) has the highest yield at 5 L/s.

### **West of the Niagara Escarpment**

Ontario's most extensive and productive bedrock aquifers border the west side of the Niagara Escarpment. The well known Amabel, Lockport and Guelph dolostone and limestone formations extend from the Niagara Peninsula to the Bruce Peninsula and average about 100 m in total thickness. The hydraulic conductivity of these formations is high due to a dense network of fractures which have been opened in some areas by chemical dissolution.

Some of the municipalities that have high capacity wells in the Amabel, Lockport and Guelph rocks include Orangeville, Acton, Arthur, Dundalk, Erin, Guelph, Cambridge, Fergus and Markdale. Although the well yields are variable in these rocks, supplies of up to 60 L/s have been found. The water quality usually has a high mineral content, depending on the occurrence of lenses of anhydrite, gypsum and salt.

The second most productive bedrock aquifers in Ontario are found in the Counties of Oxford, Perth, Huron and parts of Grey, Middlesex and Norfolk. The Dundee Detroit River Group, Bois Blanc and Salina in this area consists of fractured crystalline limestone with some sandstone and dolomite. Municipalities with high capacity wells in these formations include Walkerton, Teeswater, Wingham, Goderich, Centralia, Woodstock, Ingersoll and Stratford. Well yields up to 150 L/s have been reported.

The Dundee and Detroit River aquifers are also found in the southwest corner of the Province (south of Lake St. Clair), but the water is often sulphurous. As a result, it is mainly used for irrigation purposes. The mineralization in this area increases with depth.

The region between London, Sarnia and the north shore of Lake Erie is underlain by shales. These formations yield small supplies and the water quality is usually poor.

## **3.4 Groundwater in Overburden**

Groundwater in overburden is found in all saturated sand and gravel sediments that were deposited during the Pleistocene (Great Ice Age) Epoch, when Ontario was covered by massive

ice sheets. The distribution of overburden ranges from thin or absent in eastern parts of Southern Ontario, along the Niagara Escarpment and over the Canadian Shield to over 200 m thick in the Oak Ridges Moraine. The size and extent of the water-bearing sediments is often extremely complex, particularly in areas of major glacial activity, which occurred during the most recent Wisconsin Stage.

There are dozens of glacial landforms such as drumlins, eskers, kames, moraines, spillways and shorelines that contain surficial or buried sand and gravel deposits. Except for outcrops of shallow sand deposits, overburden aquifers are discovered primarily by drilling. In densely populated rural areas, the aquifers may be accurately delineated however, many overburden aquifers in Ontario remain only partially mapped.

Overburden aquifers in Ontario are mainly found in glaciofluvial deposits (outwash deposits and ice-contact stratified drift) and glacioacustrine deposits (sediments deposited in lakes by meltwater rivers). Local glaciomarine deposits (sediments deposited into a sea by meltwater rivers) are found east of Ottawa and Brockville.

The highest yielding aquifers are usually discovered through test drilling programs for municipal, commercial, industrial or irrigation supplies. Such drilling programs, however, seldom delineate the full extent of the aquifers. As a result the potential capacity of most aquifers in Ontario is not precisely known.

The capacity of wells in overburden aquifers ranges from about 1/10 L/s to over 100 L/s. The smallest yields are found in thin sand lenses in glacial till sheets or in glaciolacustrine (water lain) deposits of fine sand. The largest yields are found in outwash and spillway deposits of coarse sand and gravel.

Unlike the bedrock aquifers, overburden aquifers cannot be categorized by regions within the Province. Instead, overburden aquifers are best summarized in terms of their production capacity. The most significant sand and gravel aquifers are summarized below.

### 1. Glaciofluvial Deposits

Glaciofluvial deposits include glacial outwash and ice-contact stratified drift. Outwash deposits generally support the largest capacity overburden wells in Ontario. These deposits are found throughout southwestern and central Ontario in glacial meltwater channels, including buried bedrock valleys and extensive deltas which are laid down where meltwater streams emptied into glacial lakes. The most productive outwash aquifers are the gravels which are deposited in narrow bedrock valley systems or close to the original ice margins.

There are numerous bedrock valley aquifers in the soft shales located east of the Niagara Escarpment. The Laurentian Valley, a wide, deep bedrock valley, extends from Georgian Bay to Lake Ontario. Numerous small bedrock valleys drained upland areas west of the Niagara Escarpment during pre-glacial periods. High capacity wells capable of yielding

50 to 100 L/s have been located in valley aquifers in Halton Hills, Milton, Brampton, Caledon, King Township, Vaughan, Markham, and the northern parts of Toronto.

The most extensive outwash aquifers include the Alliston Aquifer Complex; the London Aquifer; the Kitchener-Waterloo Aquifer Complex; and the Oak Ridges Aquifer Complex. These major aquifers support high capacity wells in Kitchener-Waterloo, Barrie, Bradford-West Guilmubury, Brighton, Aurora, Newmarket, Stouffville, Uxbridge and Port Perry. At some locations, the municipal demand has exceeded the sustainable supply and heads in the aquifers have slowly declined over a period of several decades.

Ice-contact stratified drift is variable in size and extent and usually outcrops at the surface. They comprise discontinuous deposits with within glacial features such as eskers, kames, and moraines. The ice-contact deposits are highly variable in transmissivity due to rapid changes in thickness and sediment gradation. Nevertheless, the deposits constitute a significant groundwater resource across most of the south-central part of the Province.

## 2. Glaciolacustrine Deposits

Glaciolacustrine deposits tend to be fine grained sands that were originally deposited along the shores of glacier-fed lakes. In some areas, such as Simcoe, Northumberland and Norfolk County, these surface sands are regionally extensive. These shallow aquifers are often unprotected by clay soils and are somewhat vulnerable to surface contamination.

Glaciolacustrine deposits provide good supplies for small-scale rural uses; however large-scale uses for municipal, industrial and irrigation purposes are limited. Some of the highest yielding wells in these deposits are found at Alliston, Beeton, Tillsonburg and Simcoe.

## 3. Glaciomarine Deposits

Glaciomarine deposits are only found mainly in eastern Ontario, which was originally flooded by seawater. These deposits are the least productive overburden, however well supplies are usually adequate for residential uses. Large, municipal-scale aquifer systems in these deposits are rare.

### **3.5 Groundwater Studies**

Between 2001 and 2004, the MOE provided over \$15M in grants to conservation authorities and municipalities to undertake a variety of groundwater studies. The grants covered 70 to 85% of the total costs of the work. In order to ensure a consistent approach and methodology to the studies, the MOE developed a comprehensive “Technical Terms of Reference” for the studies. Some of the key components of each groundwater study included:

- Mapping the regional and local groundwater conditions
- A conceptual model of the groundwater system
- Identification of information and data gaps
- Water well data validation
- Preparation of groundwater intrinsic susceptibility maps from the MOE water well data base (based on calculation of an intrinsic susceptibility indices (ISI) for each well in the study area)
- Inventory of potential regional contaminant sources
- Assessment of groundwater uses within each study area, including inventory of permitted large scale users (i.e. – over 50,000 L/day) in areas not serviced by public supply

In 2002, the MOE allocated an additional \$5M for mapping wellhead protection areas in all communities that rely on groundwater. Approximately 300 municipal wells were included in a total of 32 individual studies. The Wellhead Protection Area (WHPA) mapping focuses on delineation of the recharge areas which contribute water to each municipal supply well. These well capture zones can then be integrated into municipal official plans. This allows land uses within the WHPAs to be controlled, where required, to ensure long-term protection of the groundwater resources. It is important to note however that a variety of approaches to the delineation of WHPAs were allowed in the Terms of Reference. As a result, the level of detail and potential reliability of WHPAs is variable across the Province. In addition, as the WHPAs are primarily developed on limited hydrogeological data, the actual value of the delineation has yet to be determined in most cases.

By the end of 2004, over 95% of Ontario communities had a common base of information on their groundwater resources. The 2004 groundwater initiatives also included development of source protection plans and improvements to the water taking program. Summaries of the groundwater studies can be reviewed on the MOE internet site at [www.ene.gov.on.ca/envision/water/groundwater/groundwatermain.htm](http://www.ene.gov.on.ca/envision/water/groundwater/groundwatermain.htm).

### **3.6 Natural Groundwater Water Quality**

Most natural groundwater in Ontario has a much superior water quality to surface water. For example, natural groundwater is free of the harmful bacteria commonly found in surface waters and rarely exceeds health-based concentration limits of chemicals.

The Provincial Drinking Water Objectives (PDWOs) include recommended limits for the most common chemical and physical parameters. The PDWOs include aesthetic and health-related parameters, as well as operational guidelines for groundwater that is treated for public supplies. The suitability of groundwater quality for non-domestic uses such as irrigation, livestock watering, industrial process, geothermal energy, etc. requires site-specific assessments.

The quality of natural groundwater depends on the mineral composition of the overburden and bedrock formations that it migrates through. In general, groundwater becomes more mineralized as it migrates from the surface recharge areas to deep aquifer systems.

The most common characteristic of overburden and bedrock groundwater in Ontario is high hardness. Iron is often elevated above the PDWO, particularly in sand and gravel aquifers and chloride, sodium and sulphate exceed the PDWOs in some bedrock formations.

A general indication of groundwater quality across the Province is provided on water well records. The assessment of quality, however, is subjective and based on the water well contractor's visual inspection, along with smell and taste. Only significant indicators of groundwater quality are usually reported, such as "fresh, salty, sulphurous, natural gas, high iron, etc". Under the present water well regulations (Regulation 903), the contractor is not required to provide a laboratory analysis of the groundwater quality in newly constructed wells.

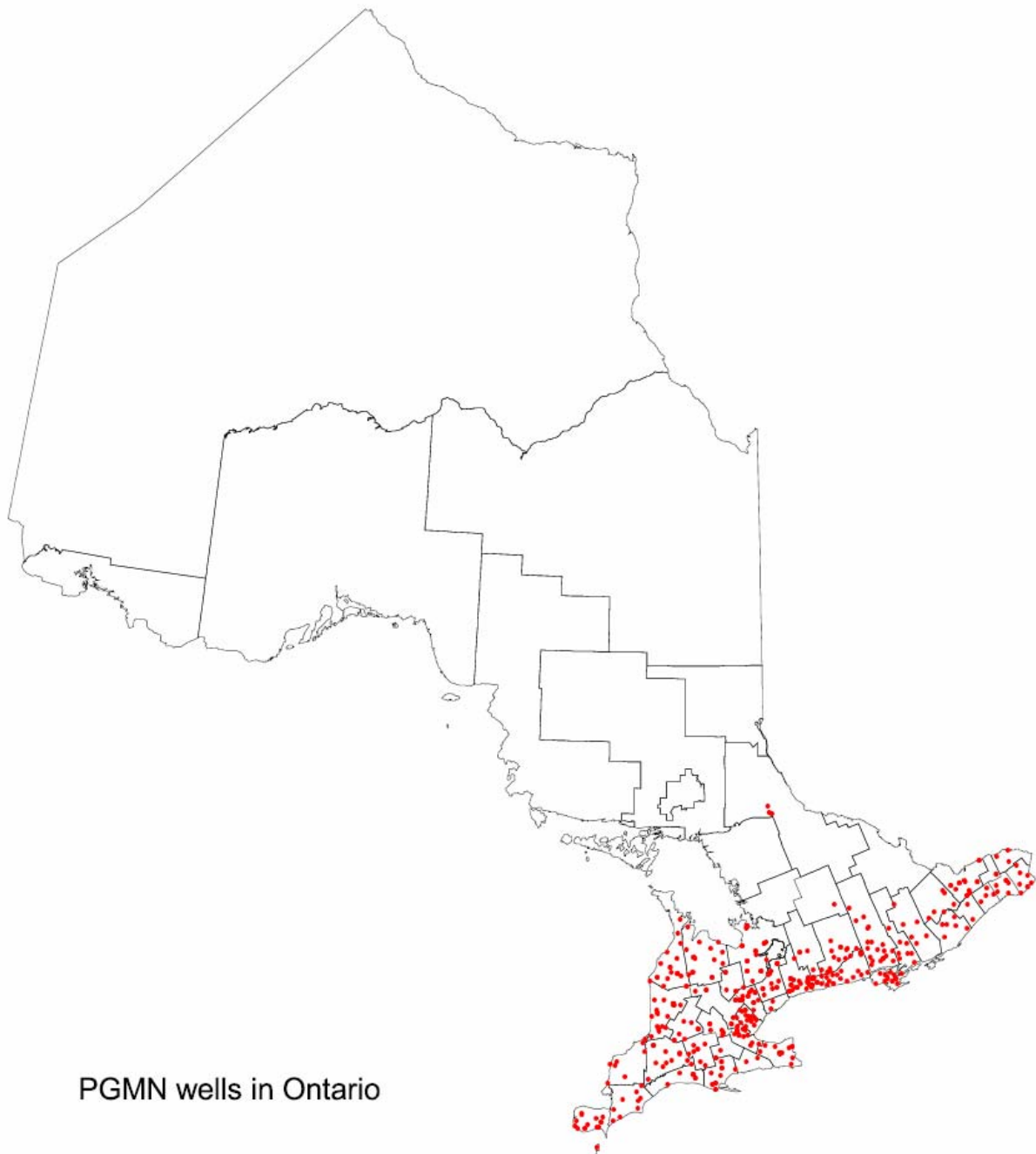
The most complete groundwater quality profiles are available for public water supplies. The latter supply systems include communal wells (supplying over 5 residences), restaurants, hospitals, schools, camp sites, resorts, trailer parks, etc. The Drinking Water Systems Regulation (O. Reg. 170/03) requires periodic analyses of over 100 chemical and biological parameters.

The MOE has implemented a Provincial Groundwater Quality Monitoring network across Southern Ontario (Figure 3.3). The network includes approximately 400 observation or private monitoring wells that are sampled periodically. The purpose of the monitoring network is to measure water levels and characterize groundwater quality in a variety of different aquifer systems; however the water quality inventory and baseline information is not readily accessible by the public.

Current and historical groundwater quality in the MOE database indicates that overburden aquifers have the highest overall quality. The quality of groundwater in the most productive bedrock aquifers is generally good; however, many bedrock formations are highly mineralized and not potable. For example, wells in shale usually yield salty (chloride and sodium) water and wells in gypsum usually yield sulphurous water. Some bedrock formations, including shales and limestones also contain natural gas.

For additional information on natural groundwater quality in Ontario, readers are referred to two MOE reports: *The Hydrogeology of Southern Ontario* (Ontario Ministry of the Environment, 2003) and *An Assessment of the Groundwater Resources of Northern Ontario* (Ontario Ministry of the Environment, 2002). These two studies examined general information (such as water well records) and over 1,000 laboratory analyses of samples from overburden and bedrock wells.

The security, vulnerability and risks to aquifers in general, and water wells in particular are addressed in Chapter 10.



**Figure 3.3 Provincial Water Quality Monitoring Network**

Source: EMRB, MOE (2004).

### **3.7 Development and Sustainability**

Groundwater is a renewable resource and is sustained by annual recharge from precipitation. Groundwater sustainability usually refers to the quantity that can be used for an indefinite time

© 2006, Kent Novokowski, Brian Beatty, Mary Jane Conboy and John Lebedin

without causing adverse impacts to the natural environment or existing uses. If groundwater taking exceeds the annual rate of recharge, water management strategies must be developed to mitigate adverse effects caused by aquifer mining. The most significant adverse effects include reduced discharge to sensitive surface waters (e.g. wetlands, tributary streams, aquatic and terrestrial habitats, etc.) and reduced yields of water supply wells.

The numerous groundwater studies sponsored by the MOE in 2002 to 2004 helped to map most major aquifer systems in the developed areas of Ontario. These studies identified vast groundwater resources that have barely been utilized to date. In most rural areas, municipal, industrial and irrigation water taking have not caused adverse impacts to other well users or the natural environment. In these areas, the yield of the supply wells are sustained by natural recharge to the groundwater system.

In a few areas of dense development, groundwater use has significantly exceeded the sustainable supply. In such areas, the water level in major confined aquifers has been lowered, often by tens of metres. The impact of such lowering usually lowers the water level and yield of other supply wells within the area of influence. In a few cases, especially in unconfined aquifer systems, over pumping has drained wetlands and reduced baseflow in streams.

The long-term sustainability of an overburden aquifer supply depends mostly on the annual rate of recharge. Annual recharge rates range from over 300 mm in sandy areas and surface depressions to less than 30 mm in deep aquifers, buried below clay strata. Some widespread thick aquifers contain such a large volume of stored groundwater, that they can sustain large withdrawals without causing widespread drawdown.

Urban development and clearing of forested lands can reduce the long-term sustainability of groundwater resources. For example, a significant reduction in infiltration occurs where dense development or deforestation is allowed to take place in areas of high natural recharge. These areas include closed depressions in hummocky terrain, sand and gravel deposits and outcrops of permeable rock.

There are many examples in Ontario, where permanent reductions in groundwater recharge due to land-use changes have caused reductions in aquifer water levels and discharge to streams and wetlands. Temporary reductions in recharge due to periods of below-average precipitation have also caused shortages of groundwater in shallow aquifer systems and have dried-up wetlands and tributary streams.

In the future, improved groundwater management schemes will be needed to sustain groundwater resources for well supplies in growth areas. This should include strategies to maintain groundwater recharge in urbanized areas.

### **3.8 Future Groundwater Demand**

The MOE-sponsored groundwater studies have identified abundant groundwater resources throughout the Province. Planned future growth in locations that rely solely on groundwater will require expansion of aquifer sources and greater attention to groundwater management.

In the future, the public and regulatory agencies will have to determine the tradeoff between groundwater use and acceptable changes to the environment. It will be important to set a threshold for acceptable levels of change to baseflow in streams and groundwater discharge to wetland areas.

### **3.9 Water Takings**

A brief review of gross precipitation and run-off statistics in Ontario and the abundance of surface water in and surrounding Ontario, could leave the impression that the Province is water-rich. Tate's 2002 report to the Walkerton Inquiry assessed precipitation, run-off and stored water to determine the status of water supplies in Ontario (Tate, 2002). His position and the subsequent position of Justice O'Connor was that Ontario has an abundant water supply and gross quantity issues should not be a concern for the foreseeable future. This overall analysis masks the very real water shortages experienced in many parts of rural Ontario during the period 1998-2004.

Local water shortages are occurring in Ontario and are likely to increase over time due to a combination of demographic and environmental factors. Rates of groundwater withdrawal in Ontario are significant in some locations with three times as much water being withdrawn as is recharged (Schellenberg and Piggott, 1998). Low water levels and reduced precipitation rates have been reported in a co-ordinated fashion for significant parts of the summer months since 1999 in many parts of Ontario. Since that time, water shortages have been evident in Ontario with historic low water levels in the Great Lakes and declines in wetlands in the Great Lakes Basin. The situation in Ontario in the summers of 2001 and 2002 was one of drought with Level I and II water shortages called in most of Southern Ontario. Figure 3.4 and Figure 3.5 show the precipitation and stream flow information for the summer of 2001. Where the map is red, this is an indication of a Level III, or critical water shortage. Although these levels have been documented in precipitation and stream flow, a Level III shortage was not called and corresponding responses were not implemented. The key areas in Ontario facing water constraints are shown in Figure 3.6 (Marshall, Macklin and Monaghan, 2003).

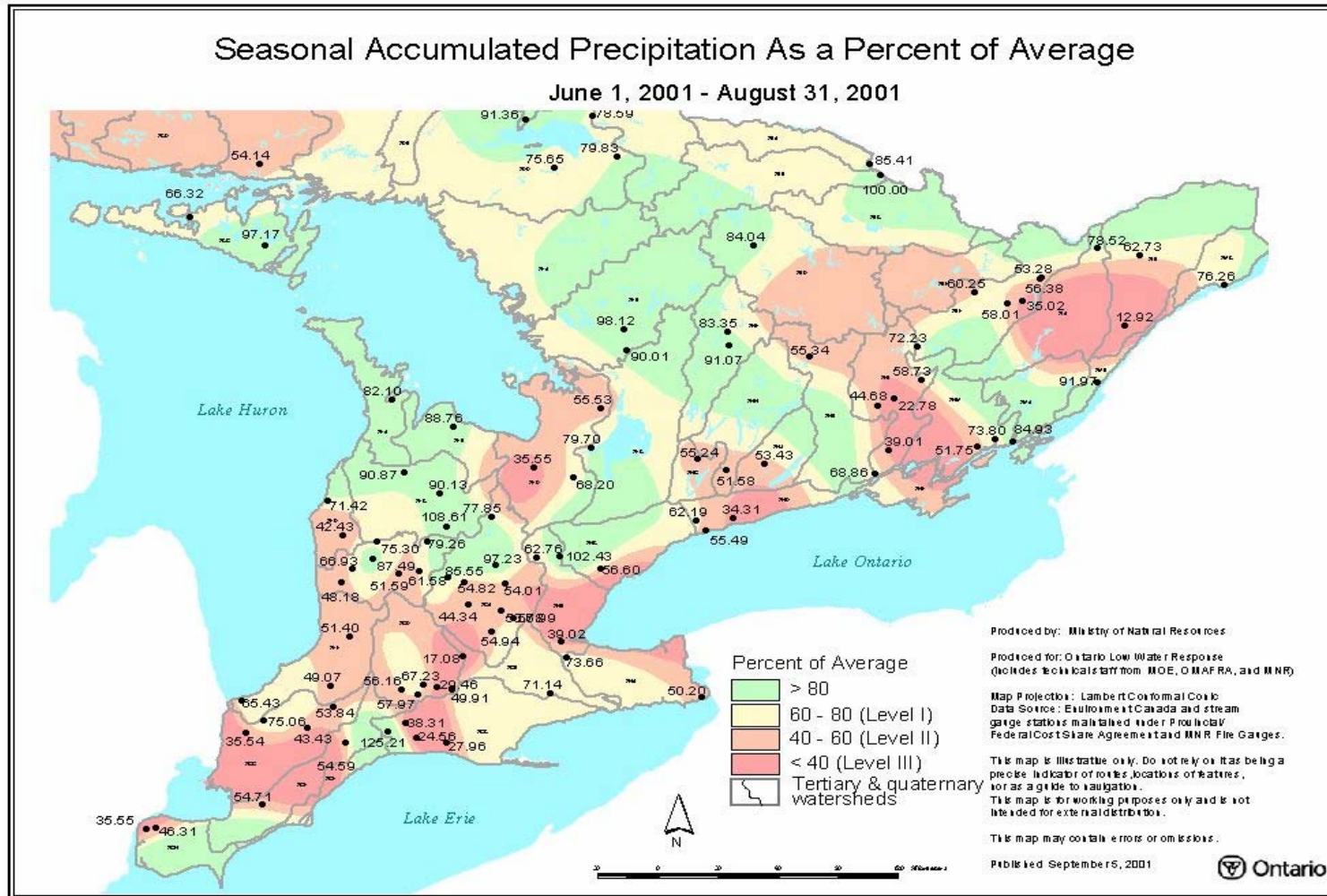


Figure 3.4 Precipitation in Ontario 2001 Source: Ministry of Natural Resources, 2001.

## Southern Ontario - Water Flow As A Percent of Lowest Average Summer Month Flow August 1 - 31, 2001

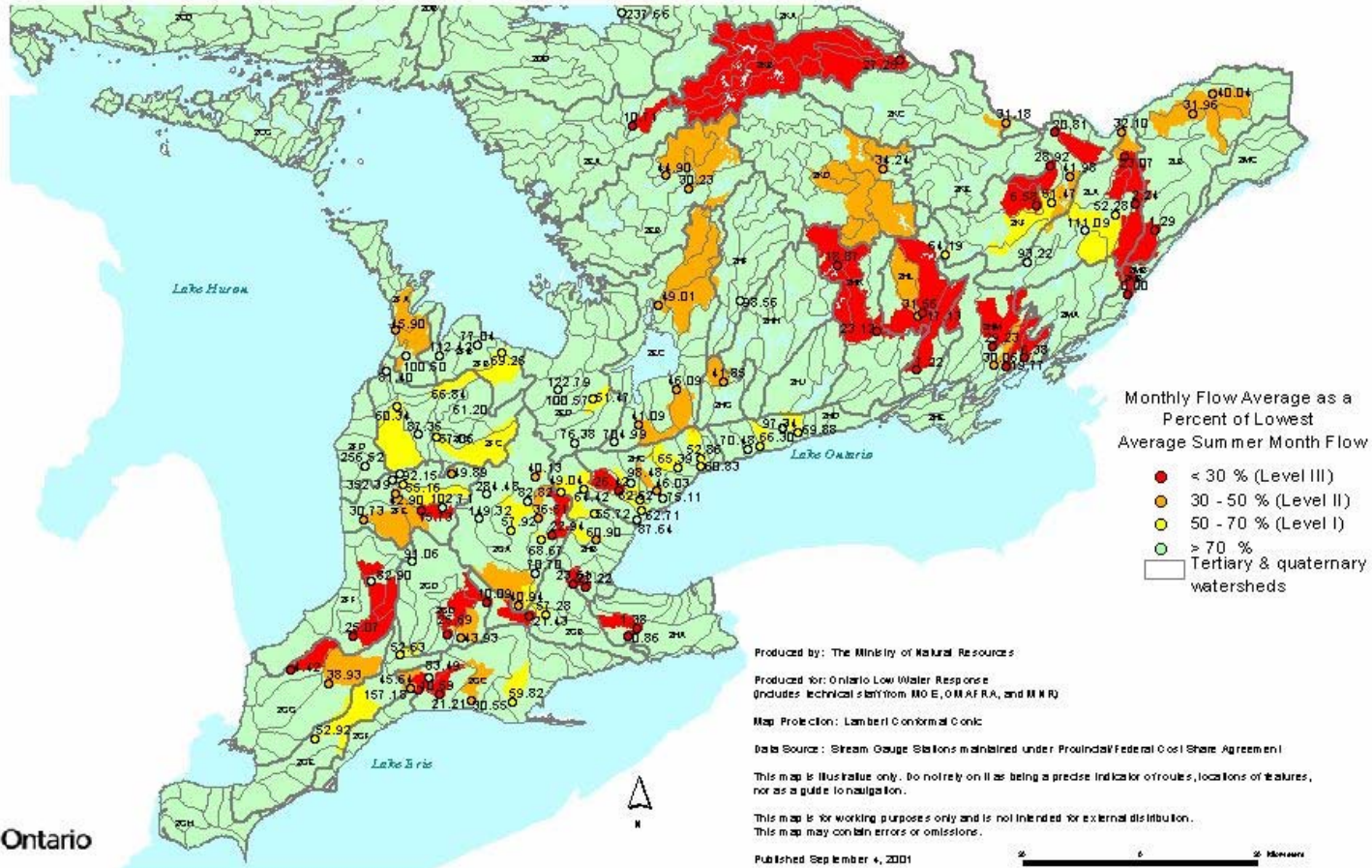
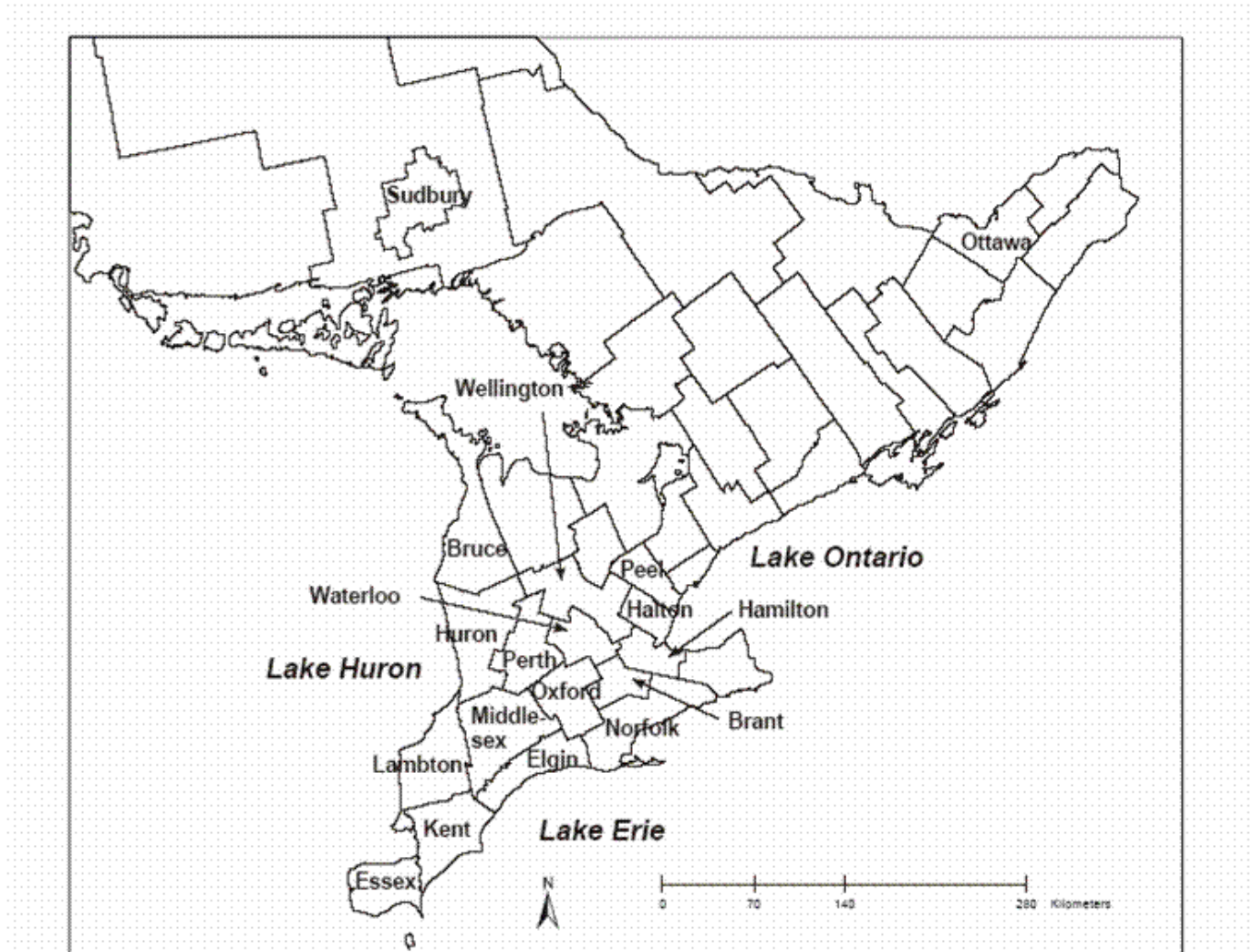


Figure 3.5 Stream Flow in Ontario 2001 Source: Ministry of Natural Resources, 2001

© 2006, Kent Novokowski, Brian Beatty, Mary Jane Conboy and John Lebedin



**Figure 3.6 Key Areas Facing Water Constraints in Ontario**

Source: Marshall Macklin Monahan, 2003

© 2006, Kent Novokowski, Brian Beatty, Mary Jane Conboy and John Lebedin

### **3.10 Conclusions**

1. Diverse geological and climatic conditions in Ontario require a variety of approaches to well design, location, and construction. This presents unique challenges for well life cycle management.
2. Generally there is an abundant supply of groundwater in most parts of Ontario, however local shortages are likely to become more common due to demographic and environmental factors.
3. Competition for local groundwater constraints requires proactive groundwater management strategies.
4. The Panel commends the MOE for implementation of the Provincial Groundwater Monitoring Network.
5. The Panel recognizes the significant expenditure of government funding in the development of groundwater studies across the Province. These documents currently exist as stand-alone reports based on a common technical terms of reference.
6. At present there is no comprehensive description of natural groundwater quality. The Panel recognizes that the MOE has taken initial steps to address this issue by developing the Provincial Groundwater Monitoring Network.

### **3.11 Recommendations**

1. The Panel strongly encourages MOE to undertake integration (including province-wide maps of aquifers and municipal wellhead protection zones) of their groundwater study results.
2. The Provincial Groundwater Monitoring Network should be expanded to include more wells in sensitive and highly productive aquifers.
3. The MOE should make available to the public a comprehensive, user-friendly, interactive groundwater website containing information such as results of comprehensive groundwater studies, water taking, groundwater monitoring network data, Water Well records data, and Ministry of Health and Long Term Care well water quality data.
4. The Panel recommends that full water budgets be completed for all watersheds in Ontario in order to guide evidence-based decision-making on water taking and water allocation. The budget should include rates of recharge; water that is consumed versus water that is returned within the watershed; timing of water migration through the watershed; and the water needs of the entire community. This is consistent with a sustainable asset management approach and will enhance water well sustainability in Ontario.

### 3.12 References

Conservation Ontario. 2003. Watershed Demonstration project – Conservation Ontario – Water use decision making on a watershed basis.

de Loë, R. Kreutzwiser, R. and Ivey, J. 2001. Agricultural Water Use in Ontario. *Canadian Water Resources Journal* 26(1): 17-42.

Dolan, A.H., Kreutzwiser, R. and de Loë, R.. 2000. Rural Water Use and Conservation in Southwestern Ontario. *Journal of Soil and Water Conservation*. 55(2): 161-171.A H

Durley, J. L., de Loë, R., and Kreutzwiser, R.D. 2003. Drought contingency planning and implementation at the local level in Ontario. *Canadian Water Resources Journal* 28, 1: 21-52.

Environmental Commissioner of Ontario. 2001. *Ontario's Permit to Take Water Program and the Protection of Ontario's Water Resources: A Brief to the Walkerton Inquiry*. Toronto: Environmental Commissioner of Ontario.

Gabriel, A.O., and Kruetzwiser, R. 1993. Drought Hazard in Ontario: A Review of Impacts, 1960-1989 and Management Implications. *Canadian Water Resources Journal*. 18(2): 117-132.

Gartner Lee Limited, Ogilvie, Ogilvie & Company and Huber Environmental Consulting 2002. Best Practices for Assessing Water Taking Proposals.

Gleick, P. 1996. Basic Water Requirements for Human Activities: Meeting Basic Needs. *Water International*. 21:83-92.

Hofmann, N. and Mitchell, B. 1995. Evolving toward participatory Water Management: The Permit to Take Water Program and Commercial Bottling in Ontario. *Canadian Water Resources Association*. 20(2): 91-100.

International Joint Commission (IJC). 2000. Protection of the Waters of United States: February 22, 2000.

Kreutzwiser, R., de Loe, R., and Benninghoff, B. 1999. Agricultural and Rural Water Allocation in Ontario: A report to the Agricultural Adaptation Council.

Kreutzwiser, R. and de Loe, R. 1999 Agriculture and Rural Water Use in Ontario, A report to the Agricultural Adaptation Council.

Leadlay, H.J., and Kreutzwiser, R.D. 1999. Rural water supply allocation in Ontario: An evaluation of current policy and practice. *Canadian Water Resources Journal*. 24.

MacRitchie, S M., Pupp, C., Grove, G. Howard, K.W.F. and Lapcevic, P., 1994. Groundwater in Ontario, hydrogeology, quality concerns, management. National Hydrology Research Institute (NHRI) Contribution No. CS-94011, Nov. 1994.

Environment Canada Publication. 117 pp. Document available on-line: [http://gwrp.cciw.ca/canada/on\\_v10.pdf](http://gwrp.cciw.ca/canada/on_v10.pdf) .

Marshall Macklin Monaghan, 2003. National Water Supply Expansion Program. Province of Ontario, A Report to Agriculture and Agri-food Canada. Prairie Farm Rehabilitation Administration.

Ministry of Natural Resources (MNR) et al. 2002. Ontario Low Water Response. Document available at [www.mnr.gov.on.ca](http://www.mnr.gov.on.ca).

Ontario Ministry of the Environment. 2002. An Assessment of the Groundwater Resources of Northern Ontario. Areas Draining into Hudson Bay, James Bay and Upper Ottawa River. Prepared by S.N. Singer and C.K. Cheng. Environmental Monitoring and Reporting Branch. Hydrogeology of Ontario Series. Report 2. <http://www.ene.gov.on.ca/envision/techdocs/4801e.pdf>.

Ontario Ministry of the Environment. 2003. The Hydrogeology of Southern Ontario. Second Edition. Volume 1. Hydrogeology of Ontario Series . Report 1. Prepared by S.N. Singer, C.K. Cheng, and M.G. Scafe. Environmental Monitoring and Reporting Branch. [http://www.ene.gov.on.ca/envision/techdocs/4800e/pdfs/4800e\\_text.pdf](http://www.ene.gov.on.ca/envision/techdocs/4800e/pdfs/4800e_text.pdf)

Ontario Ministry of the Environment (MOE). 1999. Permit To Take Water Program: Guidelines and Procedures Manual. Revised April 14, 1999.

-- . Guide for Applying for Approval of Permit to Take Water. Ontario. 1999.

-- Water Taking and Transfer Regulation under the Ontario Water Resources Act. O. Reg. 285/99.

Ontario Ministry of Agriculture, Food and Rural Affairs Food Industry Division. Final Report Strength, Weakness, Opportunities and Trends Analysis for the Bottled Water Industry January 24, 2001

Priddle, C. 2003 Interorganizational Issues Prevalent in Ontario Water Allocation and Drought Contingency Planning. MSc Thesis, University of Guelph, Department of Geography.

Renzetti, S., and Dupont, D. 1999. "An assessment of the impact of charging for provincial water use permits." *Canadian Public Policy*. 25.

Schellenberg, S. and Piggott , A.1998. An Assessment of Groundwater Usage in 13 Counties in Southern Ontario." Groundwater in a watershed context Conference proceedings, eds. L. Moraru and R. de Loe: 195 – 202. Cambridge: Canadian Water Resources Association.

Tate, D. M. 2002. Water Quantity and Related Issues: A brief overview. The Walkerton Inquiry Commission paper 22.

Vandierendonck, M. and Mitchell, B. 1997. Water Use Information for Sustainable Water Management: Building Blocks and the Ontario Situation.” *Canadian Water Resources Journal*. 22(4): 395-415.

## **4.0 Present Status of Water Quality in Wells in Ontario**

Municipal water supplies have prescribed frequencies for testing and specific parameters for water quality analysis. Since the late 1980s, standardized testing of the parameters listed in the Ontario Drinking Water Objectives (ODWO) has been a legal requirement of Certificates of Approval. Older Certificates of Approval did not require testing for a number of volatile organics until 1996. The new Safe Drinking Water Act, 2002 stipulates the frequency and parameters that need to be assessed for all municipal wells.

Privately owned wells do not have any mandatory testing requirements in Ontario as this responsibility is left to the well owner. The Ministry of Health (MOH) offers a complimentary water testing service for bacteria, nitrate and fluoride. Results are recorded in a confidential central database by the MOH. The Ontario Federation of Agriculture has a voluntary water testing program that is available to all Ontario residents.

There have been a number of surveys of quality of water in privately owned wells (Goss and Rudolph, 1992; Goss et al., 1998; Fleming and Bradshaw, 1992; Lee-Han and Hatton, 1991). Two more recent reports by the MOE (MOE, 2002; 2003) included water quality analyses from over 1000 overburden and bedrock wells in southern and northern Ontario. This chapter will discuss the results of these surveys to provide an overview of the present status of water quality in wells in Ontario. These surveys were designed to provide a general picture of well water quality in Ontario, but are not representative of conditions in every location of the Province or in every type of private well.

### **4.1 Private Well Water Quality**

#### **4.1.1 Bacteria**

Total coliforms and fecal coliforms or *Escherichia coli* (*E. coli*) are bacteria assessed by the Ministry of Health and commonly used as indicator organisms for well water quality. The latter bacteria have similar life cycles to pathogenic bacteria and are associated with the intestinal tract of mammals and discharged in high numbers. The presence of these organisms in water is a strong indication of recent sewage or animal waste contamination. The absence of total coliforms is a good indication that the water is clean.

An epidemiological study conducted among farm families in Ontario showed that human health was not affected by the presence of total coliforms in drinking water (Raina et al., 1999). The presence of fecal coliform or *E. coli* bacteria in drinking water provides a better indication that human health may be compromised. Fecal coliforms include all coliforms that can ferment lactose at 44.5°C.

Bacteria are carried to groundwater when water infiltrates soil. The transport of microorganisms is affected by their surface charge, their population dynamics, as well as by biological, physical and chemical properties of soil, and the geology of the location. Microorganisms are transported, not in solution, but as colloids. It is reasonable to

assume that the concentration of a solute within the pore space is uniformly distributed, but that may not be true of colloids. Bacteria are much larger than chemical ions and their movement is more likely to be affected by preferential flow. They have variable surface charges which allow stronger adsorption to soil particles. Bacteria have a large ratio of surface area to volume that provides many sites for adsorption. Another consideration with microorganisms is that their populations are dynamic. They are alive and influenced by factors that affect their survival. Moreover, many are also motile.

Fractured bedrock (e.g. shale, sandstone, and limestone) and some shallow overburden profiles are vulnerable to bacterial contamination. In unconsolidated material, macropores can be formed by termites, earthworms, and holes left by decayed roots. Fractures in this setting can be formed through swell-shrink behaviour of clay soils. Clay rich soils tend to form macropores to a greater extent than sandy soils. Where the pores or fractures are large enough, bacteria will move freely through the soil until water flow stops, or until small pores are encountered. Bacteria will move freely through holes and cracks in the soil that have effective diameters larger than the organisms. Bacteria move most quickly through pores that drain under gravity. The size and direction of macropores and fractures can vary greatly, but where they occur, water will move to depths up to 5 or 6 m, at faster rates than would occur if infiltrating through the small soil pores.

Private wells sample local groundwater resources. The groundwater is untreated and there is usually a number of possible sources of bacteria. The main sources of fecal bacteria entering private wells are livestock manure and septic systems. There is a need to identify the origin of the contamination if remedial action is to be carried out. The use of bacterial indicator species is the most cost-effective way of identifying contamination of fecal origin. However, where there may be several sources of fecal bacteria, the use of only one or two indicators is not always effective in locating the source of contamination. Surveys from Ontario showed approximately 20% of the wells tested had animal fecal indicators present (Conboy and Goss, 1999). For large diameter wells and drilled wells in a pit, well casings can provide openings from the surrounding environment directly into the water supply. Vermin may inhabit the area surrounding the well and at times fall directly into the well. Bacteria can move with soil and water through unsealed joints, poorly constructed wells and through a poorly sealed cap or annular space.

In drilled wells, the two most obvious areas where bacteria enter the well are through the annular space or through the cap. Many drilled wells with water testing positive for only total coliform bacteria have earwigs, spiders, beetles etc. nesting in the well cap and falling into the water supply. Drilled wells can also have holes or develop holes if the joints are poorly welded.

During 1950 – 54, Johnston (1955) surveyed 484 private residence wells in rural Ontario to assess levels of nitrate and bacteria. In this study, 14% of the wells exceed ODWO for nitrate and 15% exceeded ODWO for fecal coliform (Table 4.1).

The Ontario Farm Groundwater Quality (OFGWQ) survey (Goss et al. 1998) sampled 1292 farm wells across Ontario, set in various soil and geological profiles and operating in different types of farming operations. All of these wells were assessed for total and

fecal coliform bacteria. The incidence of bacteria decreased with depth for dug or drilled wells and was higher in older wells than in younger wells. Smaller numbers of bacteria were recorded for samples taken in the winter than in those taken in summer.

Approximately 40% of farm wells tested contained one or more of the target contaminants above the maximum acceptable concentration; 34% of wells had more than the maximum acceptable number of coliform bacteria. The results for nitrate contamination were not significantly different from those reported earlier by Johnston; however, the frequency of contamination by fecal coliform bacteria was greater in the 1990s. Fleming and Bradshaw (1992) found that the proportion of wells contaminated with coliform bacteria was significantly greater for dug or bored wells than for drilled wells.

**Table 4.1 Comparison of Private Well Water Quality Surveys**

| <b>1950 – 1954 (Johnston, 1955)</b> | <b>1991-1992 (Goss et al. 1998)</b> |
|-------------------------------------|-------------------------------------|
| 484 wells                           | 1292 wells sampled                  |
| 14% high for nitrate                | 14% high for nitrate                |
| 15% high for fecal coliform         | 34 % high for fecal coliform        |
|                                     | 6 wells exceeded for pesticides     |

Subsequent to the OFGWQ survey, many of the same wells were re-sampled during three different studies focusing on different aspects of well water contamination. A follow up study to the OFGWQ survey examined the incidence of gastro-intestinal illness as it related to the presence of bacteria in well water. People drinking water contaminated with *E. coli* were twice as likely to be ill as those drinking water that did not have *E. coli* present (Raina et al., 1999). The presence of *E. coli* in well water increased the incidence of gastro-intestinal illness (Raina et al., 1999). In the United States, one-third of all waterborne disease outbreaks reported from 1971 to 1976 were traced to the consumption of water from untreated groundwater sources; later studies also showed illness as a result of groundwater contamination with *E. coli* bacteria (Craun, 1978; 1984; Macler and Merkle, 2000). This information shows that *E. coli* contamination of groundwater presents a significant health risk in some geological settings that are particularly vulnerable to surface impacts.

Another debate is whether contamination is primarily due to poor conditions at the wellhead or contamination in the aquifer – at least locally. Related to this issue is the use of water supply wells compared to monitoring wells for groundwater studies. In a study by the University of Waterloo, multilevel wells were drilled in fields nearby to some of the wells sampled in the farm survey. This study showed consistently that where contamination was found in the well water sample, it was also found in the multilevel wells. This shows that samples from private wells are representative of contaminant conditions in the aquifer (Rudolph et al., 1998).

In 1997, 300 of the original 1292 wells were resampled to assess the effectiveness of indicator organisms and to assess vulnerable well locations (Conboy and Goss, 2000).

Some wells were sampled a total of 13 times over a 5 year period. The bacterial results from all the studies showed that some wells tended to be contaminated almost every time they were sampled, whereas other wells were consistently free of bacteria. Further analysis examined factors affecting vulnerability of wells and likely sources of bacteria. This study assessed the influence of i) season; ii) land use practices; and iii) well construction. The most important factors impacting the vulnerability of the well to bacterial contamination were factors related to the well itself – depth, construction and location, and soil and geology.

A well that was vulnerable to bacterial contamination tended to be uncased in fractured bedrock with a shallow soil profile. These conditions did not permit much interaction with the soil matrix and allowed water and *E. coli* bacteria to enter the wells at any depth with a reduction in concentration occurring mainly by dilution. The protected wells were usually cased in thicker soil profiles, which allowed for more interaction with the soil. There were often protective layers such as clay; the wells were cased to depth and the bedrock was not usually fractured (see Figure 4.1 (Conboy, 1998)).

Where the majority of survey tests found bacteria entering the well, the indication was that there was likely a permanent source of fecal bacteria entering the well on a regular basis. Biotracer studies were conducted to assess the source of contamination (Conboy and Goss, 2000). The sources of bacterial contamination in the well studies were: rodents falling into the well; septic systems; manure spread on fields; livestock yards; and manure storage tanks. In some of the biotracer tests bacteria traveled 6 – 76 m/hour. This indicates that bacteria were not infiltrating through the soil matrix, but rather the bacteria were exploiting macropore or fracture channels. This allowed bacteria to move to depths much more quickly than one would predict if bacteria were assumed to travel through the soil matrix. This also means that in these situations, the soil is not providing effective filtration to remove bacteria. Field observations suggest that this rapid transport may be caused by local factors. In some cases where tracer bacteria were detected within one hour, the inoculant only had to travel 6 metres; however there were a few cases where a larger distance was travelled in a short period of time. In one case, a crack in an exercise yard was inoculated and bacteria were found in the well water after an hour, despite the fact that the well was 53 metres from the inoculated site. It is possible that there was a fracture or small fault in this area which made the concrete crack and which also provided a direct route to the well water.

Underlying structures, either naturally occurring or due to faulty tile drainage, may cause certain sites to be extremely vulnerable. Other studies have also shown that the movement of microorganisms in soil can be very fast. *E. coli* was seen to move through 0.28 m with 90% collected after 17 min. (Abu-Ashour et al., 1994); 17 cm/min (McCoy and Hagedorn, 1980); and 2.8 cm/s (Skilton and Wheeler, 1988). Bacteria have been shown to move through soil columns at pore velocities of 3 - 30 m/day in laboratory experiments (Wollum and Cassel, 1978; Smith et al., 1985; Fontes et al., 1991) as well as field studies (Harvey et al., 1989; Harvey and Garabedian, 1991).



**Figure 4.1 High vs. Low Risk Wells**

Source: Conboy (1998)

#### **4.1.2 Nitrate**

Nitrate is often found in unprotected sand and bedrock aquifers. Nitrate is a non-reactive highly soluble form of nitrogen that leaches easily through the soil profile. The main sources of nitrate are fertilizers, manure, silage, and septic systems. Nitrate contamination is more common in sandy soils (Baker et al., 1989) and numerous studies worldwide show that nitrate levels in groundwater are often higher in areas of intensive agriculture. The OFGWQ survey found the occurrence of groundwater contamination was related to the type, depth, and age of the well (Goss et al., 1998). The type and the age of the well may have provided areas lacking structural integrity that allowed the nitrates to enter the well at a more shallow depth.

Ontario surveys showed that bacterial transport into well water was not always mirrored by nitrate transport. Nitrate concentrations higher than 10 mg/L are unsafe for drinking water. In studies by Conboy and Goss (2000), one-third of wells chronically contaminated with bacteria met ODWO for nitrate every time the water was assessed. Goss et al. (1998) found about 7% of the wells in their survey were contaminated with both bacteria and nitrate. The wells that were most vulnerable to contamination by bacteria and nitrate were all dug or bored wells and tended to be more shallow (Goss et al., 1998; Conboy and Goss, 2000; Murphy, 1992; Ervin and Lusch, 1992).

Nitrate from surface sources moves into the soil and can be stored until it is taken up by plants or is transported to groundwater by infiltrating water. Nitrate plumes from sewage disposal beds and fertilized lands generally migrate from the source locations toward groundwater discharge areas. In some regions of Ontario, very large nitrate plumes have lead to the closure of some municipal wells. These plumes are several kilometres in length, and are likely a result of many years of cumulative impacts of land use in the area.

Multi-level wells were also installed on a number of sites in areas characterized by coarser-textured soils (144 sites). These wells were installed in farm fields and woodlots adjacent to the drinking water wells. Nitrate concentrations exceeded the Canadian drinking water guideline for more than half the sampling intervals at 23% of the field multi-level sites. The average concentration of nitrate–nitrogen in these wells decreased from about 10 milligrams per litre near the water table to 3 milligrams per litre at a depth of about 6.5 metres. The proportion of contaminated wells was similar for both the drinking water wells and field multi-level wells in the survey, indicating that contamination is caused as much by activities on the cultivated fields as by on-farm point sources of contamination.

Although well surveys lack precision in evaluating the effects of specific farming or cropping practices, it was observed that 1) farms where manure was spread were more likely to have wells contaminated with nitrate–nitrogen and bacteria than other farms; and 2) uncultivated conditions in the woodlots appear to have provided an environment in which nitrate, but not bacteria, was removed from groundwater.

#### **4.1.3 Pesticides**

Chemical methods have been used since the 1950s to control pests in agriculture and forestry, as well as in transportation, residential use, commercial and industrial purposes and in lake and stream management. Early pesticides contained many chlorinated organic compounds that have been shown to be very persistent in the environment and bind well to fat molecules leading to problems such as bioaccumulation in organisms higher in the food chain. Newer pesticides are now primarily organophosphates and are soluble in water as opposed to fat.

There have been a number of surveys conducted to assess pesticides in private wells in Ontario (Frank et al., 1987a, 1987b, 1990, 1991; AAFC-OMAFRA, 1994; Fleming and Bradshaw, 1992; Goss and Rudolph, 1992). The various surveys examined a variety of compounds and some surveys targeted areas suspected to be contaminated by pesticides. Atrazine, alachlor, cyanazine, metolachlor, metribusin, 2-4D, PCP, 2,4,5-T, dicamba, mecoprop, simazine, dichlorprop, dinoseb and picloram were detected in wells in some of the surveys. All of these surveys in Ontario have found very few wells with pesticide levels exceeding Ontario's Interim Maximum Acceptable Concentration (IMAC). Detectable levels of pesticides were found in well surveys and more often in targeted surveys than in random samples. Atrazine is one of the most widely used pesticides in Ontario and is highly soluble in water. It has been detected in most surface water in North America and has also been detected in groundwater in US surveys.

In Ontario, Frank et al. (1990) conducted a number of surveys of pesticide residues in farm wells between 1967 – 1987. The proportion of wells with detectable pesticide levels ranged from 5.3% (1987) to 71% (1979). The early studies targeted wells suspected of pesticide contamination, while later studies examined a number of different pesticides. More recent studies assessed the effect of soil type and pesticide handling practices. Analysis of studies conducted in 1984, 1986, and 1987 showed that

approximately 10% (n=270) of wells were contaminated with pesticides. Leaching of pesticides was not found to be a significant occurrence.

MOE also assessed a number of private and municipal wells for pesticides in the mid 80s and found half the wells surveyed contained at least one pesticide residue present with atrazine being most common (MOE, 1987). In the 1991-92 Ontario survey, atrazine was detected in 6.6% (winter) and 10.5% (summer) of wells sampled; only 6 wells exceeded ODWO.

The studies by Frank et al. showed that a great deal of pesticide contamination was due to poor pesticide handling practices including spills, backsiphoning, use of well to mix pesticides or placement of well in or at edge of sprayed field. MOE (1987) and Fleming (1992) found that aspects related to the well construction and location affected pesticide concentrations in well water. Contaminated wells generally were not decontaminated easily and some needed to be decommissioned. OMAF introduced the Pesticide Grower Certification course in 1987. It is required by all farmers using more hazardous classes of pesticides. Other initiatives that may have improved handling practices include a pesticide Best Management Practice booklet and considerable public education regarding the safety of pesticide application, storage and disposal.

#### **4.1.4 Road Salt**

To maintain safe driving during the winter, salts are commonly used as de-icing chemicals for road maintenance. A large portion of road salt is flushed off the land by overland flow. However, a percentage will also enter the subsurface and gradually migrate through the groundwater system. Inorganic salts such as sodium chloride, calcium chloride and magnesium chloride are all used to cover public roads, commercial parking lots, and residential driveways.

Aside from overland flow off major roads, de-icing chemicals also enter the subsurface at snow dump locations, storage piles, and from wastewater used to clean winter equipment. The content and concentration of meltwater from snow disposal sites varies, but commonly contains copper, arsenic, and lead in addition to sodium and chloride (Howard and Livingstone, 2000).

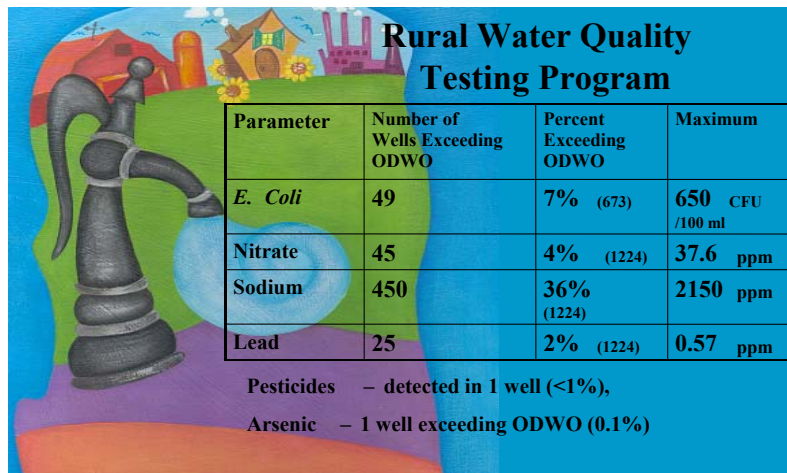
In 2001, following a five year scientific assessment, the Canadian government declared road salts containing inorganic chloride salts with or without ferrocyanide salts as “toxic” under CEPA 1999 because of tangible threats of serious or irreversible environmental damage. Studies indicated that in areas of heavy use of road salts, especially southern Ontario, Quebec and the Maritimes, chloride concentrations in groundwater and surface water are frequently at levels likely to affect biota, as demonstrated by laboratory and field studies (Environment Canada/Health Canada, 2001). Environment Canada, in collaboration with a multistakeholder working group released a Code of Practice for Environmental Management of Road Salts in April 2004 (Environment Canada, 2004). Two guides are forthcoming to assist road authorities/municipalities in meeting the requirements of the Code of Practice. The Code of Practice provided two main recommendations for road salt management: i) the development of salt management

plans by April 2005 by organizations that utilize more than 500 tonnes of salt per year (on a 5-year average) based on review of existing road maintenance operations, identification of means and goal-setting to achieve reductions in negative impacts of salt releases; and ii) the implementation of best management practices in the areas of salt application, salt storage and snow disposal as outlines in the Transportation Association of Canada's Syntheses of Best Practices (TAC, 2003).

The steady increase in chloride levels in the Grand River over the past 25 years has been identified as an emerging issue by the Region of Waterloo. Data presented in 2002 (Hodgins, 2002) indicated that 8% of the region's municipal wells have chloride concentrations greater than the Ontario Drinking Water Standard of 250 milligrams per litre. Waterloo Region has been studying the salt issue since 1994 to map sensitive areas, identify the most affected areas, develop policies to combat the problem and educate the public. A reduction of 27 per cent in road salt use was achieved (from 73,400 to 54,000 tonnes) during the winter of 2001-2002 through the co-ordinated efforts of 8 various agencies involving careful application and the use of new technologies including pre-wetting and liquid anti-icing practices. A number of regional governments and municipalities in Ontario have undertaken salt vulnerability studies and have developed salt management plans (Waterloo, Toronto, Peel, Halton, and Niagara). The City of Toronto has upgraded its equipment with electronic spreader controls, introduced pre-wetting and anti-icing techniques, and installed Road Weather Information Systems (RWIS) throughout the city. The City has also introduced new salt handling practices, provided training to its operators and management staff, and created communications and monitoring programs to support these changes.

#### **4.1.5 Other Rural Water Quality Surveys**

The Ontario Federation of Agriculture's (OFA) Rural Water Quality testing program is intended for private well owners to test their own water for bacteria and other parameters. This program is available to all residents of Ontario; however there is a fee for the testing packages. There have been approximately 1224 participants during the 5 years of the program's operation. Sodium – with the likely source being road salt – is by far the most common contaminant found in the wells assessed through this program. Bacteria, nitrate and lead were also detected in a number of samples. Pesticides were rarely detected. Results are summarized in Figure 4.2.



**Figure 4.2 Results of Ontario Federation of Agriculture Rural Water Quality Testing Program**

The Ontario Farm Groundwater Quality survey assessed a smaller number of private wells (160) for the following petroleum derivatives: benzene, toluene, ethyl benzene, and xylene. Most farms assessed for petroleum derivatives were selected based on the presence of fuel storage tanks for at least one year within 60 m of the well. Fifteen percent of farms without tanks were used as control comparisons. While anecdotal reports of significant contamination are not uncommon in Ontario, no wells in this contained detectable levels of petroleum derivatives (Goss et al., 1998). Survey participants often reported a diesel odour to their water. In rare circumstances, water has been reported as being flammable.

The interpretation of the above water quality survey findings requires consideration of the study methodology. The Ontario Farm Groundwater Quality survey was randomized and water was sampled by researchers. Although the information from the OFA water testing program is insightful, there are many factors that cannot be fully understood due to the voluntary nature of the program and the sample being taken by the homeowner. For example, in the testing program homeowners report taking water samples prior to treatment. The possibility that some of the samples with high sodium readings were taken following treatment by a water softener cannot be excluded, nor can the possibility of repeat samples on the same water supply. For these reasons, the randomized surveys should be weighted with greater accuracy when examining water quality trends.

#### **4.2 Municipal Well Water Quality**

The Ministry of the Environment conducts a survey of the quality of municipal water supplies through the Drinking Water Surveillance Program. Groundwater supplies are tested for an extensive parameter list of over 200 compounds. Thirty-four percent of the wells tested by MOE between 1990 – 1994 detected at least one volatile organic compound on at least one occasion. A 1995 Health Canada study found that 36% of municipal water supplies tested in Ontario had detectable levels of industrial solvents (TCE and PCE).

In 1995, the Sierra Club of Canada, and the University of Waterloo began a Canada-wide project to investigate the quality of municipal drinking water supplies drawn from groundwater. The Ontario survey involved sampling and analyzing water from 103 wells in 88 communities across the Province. Communities were selected to include those that conducted regular thorough water quality testing in addition to others that did not conduct rigorous testing. During the time of this survey, approximately 400 Ontario communities derived at least part of their municipal drinking water supply from groundwater. In 1995, 4% of municipal supply wells were under 10 m depth; 25% were bedrock wells; and 43% were overburden wells. Twenty-eight percent were testing for a wide range of parameters at this time. This survey found that groundwater quality was generally good as only 7.7% of the wells had detectable levels of VOCs or pesticides (other than THM).

### **4.3 Groundwater Under Direct Influence of Surface Water**

The Walkerton tragedy drew attention to the issue of wells that are not adequately protected from surface water contamination. Shallow wells in sand or fractured bedrock that are located close to runoff swales and surface water features are the most vulnerable to surface contamination. The term Groundwater Under Direct Influence (GUDI) of surface water, was coined to describe these well water resources.

Safe Drinking Water legislation requires that if a well is impacted by surface water, then filtration of this water supply is required. Impact by surface materials is determined by:

- presence of surface water organisms (Giardia, Cryptosporidium, Campylobacter, aerobic spores) OR
- physical evidence of surface water (insect parts, turbidity) OR
- regularly contain total coliform OR
- periodically contain E. coli OR
- within 50 days travel time from a surface water source.

GUDI studies were conducted to investigate depth of the water supply if i) pumping the well affected nearby surface water; and ii) the chemical water quality was closer to the signature of nearby surface water versus nearby groundwater.

The Ministry of Environment requires that either filtration can be applied or a study conducted to prove wells are not GUDI related. MOE mandated municipalities to assess their well water supplies for GUDI status, and as a result several wells were retired due to the expected cost of the study and follow-up treatment. Wells were inspected for structural deficiencies and corrected to reduce influences from the surface. Wells were also assessed for in situ filtration. Wells were sampled after heavy rainfalls to assess increases in particles or changes in geochemistry. Wells were then categorized as i) GUDI; ii) GUDI with effective in situ filtration; or iii) groundwater source. Treatment requirements varied for the three categories. Two hundred and fourteen waterworks were

identified as potentially under surface influences (Dobbin and Gerhrels, 2003) and were characterized as follow:

- 3% (6) characterization pending
- 30% (65) Groundwater (not GUDI)
- **67% (143) GUDI**
  - 46% (99) confirmed GUDI (1/2)
  - 21% (44) GUDI + effective in situ filtration

These statistics raise the issue of the role of source protection when the well itself is not secure. Source protection becomes one of the key strategies employed to keep surface influenced wells safe. Thus, land use restrictions are important to ensure a reliable supply. Many stakeholder groups raise the question of why their practices should be altered to protect an insecure water supply. The simple answer to this is that there are not always a large number of choices for water supplies and in some areas the characteristics of alternate aquifers are problematic without blending with water from other sources. Land users need to be assured that any alteration in land use beyond due diligence will be compensated as the alterations are done in the interest of the public good.

#### **4.4 Conclusions**

1. The state of water quality in private wells has not been surveyed comprehensively since the early 1990s.
2. Surveys of private wells (i.e. the 1991-92 OFGWQ survey) in Ontario have found bacteria and nitrate to be the most common contaminants in drinking water. Pesticides and industrial contaminants have been found to a much lesser degree.
3. Surveys have found that the geological setting, location, construction and maintenance of wells are the predominant factors associated with bacterial contamination.

#### **4.5 Recommendations**

1. A comprehensive province-wide survey of water quality in all private wells should be undertaken immediately. This should include all unregulated wells including rural wells, cottage wells, private wells in urban areas in addition to farm wells. This survey should be repeated at least every ten years, allowing for ample time between surveys to investigate trends and findings in more detail.
2. The Panel recommends that guidance be provided to homeowners to promote testing for more parameters than bacteria.
3. The availability of cost-effective bacterial and pathogen sampling and analysis tools for private well owners should be promoted through awareness raising initiatives.

#### 4.6 References

Abu-Ashour, J., Etches, C., Joy, D. M., Lee, H., Reaume, C. M., Shadford, C. B., Whitely, H. R. and Zelin, S. 1994. Field Experiment on Bacterial Contamination from Liquid Manure Application, Final Report for RAC Project No. 547G. Ontario Ministry of Environment and Energy, Toronto, ON.

(AAFC-OMAFRA) Agriculture Agri-foods Canada and Ontario Ministry of Food and Rural Affairs 1994. Best Management Practices: Livestock and Poultry Waste Management. Agriculture Canada and OMAFRA, Toronto, ON.

Baker, D., Wallrabenstein, L., Richards, R., and N. Creamer. 1989. Nitrate and pesticides in private wells of Ohio: a state atlas. Tiffin, Ohio: The Water Quality Laboratory, Heidelberg College.

Conboy, M. J. and Goss, M. J. 2000. Natural Protection of Groundwater Against Bacteria of Fecal Origin. *Journal of Contaminant Hydrology* 43(1): 1 – 24.

Conboy, M. J. and Goss, M. J. 1999. Contamination of Rural Drinking Water Wells by Fecal Origin Bacteria—Survey Findings. *Water Quality Research Journal of Canada* 34(2): 281-303.

Conboy, M. J. 1999. Factors Affecting Bacterial Contamination of Rural Drinking Water Wells: Comparative Assessment. Chapter 9. In John Fitzgibbon (ed.) *Advances in Planning and Management of Watersheds and Wetlands in Eastern and Southern Africa*, part of the Environmental Capacity Enhancement Project Environmental Roundtable Series, (ed.) J. Devlin.

Conboy, M. J. 1998. Bacterial Contamination of Rural Drinking Water Wells. Doctoral dissertation. University of Guelph.

Craun, G. F. 1984. Health Aspects of Groundwater Pollution. In G. Bitton and C. P Gerba (Eds.) *Groundwater Pollution Microbiology*. pp. 135-79. Toronto: John Wiley and Sons.

Craun, G. F. 1978. Disease outbreaks caused by drinking water. *Journal of Water Pollution Control Federation* June: 1362-74.

Dobbin D. and Gerhrels, G. 2003. Looking for direct surface water impact on communal wells. Presentation to A. D. Latornell Conservation Symposium, Nov. 12 - 14, 2003.

Environment Canada/Health Canada. 2001. Road Salts. Priority Substances List Assessment Report.

Environment Canada. 2004. Code of Practice for the Environmental Management of Road Salts. Report Series EPS 1/CC/5. [http://www.ec.gc.ca/nopp/roadsalt/cop/pdf/1774\\_EngBook\\_00.pdf](http://www.ec.gc.ca/nopp/roadsalt/cop/pdf/1774_EngBook_00.pdf)

Ervin, J. L. and Lusch, D. P. 1992. Selection and analysis of sites highly vulnerable to groundwater contamination in Southwestern Michigan. East Lansing, Michigan: Institute of Water Research, Michigan State University.

Fleming, R.J. and Bradshaw, S. H. 1992 Contamination of subsurface drainage systems during manure spreading. Am. Soc. Agric. Eng. Paper No. 92-2618, St. Joseph, MI, ASAE.

Fontes, D. E., Mills, A. L., Hornberger, G. M., and Herman, J. S. 1991. Physical and Chemical Factors Influencing Transport of Microorganisms through Porous Media. *Applied and Environmental Microbiology* 57(9): 2473-81.

Frank, R., Chapman, N., and Johnson, R. 1991. Survey of Farm Wells for Nutrients and Minerals, Ontario, Canada, 1986 and 1987. *Bull. Environ. Contam. Toxicol.* 47: 146-51.

Frank, R., Braun, H., Clegg, S., Ripley, B., and Johnson, R. 1990. Survey of farm wells for pesticides, Ontario, Canada, 1986 and 1987. *Bulletin of Environmental Contamination and Toxicology* 44: 410-419.

Frank, R., Clegg, S., Ripley, B., and Braun, H. 1987a. Investigations of pesticide contaminations in rural wells, 1969-84, Ontario, Canada. *Archives of Environmental Contamination and Toxicology* 16: 9-22.

Frank, R., Ripley, B., Braun, H., Clegg, S., Johnson, R., and O'Neill, T. 1987b. Survey of farm wells for pesticides residues, Southern Ontario, Canada, 1981-1982, 1984. *Archives of Environmental Contamination and Toxicology* 16: 1-8.

Goss, M. J., Barry, D. A. J., and Rudolph, D. L. 1998. Contamination in Ontario Farmstead domestic wells and its association with agriculture: 1: Results from drinking water wells. *Journal of Contaminant Hydrology* 32: 267 - 293.

Goss, M.J. and Rudolph, D. L. 1992. Ontario Farm Groundwater Quality Survey -Winter 1991/92. Agriculture Canada, September 1992.

Harvey, R. W. and Garabedian, S. P. 1991. Use of Colloid Filtration Theory in Modeling Movement of Bacteria through a Contaminated Sandy Aquifer. *Environmental Science and Technology* 25 (1): 178-85.

Harvey, R. W., George, L. H., Smith, R. L., and LeBlanc, D. R. 1989. Transport of Microspheres and Indigenous Bacteria through a Sandy Aquifer: Results of Natural and Forced-Gradient Tracer Experiments. *Environmental Science and Technology* 23(1): 51-6.

Hodgins, E. 2002. Reducing Impacts of Road Salt on Groundwater. Presentation to Grand River Watershed Water Forum, September 20, 2002.

Howard K.W.F. and Livingstone, S.J., 2000 Transport of urban contaminants into Lake Ontario via sub-surface flow. *Urban Water* 2: 183-195.

Johnston, R. A. 1955. The incidence of nitrates in rural Ontario well waters. *Canadian Journal of Public Health* 46: 30-34.

Lee-Han, H. and Hatton, B. Editors. 1991. Regional municipality of Waterloo: survey of bacteriological and nitrate contamination of private well water. Waterloo, ON, The Municipality.

(MOE) Ontario Ministry of the Environment. 2003. The Hydrogeology of Southern Ontario. Second Edition. Volume 1. Hydrogeology of Ontario Series. Report 1. Prepared by S.N. Singer, C.K. Cheng, and M.G. Scafe. Environmental Monitoring and Reporting Branch. [http://www.ene.gov.on.ca/envision/techdocs/4800e/pdfs/4800e\\_text.pdf](http://www.ene.gov.on.ca/envision/techdocs/4800e/pdfs/4800e_text.pdf).

(MOE) Ontario Ministry of the Environment. 2002. An Assessment of the Groundwater Resources of Northern Ontario. Areas Draining into Hudson Bay, James Bay and Upper Ottawa River. Prepared by S.N. Singer and C.K. Cheng. Environmental Monitoring and Reporting Branch. Hydrogeology of Ontario Series. Report 2. <http://www.ene.gov.on.ca/envision/techdocs/4801e.pdf>.

(MOE) Ontario Ministry of the Environment. 1987. Pesticides in Ontario drinking water - 1986.

Macler, B.A. and Merkle, J.C. 2000. Current knowledge on groundwater microbial pathogens and their control. *Hydrogeology Journal* 8: 29-40.

McCoy, E. L. and Hagedorn, C. 1980. Transport of resistance labelled *Escherichia coli* strains through a transition between two soils in a topographic sequence. *Journal of Environmental Quality* 9(4): 686-691.

Murphy, E. 1992. Nitrate in drinking water wells in Burlington and Mercer Counties, New Jersey. *Journal of Soil and Water Conservation* 47: 183-87.

Raina, P., Pollari, F., Teare, G., Goss, M. J., Barry, D. A., and J. B Wilson. 1999. The relationship between *E. coli* indicator bacteria in well-water and gastrointestinal illnesses in rural families. *Canadian Journal of Public Health* 90: 172-175.

Rudolph, D. L., Barry, D. A., and Goss, M. J. 1998. Contamination in Ontario farmstead domestic wells and its association with agriculture: 2. Results from multilevel monitoring well installations. *Journal of Contaminant Hydrology* 32: 295 - 311.

Skilton, H. and Wheeler, D. 1988. Bacteriophage tracer experiments in groundwater. *Journal of Applied Bacteriology* 65: 387 - 395.

Smith, M. S., Thomas, G. W., White, R. E., and Ritonga, D. 1985. Transport of *Escherichia coli* through intact and disturbed soil columns. *Journal of Environmental Quality* 14: 87 - 91.

TAC (Transportation Association of Canada). 2003. Syntheses of Best Practices – Road Salt Management.

<http://www.tac-atc.ca/english/information/services/readingroom.cfm#syntheses>.

Wollum, A. G. and Cassel, D. K. 1978. Transport of Microorganisms in Sand Columns. Soil Science Society of America Journal 42: 72-6.

## **5.0 Regulatory Framework in Ontario and other Jurisdictions**

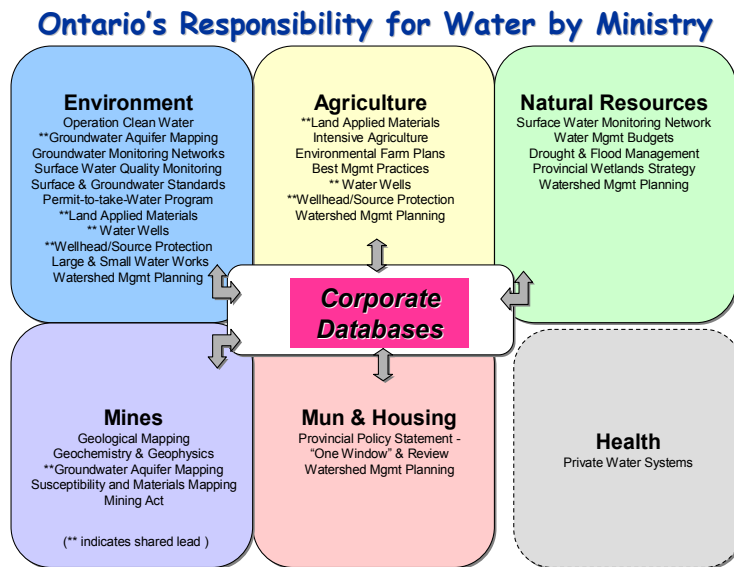
During 2002–2003, Ontario and most other provinces updated their water policies and legislation. Many have specifically addressed the well construction legislation whereas others have focused on groundwater protection. Many provinces including Ontario have also enacted Safe Drinking Water regulations. These types of regulations focus on water treatment; testing; development and implementation of standards; reporting adverse effects; and public notification. This Panel is focused on the sustainability of wells and a full analysis of Acts relating to treatment, testing etc. is beyond the scope of this document.

Water well legislation typically covers well driller qualifications, construction, materials, location requirements, and administrative procedures. In Canada, the three territories have no specific water well legislation although these issues may be dealt with under an overall water or environmental protection regulation. As of 2005, Manitoba, and Saskatchewan had not updated their regulation and their current requirements lack specificity to determine if a well was constructed appropriately. The remaining provinces have recently revised their regulations. Ontario's well regulation is one of the more clearly written regulations in Canada on this subject. Regulation 903, enacted by the Ontario Ministry of Environment, provides clarification to ensure appropriate construction, sealants, decommissioning techniques, and materials are used, but also allows for some flexibility.

This chapter will i) review the roles of groundwater and farming associations and the Ontario Ministry of Environment in promoting water well sustainability; ii) review Ontario legislation impacting water well sustainability; iii) compare Ontario water well construction legislation with that of other jurisdictions; and iv) review broader legislation governing water quality and water quantity relevant to wells and well construction.

### **5.1 Roles of the Ontario Ministry of Environment**

The Ministry of Environment's mandate is to protect the quality of the natural environment in order to safeguard the ecosystem and human health. MOE takes an ecosystem approach to protect and manage Ontario's water resources. MOE has the primary role in protection of our environment but there are many other Ministries with important roles (Figure 5.1). Federal and local groups also have roles in water management and protection.



**Figure 5.1 Ontario's Responsibility for Water by Ministry**

Source: Cam Baker, Ontario Geological Survey (2003)

The MOE has six divisions – four of the divisions - Drinking Water Management Division, Operations Division, Environmental Sciences and Standards, and Integrated Environmental Planning Division all play a role in keeping water and wells safe in Ontario (See Figure 5.2).

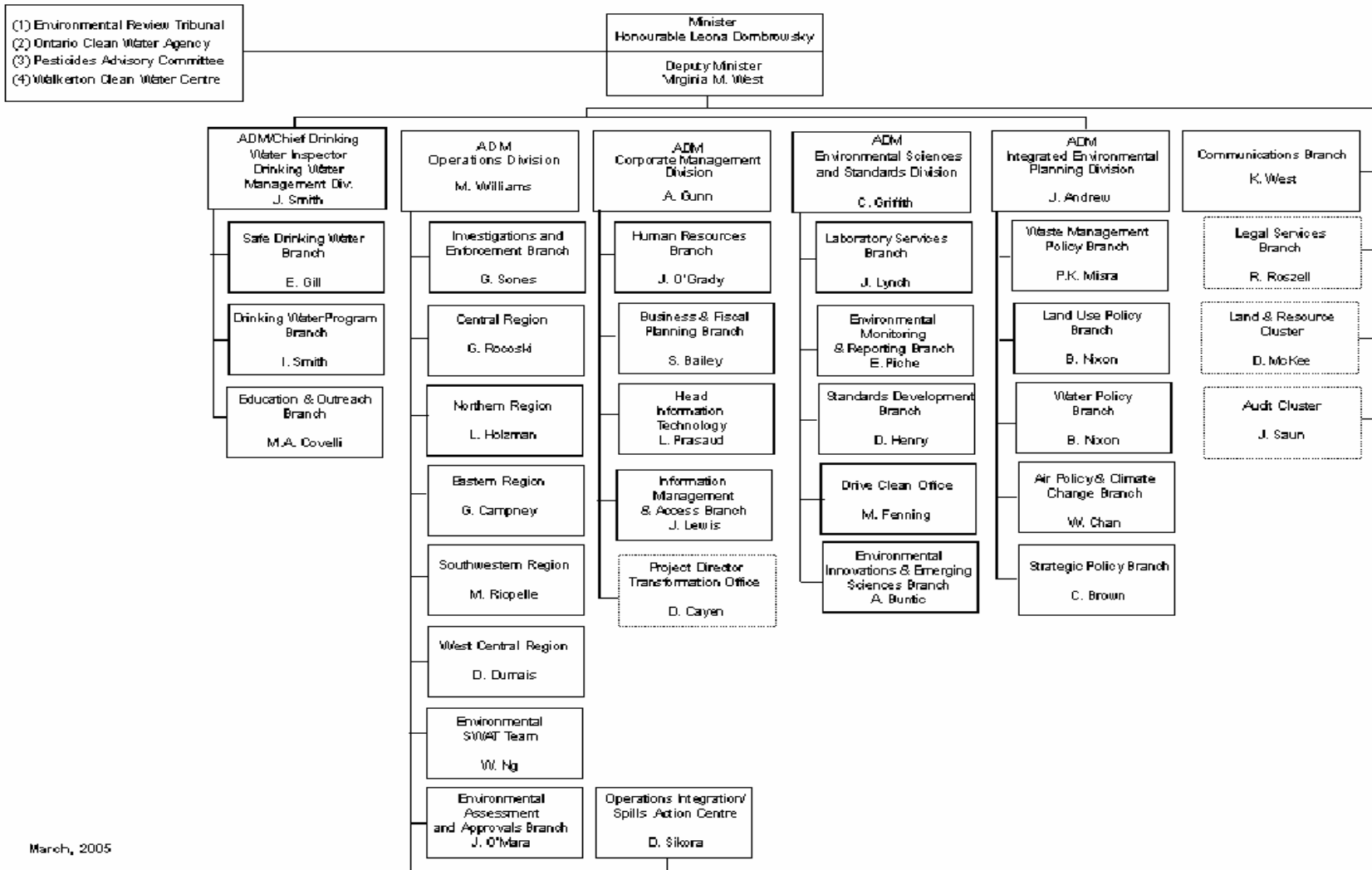
### **5.1.1 Operations Division**

The Operations Division oversees field monitoring and inspections; respond to calls from the public; investigate complaints; process Certificates of Approval and Permit to Take Water (PTTW); communicate with the public; and provide outreach. Field officers have 15 programs to deliver, with only one of the programs focused on groundwater. The field officers have access to technical support with which to provide information on ground and surface water; source water problems; maintain water-related information; conduct studies; and issue PTTW. Ritter and Gore (2002) reported that about 50 % of the pollution incident calls received by field officers receive a field response.

### **5.1.2 Environmental Science and Standards Division**

The Environmental Science and Standards Division includes the Environmental Monitoring and Reporting Branch (EMRB) that is responsible for the well program. The EMRB monitoring activities includes the Groundwater Monitoring Network. Water is monitored for a suite of parameters to evaluate trends in different locations. There are 372 monitoring wells used for this purpose in Ontario. Another relevant monitoring program is the Drinking Water Surveillance Program which began in the mid 1980s. This program was designed to assess long term trends in drinking water quality in Ontario by analyzing hundreds of substances known to be in use such as trace organics and inorganics. The program began with the largest water treatment plant and has expanded to include the majority of all municipal water systems. Three samples are

# MINISTRY OF THE ENVIRONMENT



March, 2005

Figure 5.2 Ontario Ministry of Environment Organizational Chart

Source: <http://www.ene.gov.on.ca/envision/org/orgchart.htm>

taken - pre-intake, processing and distribution. MOE covers the cost of testing and results are shared with municipalities.

The EMRB is also responsible for the Water Well Record Program. Water well records date back to the early 1900s and represent the most comprehensive database in Ontario on geological materials, well yield, and well location. For groundwater, the main source of information is the well program. Water well contractors are required to submit water well records to the owner of the new well and the Ontario Ministry of the Environment. The record includes information on the location; owner's name; date of construction; contractor's name; geologic log; water quality record; well construction details; and yield. Prior to 1998, well records were maintained as paper files; however, since then many records have been computerized.

The reliability of the information on well records prior to 1998 remains a concern, along with the number of undocumented wells. The initiative to update and modernize the water well database is still under development. According to EMRB, one of the major issues in making water well records data publicly available is the protection of privacy of information. Other barriers noted by EMRB to proceeding with a publicly accessible water well records database were lack of resources; lack of location information for many records; and the challenge of integrating the water well information system within the structure of EnviroNet or ENET. This system consolidates information for air and hazwaste and programs of the Ministries of Natural Resources, Agrifood and Northern Mines and Development. EMRB noted that the project to develop an information system will eventually go to tender. The Panel is aware that the technical capability to establish a web-based interactive water well information system exists within consulting companies in Ontario.

Over the last few years, municipalities, conservation authorities and a number of other groups have been working with the well driller logs to assist in groundwater characterization studies. Significant improvements in local well records have resulted from field verification and correction of errors where present. These enhancements are incorporated into the MOE database to increase the accuracy of the overall dataset. New requirements for improved well location information under Reg. 903 using georeferencing data provide an opportunity for better management of water well infrastructure in Ontario.

There has been a decline in recent years in the number of inspection staff at MOE to support enforcement and compliance with regulations. There have been no well inspection positions at MOE since 1998. Prior to 1995, the Water Resource Branch employed several hydrogeologists; undertook groundwater and well mapping; and coordinated inspections with the Operations Division. Wells are approximately 15% of EMRB business. The EMRB provides a supporting function to Operations division by providing advice and expertise. There is one experienced staff member within the branch to handle all incidents related to apparent non-compliance with the regulations, such as licensing violations and issues of substandard construction. Actions to revoke, suspend or refuse license renewals are carried out through legal services branch after thorough investigation by EMRB. The number of violations were estimated at between 100 – 200 annually, ranging from insurance violations to serious infractions. The number of practicing

unlicensed drillers was not known, but was thought to be no more than a few per year. MOE renews approximately 23,000 licenses each year.

### Water Policy Branch

The Water Policy Branch is part of the Integrated Environmental Planning Division and takes the lead on most water related subjects with the Strategic Policy Branch taking the lead role in source protection legislation. There are a number of inter-ministerial committees that interact with the Water Policy Branch. These include the Drinking Water Coordinating Committee; the Water Policy and Planning committee; and the Land and Water Committee. The main role is policy planning, development and coordination of programs supportive of policy objectives. A concept piece is developed through a small group to articulate the nature of the issue and a strategy to best respond. This is presented to the Assistant Deputy Minister (ADM) and others for consideration. If the proposed policy or program has a significant cost or will affect others outside of MOE, then a cabinet submission is prepared. Some proposals are posted on the Environmental Bill of Rights (EBR) Environmental Registry. The Water Policy Branch also comments on submissions by other ministries.

#### **5.1.3 Drinking Water Management Division**

The role of the Drinking Water Management Division is to ensure that drinking water systems follow Ontario's standard for protecting Ontario's drinking water. This includes adherence to the Safe Drinking Water Act; providing advice on policies specific to inspections; monitoring the frequency and efficiency of inspections; and the development of training programs for provincial officers. It is important to note that the activities of this Division are directed at municipal water supplies, small waterworks, and designated facilities (i.e., large community centres and recreational facilities).

### **5.2 Provincial Regulation of Wells – Regulation 903**

Well construction is regulated under the Ontario Water Resources Act Well Regulation (Regulation 903) (see Appendix H). This governs the construction and maintenance of all wells and dictates who can work on wells. Regulation 903 has recently been revised with many of these changes effective as of August, 2003. The revisions have provided clarification of the appropriate training for well technicians; improved construction and decommissioning standards; require mandatory placement of well tags on all new wells; and provide for educational information to well owners provided by well contractors.

#### **5.2.1 Summary of the Regulation**

Wells in Ontario must be constructed by well technicians licensed by the Ministry of Environment. Well contractors must take a 30 hour course and have 4000 hours of relevant work experience before they are licensed. Contractors must pass an exam every three years, and licensed contractors must attend at least one day of continuing education per year for renewal of licenses.

When a well is constructed, the well owner is provided with a sample of water to assess clarity; a well tag is affixed to the well and a well driller's record must be completed. The well record requires information about the well owner, geological stratigraphy, yield tests, GPS coordinates for the well location and a site map. Well records must be provided to well owners and to the Ministry of Environment. Homeowners must also be provided with an MOE well education package.

Older wells may become contaminated by surface materials as the percolating water exploit short cuts in the stratigraphy. This allows surface material to enter the water supply without the benefit of the attenuation processes that remove materials from the percolating water. Often the construction of the well itself may have created the short cuts. Poorly sealing the annular space or sealing the annular space with inappropriate materials allows large gaps to remain in some wells. Others have enhanced infiltration because of selection of porous materials surrounding the well. Other short cuts provided by a poorly constructed well include unsealed joints or casing that is corroded or damaged during installation of the well itself. The revised construction requirements of Regulation 903 address many of these issues. New wells must be constructed with a casing finished above-grade, with the ground surface graded away from the wellhead. Specified sealants must be used to 20 foot depth and a proper vermin-proof cap attached. Flowing wells must be constructed to control the flow and wells with mineralized water (more than 6,000 mg/L TDS or 500 mg/L chlorides or sulphides) are to be decommissioned at the expense of the well owner.

#### **5.2.1.1 Well Types Permitted**

Drilled wells and large diameter dug or bored wells are permitted in Ontario. This is because there are locations in Ontario where the larger diameter is necessary for adequate storage, and excessive mineral content in deeper water limits this supply. The new legislation has stipulated provisions to ensure that the construction of a large diameter well is secure. The specifications of casing material are laid out in the legislation. Concrete tile casing has been used in the past on large diameter wells but presents a risk due to the number of joints present in the well with a number of these joints near surface. The regulation stipulates permanent watertight bonds, and any concrete used on well construction must be fully cured before installation. This stipulation will ensure that unsealed joints, or joints that leak after a period of time are not present in new wells. Large diameter wells will be lined with galvanized steel or fibre reinforced plastic casings. Well pits or wells constructed within an older well are no longer permitted. The new legislation has also clarified sealant selection and annular space requirements.

#### **5.2.1.2 Decommissioning**

Wells that have not been used or maintained for future use must be plugged and sealed according to the requirements of Regulation 903. Decommissioning standards stipulate the materials and techniques to properly plug and seal different diameter wells (see Chapter 9). New standards require casing and pit materials to be removed. Instructions in regulation are more specific than in previous versions to ensure consistency across the Province.

### **5.3 Legislative Requirements in Ontario Compared to Other Jurisdictions**

#### **5.3.1 Construction of Water Wells**

A large focus of modern well regulation is on applying and maintaining an adequate seal to prevent vertical migration of contaminants and protecting wells from entry of foreign material. Casing material, joints and depth, annular sealing and the cap could all provide vertical short-cuts and permit surface water entry if not adequately addressed during construction and maintenance. Ontario's regulation is relatively specific about materials to be used for sealants and casing materials, the size of the annular space and the depth of the casing to try to address all these potential problems at the point of construction. Most provinces specify that new materials must be used in construction of wells; others specify diameters and thickness of casing and the most detailed regulations (Alberta and Ontario) provide reference to standards organizations.

Field observation of wells shows that sealing of casing joints is poorly addressed by many well contractors in Ontario (Conboy and Goss, 1999; Conboy and Goss, 2000). These joints often leave signs of moisture, water staining, debris or roots on the interior of the well. Ontario's new regulations will eliminate the use of cement cribbing for new wells. This will reduce the number of near surface well joints and the potential for surface material to impact aquifers. In Nova Scotia, dug wells can still be constructed with brick or concrete. The legislation specifies joints sealed and annular space filled with an impermeable substance (bentonite, concrete, puddle clay).

The annular seal acts as an additional barrier to the casing. A proper annular seal prevents the mixing of aquifers and reduces corrosive action upon the casing itself. In some regulations the proportion of the annulus that must be sealed, the methodologies and materials are specified. In some provinces, the entire length of the casing must be sealed with appropriate materials (Alberta and New Brunswick); whereas in Nova Scotia the annular space need only be grouted where contamination occurs or in dug wells. Other areas focus on particular portions of the casing to be addressed; in some locations the bottom (PEI) and most others focus on some specific distance from ground surface. In Minnesota, the construction code has increased the depth of grouting (from 30 to 50 ft). It also provides specific drilling and grouting methods to suit different types of geology.

Well caps should keep any surface material, including insects, out of the well. Large diameter wells are often difficult to seal to this degree. Drilled well caps have been improved in the last couple of years so that a vermin proof drilled well caps with screened vent and a rubber gasket for a tight seal are available. Ontario, Newfoundland and Alberta regulations specify that this cap must be used on drilled wells.

Wells in Ontario are to be finished above-grade with ground sloping away from well head. This prevents surface material from directly entering the well. Many regulations do not specify a minimum height. Alberta, Ontario, Nova Scotia and PEI have banned the use of well pits.

In a number of jurisdictions, prior approval is needed for well construction. For example, in Wisconsin, the applicant must complete and submit a form to the county at least two working

days before constructing the well if the owner or well constructor is interested in receiving information about potential contamination sources. Permits may be applied for after construction provided the property owner or the property owner's designated agent gives notice to the administrator prior to construction.

### **5.3.2 Set backs**

Wells are to be constructed to prevent contamination by surface water, seepage and other contaminant sources. Some regulations specify separation distances. Table 5.1 is a comparison of required minimum casing depths and set backs for different jurisdictions. The reason for set backs is either to protect the well from potential impacts or to ensure ability to service the well in future. The distances set out are minimum distances but are not a guarantee of complete attenuation of contaminants. Many rural residential properties have size limitations that may limit greater spacing but where possible, greater spacing would be desirable. Very few jurisdictions specify distances from unused wells. Ontario and Nova Scotia specify greater distances from wells that are dug/bored or that cannot achieve minimum casing requirements because of the aquifer location.

**Table 5.1 Minimum Casing Depths and Set Backs for Various Jurisdictions**

| Source of Pollution  | New Brunswick | Newfoundland                            | Nova Scotia                             | Ontario | Alberta | Maine    | BC       | PEI   |
|--|---------------|---|---|---------|---------|----------|----------|-------|
| Casing depth (min)   | 6 m           |   | 6.1 m                                   | 6 m*    | 1 m     |          | 15 feet  | 12 m  |
| Cesspool (receiving raw sewage)  | 30 m          | 30 m                                    | 15.2 m                                  | 15 m    | 100 m   |          | 30 feet  | 100 m |
| Seepage (leaching) pit, filter bed, soil absorption field, earth pit privy, or similar disposal unit                         | 25 m          | 16 m                                    | 15.2 m                                  | 15 m    | 15 m    | 100 feet | 30 feet  | 15 m  |
| Septic tank, concrete vault privy, sewer of tightly jointed tile or equivalent material, or sewer connected foundation drain | 15 m          | 16 m                                    | 15.2 m                                  | 15 m    | 10 m    | 60 feet  | 30 feet  | 15 m  |
| Sewer of cast iron with leaded or approved mechanical joints, independent clean water drain, or cistern                      | 3 m           | 3 m                                     | 3 m                                     | 15 m    |         |          |          | 3 m   |
| Pumphouse floor drain, cast iron with leaded joints, draining to ground surface  |               | 1 m                                     | 610 mm                                  | 15 m    |         |          |          |       |
| Building   | 2 m           |   | 1.6 m                                   | 15 m    | 3,25 m  |          | 3 feet   | 1 m   |
| Property Line  |               |   | 1.5 m                                   | 15 m    |         |          |          |       |
| Highway  | 10 m          |   | 6.1 m                                   | 15 m    |         |          |          |       |
| Landfill   |               | written approval from minister required | 61 m with written approval by inspector | 15 m    | 500 m   |          | 120 feet |       |
| Petroleum storage (above ground)   |               |   |   | 15 m    | 50 m    |          | _____    | 15 m  |

\* where the only usable aquifer is shallower than 6 m the well is to be cased to this aquifer or a minimum of 3 m.

### **5.3.3 Disinfection**

In Ontario, contractors must disinfect wells when they perform work on the well to remove any contaminants that may have been introduced during the work. There is no consensus on length of time or concentration for adequate disinfection in the literature or in guidelines across North America. In setting standards, the need to properly disinfect the well must be balanced with the risk of formation of dangerous gases at the wellhead or organic contaminants in the water (trihalomethanes) that can result from the oxidizing action of chlorine.

The American Waste Water Association standards provide the basis for the concentrations used in most regulation in the US, which is between 50 mg/L and 100 mg/L for a 24 or 12 hour period. Ontario requires 50 mg/L for at least 12 hours, PEI requires 100 ppm for 8 hours and Alberta requires 200 ppm for 12 hours. BC requires a minimum concentration of 100 pm chlorine with displacement into the formation for 3 hours. In Nova Scotia, regulations stipulate the need to disinfect and clean all new or repaired dug wells, but do not specify the same requirement for drilled wells.

### **5.3.4 Training for Well Drillers/ Technicians**

There is significant variation regarding who is eligible to work on wells in Canada. In some provinces, applicants must have significant work experience, course work and an exam (Ontario, Nova Scotia, Alberta, Newfoundland). At the other extreme, some only require payment of a fee (Manitoba). In some regions, well drilling is considered a formal trade and has requirements for experience, education and testing. Pump installers do not always have the same requirements.

In Alberta there are 5 classes of well driller's license. A contractor that can drill all classes of wells must be a certified journeyman in the trade of water well drilling. Only this class of license is qualified to drill wells for diversion and use of groundwater. Class B is for well diggers and the other 3 classes deal with contractors who will drill monitoring wells, contractors who recondition wells or those looking for saline groundwater.

The National Ground Water Association (US) requires mandatory licensing based on proven competence (testing and experience) for both water well drillers and pump installers (NGWA, 2000). In Maine, well drillers are bound by a code of professional ethics and have strict education and experience requirements with provisions in the legislation for resolving complaints including penalties. In addition to strict experience and examination requirements, Wisconsin requires a voucher signed by the licensed supervisory driller.

As so much of the well technician's training comes from an apprenticeship, it is important to ensure that new standards are understood and implemented by all drillers. Ontario's Reg. 903 requires the completion of a 10 day course, 4,000 hours of field experience under the supervision of a licensed contractor, a written exam and 7 hours of continuing education per year. This is comparable to other jurisdictions and should allow communication of key messages to keep the industry updated. Ontario drillers have commented that the initial course could be extended to

cover more specific issues relevant in practical situations. Well drillers often become very specialized and the expense of drilling equipment often will ensure that well drilling activity is a priority. As a result, many clients attempting to upgrade or decommission older wells may have difficulty finding available contractors.

### **5.3.5 Well Decommissioning**

Regulations regarding decommissioning wells may specify which wells should be sealed, the manner they are to be sealed and responsibilities regarding unused wells. In Ontario, wells that are not used or maintained for use are to be decommissioned. Responsibility for the decommissioning falls on the well owner. The decision to maintain or decommission the well is made by the well owner. This has created a situation in Ontario where there are a large number of abandoned wells with many occurring in close proximity. The Healthy Futures Upgrade and Decommissioning program has had participants decommissioning as many as eight wells at a time. The Well Aware Phase II Guided Self Assessment (GSA) found that about 20% of the participants, who were generally non-farm rural residents, had at least one additional well. Many areas of Ontario have switched rural residents to a municipal water service, but have not compelled the homeowner to retire the well leaving many abandoned wells in close proximity.

In Quebec, a well must be decommissioned if it has not been attached to a pump for three years, where a replacement well has been installed or where a well is not producing adequately. In Alberta, the well owner is also responsible for decommissioning a well when it is no longer being used; when it is in a poor state of repair; or where the well produces water that is unsuitable for drinking. The drilling contractor is legally responsible for immediately plugging a well when it is not completed due to construction problems or inadequate yield.

In Ontario, wells being decommissioned must be disinfected, filled with clean gravel in water bearing zone and then filled with alternating layers of clean fill and impermeable materials. Casing should be removed and the remaining casing capped below ground. In Alberta, casing is not required to be removed, but measures to address water in the annular space are suggested where the casing must be left. By regulation, a well must be filled full length with impervious material. That material must be introduced into the well at the bottom and be placed progressively upward to ground surface.

Minnesota has devoted extensive resources to sealing not-in-use wells. In the 1970s and 1980s, a number of serious ground water contamination problems were discovered where contaminants were either introduced through a well or spread laterally and vertically through not-in-use wells. Minnesota has a well disclosure program that became effective in 1990. Disclosure is a process where a seller identifies the number, location, and status (in-use, not-in-use, sealed) of all wells on a property to a buyer. A well disclosure certificate is filed at the time of recording the property transfer, and Minnesota Department of Health (MDH) follows up on not-in-use wells. MDH receives 20-30,000 certificates annually, with ~15% showing not-in-use wells.

In Maine, when a new well is to be drilled to replace a contaminated drilled well, regulations compel the sealing of the first well within a reasonable length of time (30 days), at the owner's expense. The driller must inform the homeowner in writing of this and both parties sign a

document including a statement of acceptance of these conditions by the homeowner as a requirement of remaining in compliance with these rules.

In many jurisdictions, a cost sharing program is offered to encourage well sealing. In Alberta, municipal and provincial governments jointly provide a full subsidy for decommissioning wells. Ontario has had a subsidy program provided by the Ontario Ministry of Agriculture and Food Healthy Futures funding. This program provided 64% of the cost of well decommissioning. There were more than 650 participants over a two year period; however, over \$1 million was unspent for this program. Greater incentive and longer term programs may be needed in Ontario.

### **5.3.6 Inspection**

Across Canada, the number of well inspectors has declined in the last decade. In the past, water well inspectors spent a great deal of time in the field with water well drillers allowing time to observe the contractor's work. This provided an opportunity to inform contractors of how to meet regulatory guidelines. It also allowed direct assessment of wells. Currently, the majority of the provinces use a complaint-based approach to enforcement. In Ontario, where the complaint focuses on well water quality, the well may not even be assessed as part of the investigation. Although inspection and enforcement is an appropriate tool to monitor well drilling practices, not all elements of the well construction can be examined after it has been completed (annular seal, seating into bedrock etc.). This makes it important to have outreach promoting best practices and voluntary compliance. In the past, an important role of the inspector was communication between the government and water well contractors. This now falls on water well associations. Where these organizations are sufficiently funded, organized and represent the majority of contractors in the Province, this approach is effective.

Some jurisdictions have a more comprehensive well inspection program. In Minnesota, there are 18 inspectors. Approximately 12,000 – 13,000 wells are constructed and a similar number are sealed annually by 563 contractors. Field staff are equipped with a variety of metal locators and geomagnetometers, downhole casing detectors, small downhole cameras, and GPS units. Minnesota inspects approximately 25% of wells being constructed and 5-10% of well sealings with at least one project from each contractor inspected annually.

Enforcement is a critical component of ensuring wells are constructed properly and ensuring a functional industry. Observations made during the Healthy Futures upgrade and decommissioning program audits indicate that lack of enforcement can lead to poor construction practices. Recently upgraded wells or decommissioned wells were observed for adherence to best practices. Best practices were used in 59 of 396 (15%) of well upgrades and 61 of 102 (60%) decommissions. Many contractors who did not adhere to best practices offered lower prices to the client, making the use of poor practitioners favorable to clients.

### **5.3.7 Water Testing**

Ontario does not have mandatory testing for private water supplies. To encourage regular monitoring of water quality, the Ministry of Health and Long Term Care (MOH) offers a complimentary service to assess water for bacteria, nitrate (once a year) and fluoride as

requested. The bacterial testing is widely available and used by many rural residents; however, testing for other parameters is not common. Newfoundland also has a bacteria water testing service. Well Aware Phase II Guided Self Assessments surveyed 450 participants on water testing habits and found 90% do not test for parameters other than bacteria. MOH recommends testing water for bacteria three times per year; less than 25% of participants were adhering to this recommendation.

In most jurisdictions the legislation is aimed at water supplies for larger numbers of people. The US EPA *Safe Drinking Water Act* does not cover wells serving fewer than 25 people. Some areas do address private wells specifically. Quebec and New Brunswick, for example, have legislated requirements for water testing in private wells. In Quebec, people drawing water from their own wells are required to sample for coliforms twice a year and for nitrates once a year. The Potable Water Regulation from New Brunswick applies to surface water, ground water and domestic wells. Under this legislation, all new wells must be tested. Well contractors sell homeowners water testing vouchers entitling them to an analysis for inorganic substances and micro-organisms. It is mandatory to have wells tested within 12 months of their construction.

In New York, if a homeowner discovers contaminants in their well, the state will provide water on an emergency basis or put special filters on the tap. Leaking underground storage tanks are a particular problem. The government encourages homeowners to be on public systems.

New Jersey requires mandatory testing of well water when an owner sells or rents their land. The wells would be tested for all regulated contaminants, as well as the pesticides and radionuclides that may be present in New Jersey drinking water. These parameters would depend on the region. The results of the testing would have to be disclosed to the buyers or renters. There is also a provision for zero interest loans for testing and cleanup of private wells.

#### **5.4 Legislation in Ontario Impacting Municipal Wells**

Municipal wells operate under a Certificate of Approval and as such have more onerous requirements for construction, maintenance, water testing and quality standards. In the late 1990s inspections of the water treatment facilities had dwindled significantly and were less thorough than current procedures. Since the Walkerton tragedy of May 2000, there have been more frequent inspections in Ontario. In the three years prior to the Walkerton incident approximately 30% of the facilities were inspected. However, this has increased to 100% inspected annually since 2000. There has been extensive hiring and training of field staff to inspect municipal facilities and one of the requirements is to examine the sources of water, including the production wells. The Certificate of Approval for a municipal water supply must have an engineer's report that includes a hydrogeological study where the application is related to a groundwater supply. Raw water quality must be documented and discussed.

There has been a great deal of movement in the legislation pertaining to water supplied to the public in the last three years. The legislation has divided water providing facilities into a number of categories depending on the size of the population served, with strict testing, treatment and reporting requirements for the different categories. New legislation also ensured that where the groundwater was under direct influence of surface water (GUDI), then the requirements would

be identical to that of facilities receiving water from a surface water body. This imposes a filtration requirement in addition to the chlorination required in all systems. Large waterworks serve more than 100 private residences and a small waterworks provide water for over five and under 100 private residences. Another group of facilities – labelled designated facilities were also captured under new legislation. Modification of the legislation in 2005 removed some of the burden for testing on low risk facilities.

Water served to the public is guided by the Drinking Water Systems Regulation (170/03). This legislation was developed under the Safe Drinking Water Act (2002) and Ontario Water Resources Act. The Drinking Water Systems Regulation sets out a duty to provide water that meets the ODWS, to report adverse test results and sets out requirements for approvals in municipal and non-municipal regulated systems. It is supported by the Ontario Drinking Water Quality Standards Regulation (O. Reg.169/03), two regulations dealing with the language in regulations (O. Reg. 171/03 and 172/03), regulations pertaining to designated facilities --schools, private schools, day nurseries (O. Reg 173/03), and large (O. Reg. 175/03 – previously 459/00) and small waterworks (O. Reg. 176/03 previously 505/01) legislation. Private systems (serving under 5 households) have not been impacted by any of this legislation.

The requirements of hydrogeological studies, engineering reports, monitoring of the raw water quality and better well construction due to the high volume of water used in larger systems provides additional assurances for these water supplies. The expertise enlisted will ensure a proper construction and location of the well, an understanding of hydraulic connections with the surface, and adequate monitoring to detect whether sealants, or other structural components of these large wells, have been effective.

## **5.5 Role of Associations**

There are a number of associations in Ontario that are involved in the water well industry, some of which include farm associations, cottagers' associations, Association of Municipalities of Ontario (AMO) and Northwestern Ontario Municipal Association (NOMA).The Ontario Ground Water Association (OGWA) represents water well contractors, pump installers, manufacturers and suppliers, scientists and engineers who work in Ontario. The OGWA has a critical relationship with the MOE in the following areas:

- Direct consultation with MOE's Policy Branch regarding the development of Regulation 903;
- Partner in the development and execution of the Well Aware outreach program;
- Facilitation between MOE and the water well industry with regard to implementation of the Regulations; and
- Group consultation with MOE with regard to development of proposed Source Protection legislation.

This working relationship with the MOE allows OGWA to implement, through the water well industry, required practices to comply with Regulation 903.

In addition to OGWA, the Association of Professional Geoscientists of Ontario (APGO) participated in the Well Aware Program and has contributed opinions to the MOE on the development of Regulation 903. Similarly, the Professional Engineers of Ontario (PEO) has expressed opinions on monitoring and geotechnical well construction and decommissioning as addressed in Regulation 903 (see Sections 7.3 and 9.3).

## **5.6 Conclusions**

1. Ontario's Regulation 903 is well-written and comprehensive in addressing private wells, adding clarification to ensure proper construction, sealants and decommissioning techniques and materials are used, while allowing for some flexibility. Ontario does not have specific water testing requirements in the legislation but has encouraged water testing through a complimentary service offered through the Ministry of Health.
2. The Panel believes that bacterial testing of private wells by well owners is presently inadequate.
3. Based on interviews with stakeholders, well inspection and enforcement of Reg. 903 is presently inadequate.
4. There has been a significant improvement in legislation addressing the construction and operation of municipal wells. The Panel considers the current level of inspection and enforcement to be rigorous.
5. The Ministry of Environment has collected groundwater data for a number of years through the Drinking Water Surveillance program, the Water Well Information System and the Groundwater Monitoring Network. This data remains difficult to access by the groundwater stakeholder community and therefore is a barrier to proper resource/infrastructure management.
6. The Panel recognizes that new privacy laws have impacted the ability of private well owners and practitioners to identify the location of wells. This may lead to safety issues if existing wells cannot be found.

## **5.7 Recommendations**

1. The Panel recommends that the process of collecting, compiling and disseminating the Water Well records data be more transparent and accessible to the groundwater stakeholder community (See also Recommendation 3.3).
2. To build upon MOE's source protection and water taking permit initiatives, a stakeholder group should be established immediately to explore alternatives for managing the Water Well database. This stakeholder group should report to the Minister within 12 months of its formation.
3. Ontario should clearly set out water quality testing requirements for private water wells. At a minimum bacterial content, nitrate, fluoride, iron, hardness, and turbidity should be

measured immediately following new well construction. For this testing requirement to be implemented successfully, the testing must be legislated.

4. Mandatory membership in an accredited professional groundwater association should be required for all workers engaged in water well activities. This action is needed to facilitate the transfer of knowledge from those on the cutting edge to the broader water well industry and to ensure that a highly skilled workforce is sustained throughout the Province.
5. To ensure due diligence and compliance with Reg. 903, a third party organization should be engaged to develop an outreach and education program for the drilling industry.
6. To support the objectives of Reg. 903, enforcement of the regulation should be provided by a third party organization who has qualified, experienced staff that are knowledgeable about the water well industry.
7. The Panel recommends that the decommissioning requirements of Reg. 903 be strengthened by compelling more formal linkages between replacement well construction and decommissioning of the existing wells.
8. The Panel recommends that the Water Well record for decommissioning should state the reason for well closure (See also Recommendation 2.4)

## **5.8 References**

Conboy, M. J. and M. J. Goss. 2000. Natural Protection of Groundwater Against Bacteria of Fecal Origin. *Journal of Contaminant Hydrology*. 43(1): 1 – 24.

Conboy, M. J. and Goss, M. J. 1999. Contamination of Rural Drinking Water Wells by Fecal Origin Bacteria—Survey Findings. *Water Quality Research Journal of Canada*, 34(2): 281-303.

Ritter, L., and Gore, 2002. Sources, pathways, and relative risks of contaminants in water. Walkerton Inquiry Commissioned Paper 10.

## **6.0 Evolving and Other Important Legislation Affecting Water Well Sustainability**

The construction, maintenance and decommissioning of wells is important to the sustainability of wells in Ontario. It is also important to consider factors impacting the water supply available to those drawing water from wells.

Water is protected in Ontario by federal, provincial and in some locations local legislation. There are a number of pieces of legislation designed to protect water quality and water quantity broadly. This includes some that are more specific to municipal drinking water and to a lesser degree private water supplies.

Before 2000, water quality was protected through several guidelines and objectives. For example, the Ontario Drinking Water Objectives were targets set for water supplies but there was no force of law behind the objectives. Since 2000, the Ontario Drinking Water Standards have been implemented and regulations governing water consumed by the public have been developed and improved to ensure that drinking water is safer in Ontario.

### **6.1 Source Protection Planning**

An integral part of a sustainable water supply is the assurance of long-term quantity and quality. The Walkerton Inquiry recommendations (O'Connor, 2002a; 2002b) as endorsed by the Province, called for the application of a watershed-based approach in evaluating proposed water takings and in assessing land use changes that could impact on the availability and quality of source waters. The goal of watershed-based drinking water source protection planning is to protect human health through the protection of current and future sources of drinking water. The Government of Ontario has recognized the need for a multi-barrier approach to protect drinking water sources. A multi-barrier approach would ensure selection of a reliable water supply; proper siting and construction of municipal wells; proper maintenance and testing of the water supply and post-treatment testing; and follow up to ensure that water delivered to residents met Ontario Drinking Water Standards.

In May 2000, new legislation aimed at enacting this multi-barrier approach was put in place. The Safe Drinking Water Act, Small Waterworks Legislation for Designated Facilities (O. Reg. 505) and Drinking Water Protection Legislation for Larger Waterworks (O. Reg. 459) address testing, treatment and delivery of drinking water. Drinking water source protection legislation is designed to provide the first barrier in this multi-barrier approach. Effective June 1, 2003, the Drinking Water Systems Regulation (O. Reg. 170/03) replaced the Drinking Water Protection Regulation for Larger Waterworks (O. Reg. 459/00) and the Drinking Water Protection Regulation for Smaller Waterworks Serving Designated Facilities (O. Reg. 505/01). MOE recently engaged in public consultations, through the Advisory Council on Drinking Water Quality and Testing Standards, on Ontario Regulation 170/03, as it pertains to smaller, private systems.

An Advisory Committee on Watershed-Based Source Protection Planning was formed in November 2002 to set out a framework for watershed-based source protection planning. The Committee consisted of representatives from several different ministries and stakeholder groups. The resulting report, "Protecting Ontario's Drinking Water: Towards a Watershed Based Source Protection Planning Framework" (MOE, 2003), was completed in April 2003. The Drinking Water Source Protection Model developed by the Advisory Committee aligned very closely with the recommendations of Justice O'Connor in his Walkerton Part II report – Chapter 4 (O'Connor, 2002b) including the development of source protection plans at the watershed scale through a local process coordinated by Conservation Authorities. There will be stakeholder involvement in the development of the plan and the Ministry of the Environment has the ultimate responsibility for approving these plans. Where there is insufficient capacity in the Conservation Authority, the Ministry will complete the plan.

In February 2004, MOE released a White Paper (MOE, 2004) to consult on three key areas of source protection: i) the planning components of source protection legislation; ii) improvements to the permit to take water program; and iii) principles and factors related to implementing a system of charges for water taking. A proposed Drinking Water Source Protection Act was posted on the EBR registry in June 2004. The Ministry of the Environment established two multi-stakeholder advisory committees tasked with providing advice to the government on the implementation and technical aspects of source protection: i) a Technical Experts Committee (TEC), which was tasked with providing advice on an Ontario-based threat assessment process and appropriate risk management tools for various levels of threat; and ii) an Implementation Committee, which was tasked with providing advice on tools and innovative funding mechanisms and incentives to implement watershed-based source protection planning. The work of the committee was posted for comment on the EBR in December 2004.

Education for private well owners is an important element of source protection. Both the Technical Experts and Implementation Committees examined how private wells fit into the context of source protection planning. Private wells are not only a water supply that may tap into the same aquifer as a municipal supply; they can also be pathways for contaminants to enter the aquifer if not maintained properly.

The TEC formed a "Private Services Sub-committee" to focus on wells, surface water intake pipes and septic systems for individuals. Many of the recommendations of the TEC and the Implementation Committee were similar to the recommendations of this Panel<sup>1</sup> including: inspection for new wells; public education; incentive programs for decommissioning; linking decommissioning of wells with construction of a replacement well; and development of a comprehensive guide for well owners. Data management issues were also discussed in detail in these reports. The TEC committee identified Medical Officers of Health and source protection planning committees as mechanisms for implementation of the recommendations. The

---

<sup>1</sup> The bulk of this Panel's work was completed prior to the release of the TEC and Implementation Committee reports; however, the Panel felt that it was important to discuss the findings of these reports with respect to private wells.

Implementation Committee recognized the importance of collaborating with non-government organizations (NGOs). The Well Aware program has demonstrated the effectiveness of NGO involvement in outreach initiatives. The messages conveyed are non-threatening with broader objectives than the protection of human health. This creates an empowering climate in which the well owner progresses far beyond regulatory requirements and approaches the maintenance of their well and septic system as a progressive, site specific, continual process.

In source protection planning, risk management is an essential component of the decision-making process. In a municipal supply, the risk to human health associated with consumption of unsafe water is so great that water treatment is essential. Treatment of private supplies presents a greater challenge. Surveys of private water supplies show that most groundwater quality meets ODWS for most health objectives (Goss et al. 1998; Conboy and Goss, 2000). Bacteria is the most common contaminant found in private water supplies. However, two-thirds of the wells sampled did not have bacteria. In many circumstances, private well owners are inclined to install treatment systems without knowledge of the water quality, and without addressing structural problems with the well. This approach could have negative impacts on the aquifer and pose a threat to the environment. All treatment systems require some type of maintenance. The use of water treatment systems may instill a false sense of security among well owners. As a result, well owners may not undertake routine treatment system maintenance which could compromise water quality. A diligent water testing program, coupled with regular assessments of the well is a proactive approach that would lessen the need for treatment equipment in many cases. This approach creates a connection between the individual's actions and their water supply.

Source protection planning is in many ways similar to Sustainable Asset Management in its approach and objectives. The asset management approach integrates quality and risk management principles and provides a comprehensive, flexible and proactive means of optimizing drinking water quality and protecting human health. It does not eliminate the requirement for compliance monitoring but allows it to be viewed in the proper perspective as providing verification that preventative measures are effective.

Figure 6.1 summarizes the key questions that must be addressed for a sustainable asset management approach to private wells. Some of the issues and the tools available in Ontario are discussed.

## **6.2 Nutrient Management Act**

New legislation aimed at reducing non-point source pollution was passed on June 27, 2002. The Nutrient Management Act addresses land-applied materials containing nutrients. It also addresses any other land applied substance – pulp and paper sludge, sewage/septic disposal, etc. The Act provides a comprehensive nutrient management framework for Ontario's agricultural industry, municipalities and other generators of materials containing nutrients, including clear environmental protection guidelines. The Act is administered by both the Ministry of the Environment and the Ministry of Agriculture and Food and incorporates best management practices regarding manure management practices into legislation.

## **How does Ontario shift to a proactive sustainable approach for private wells?**

### **Understand the asset**

It is important to look at the best indicators of the condition of the well and key pieces of information that could foretell if problems are imminent. The type, age, depth and location of private wells are all pieces of information routinely collected; however, none of these parameters are signs of the capacity of the well to provide satisfactory service. In many other industries key items are monitored for indications of degradation. Condition-based approach to maintenance has shown savings over a simple time or schedule based approach. Ontario needs to invest in research into identifying key indicators that would help understand when a well is nearing the end of its natural life or when key repairs are needed to extend the life of the well.

**Well Aware program** – Guided Self Assessment (GSA) provides information on private wells – condition, age and types as well as well owner knowledge base to address problems.

**Well Surveys** – More comprehensive and more frequent with time between large scale surveys to conduct analysis.

**Water Well Information System** – Enhance accessibility and reliability of data.

**Water Testing Database** – MOH testing could be analyzed for trends and become a key tool for proactive management of private wells.

**Water Quality Database linked to Well Driller/Geological Data** – Allows trends analysis, spatial analysis and leads to proactive management.

### **Collaborate and facilitate the transfer of knowledge**

- Greater resources and flexibility to researchers seeking to advance knowledge on wells
- Develop resource of highly trained individuals and foster inter-jurisdictional collaboration.
- Fund field trips to learn more about best practices in other regions.
- Greater collaboration between highly trained QP and Well technicians – division between researchers, professionals and laborers. There needs to be greater integration of these resources to determine feasibility, economics, protection of the environment.

### **What would it cost to proactively manage wells?**

- Cost versus worth – without a water supply rural homes can't get a mortgage – minimum quantity and quality parameters set out in mortgages - no bacteria and min 3 gpm.
- Affordability is central to a successful approach.
- People will accept the need to do proactive maintenance if this is available and if messages sent example – furnace and air conditioner service contract/insurance – clean furnace and air conditioner once a year and cover costs through insurance program. Oil changes and routine service at set mileage
- How do you ensure long term affordability? – Price protection plans, service plans, insurance programs, etc.

### **What are the tools to ensure safe water and healthy environment?**

The tools to ensure environmentally sound practices are not always the same tools private well owners would use for safe drinking water. Bottled water, UV lights and other treatment may provide safe drinking water, but what happens to the well when investments are made in treatment and bottled water and not the structural integrity of the well?

Is it more efficient to rehabilitate old wells or build new ones? Implications to the environment versus costs?

**What do you need to do?** The key is with the homeowner. Teach them what their well should look like, when and how to test water, what these results mean, where to go to address problems at reasonable prices to fix the problems.

**When** – Need to make up for 10 years of complaints-based responses, and limited staff resources to address these complaints. Need to make up for lack of inspection and enforcement of construction standards and need to make up for lack of understanding re: risk associated with abandoned wells. The client has not felt compelled to address that old well in many years. Why now?

**Measuring performance** – how do you know when things are improving?

Create a simple well scorecard – like Well Aware GSA and evaluate selection of wells on a regular basis.

**Figure 6.1 Answering Key Sustainable Asset Management Questions for Private Wells**

The Nutrient Management Act ensures that nutrients are applied according to crop requirements and limits application if excessive stores of major nutrients are found in soil reserves. The Act is based on the need for Nutrient Management Plans (NMP) for the purpose of allocating proper

nutrients for crop use to reduce nutrients lost to the environment and maximize the crop yield. There is a focus on controlling run-off, erosion and material leaving through tile drains. New barns or storages or manure spreading are not permitted within 100 m of municipal wells, and set backs from private wells are also prescribed. The Nutrient Management plan will identify areas with high vulnerability to erosion through assessment of slope, proximity to water bodies or other sensitive features and depth to bedrock. The plan will ensure proper buffer strips /setbacks to these sensitive features. Farmers will implement mandatory permanent vegetated buffers (3 m from top of bank; 20 m for liquid; 10 m for solid) and retire productive farmland for this purpose. The legislation is now in effect for new and expanding farms; however, there is still discussion about implementation on existing farms. The original approach focused on categorizing farms by size and having the larger farms phased in by 2005. The provincial nutrient management advisory committee has been struggling with the issue of how to ensure that nutrient management legislation is compatible with source protection concepts and how to ensure funding is available to address the greatest need when using a size based approach. As a result, there is a proposal to approach nutrient management in a risk-based fashion. This is an evolving issue that had not been resolved at the time this document went to press.

### **6.3 Other Water Quality Legislation**

Surface water quality in Ontario is protected federally through the Fisheries Act, and through the Peace Order and Good Governance legislation, where the matter is of a national concern. There are several other Federal Acts that play a role including the Boundary Waters Act, the Atomic Energy Control Act, the Pesticide Control Act and the Canadian Environmental Protection Act (CEPA). In Ontario, the management of the Fisheries Act is typically ceded to Conservation Authorities and this Act is frequently used in groundwater takings. At the provincial level, water quality is protected through the Environmental Protection Act, the Ontario Water Resources Act, and the Wells Regulation. The Safe Drinking Water, and the Water Works and Sewage Act provide further protect municipal drinking water supplies. Source protection legislation (in development), and the recently passed Nutrient Management Act will shift the current legislation from reactive to preventative strategies in water quality.

#### **6.4.1 Ontario Water Resources and Environmental Protection Acts**

Provincially, the Ontario Water Resources Act (OWRA) and the Environmental Protection Act (EPA) have been used interchangeably to protect water quality in Ontario. The Ontario Water Resources Act (OWRA) is the central piece of legislation to protect groundwater and surface water. Administered by the Ontario Ministry of Environment (MOE), the OWRA prohibits discharges of any pollutant into water. After the deaths at Walkerton in May 2000, the Ontario Drinking Water Objectives were incorporated into enforceable regulatory standards, initially as O. Reg. 459/00 under the Ontario Water Resources Act, and then, in June 2003, as O. Reg. 169/03 under the Safe Drinking Water Act, 2002.

The Environmental Protection Act (EPA) defines the regulatory amount of prohibiting contaminants that can be discharged into water. The EPA has been amended to define the role of

MOE in prevention and clean up of water pollution. MOE will often refer to both the OWRA and EPA when laying a charge regarding water pollution (Ritter and Gore, 2002).

#### **6.4.2 Local Programs**

In Ontario, several jurisdictions have adopted their own groundwater protection strategies. The Region of Waterloo, Halton and Peel, Oak Ridges Moraine Conservation Plan and the County of Oxford all have examples of groundwater strategies. An integral component of the groundwater protection strategy is the collection of data to fully understand the resource and factors that may impact the sustainability of this resource. In some areas such as Waterloo, Oak Ridges Moraine and Oxford county, the resources have been studied, mapped and modelled in considerable detail.

Several municipalities have used the information to develop long term water plans, and groundwater protection strategies. Some aspects of these strategies include development of conservation targets and mechanisms to achieve these reductions; development of by-laws regarding source protection; nutrient management; septic system pumping; private well construction or private water testing. Other areas have implemented programs targeting rural groundwater protection by funding adoption of Best Management Practices, proper maintenance and construction of wells and septic systems and attention to abandoned wells. Some regions have used information from their studies to amend their official plans.

#### **6.4.3 Groundwater Protection in Other Jurisdictions**

Groundwater protection strategies in most jurisdictions define wellhead and capture zones and appropriate land use guidelines are applied within these zones. The extent of a wellhead protection zone also depends on the nature of the target contaminant.

In Canada, Manitoba, New Brunswick, Quebec, Newfoundland and Nova Scotia have enacted legislation allowing for the creation of protected watersheds or wellfields. New Brunswick regulations focus specifically on the concept of wellhead protection, imposing detailed restrictions on what chemicals can be stored or used in each of the three protection zones, which are defined individually for each well field. Anything not explicitly permitted is prohibited, and compliance is monitored by provincial and municipal inspectors. British Columbia has had more problems with waterborne disease than any other province in Canada, and has become the most aggressive in trying to address these problems. Victoria owns 90% of 87 km<sup>2</sup> catchment area of the watershed supplying drinking water and has restricted activities greatly – people are denied entry. BC enacted Bill 20, the *Drinking Water Protection Act*, in April, 2001 requiring drinking water source assessments and the identification of potential threats. Drinking water officers will oversee a source-to-tap assessment of every drinking water system in BC to address all potential risks to human health.

The Quebec legislation attempts to cover aspects of Ontario's Nutrient Management Act and source protection under one act. In addition to providing for the protection of groundwater intended for human consumption, the Regulation provides the standards for siting wells, determining management areas and carrying out agricultural activities near wells. In Quebec,

municipal wells (or any other well with average flow rate greater than 75 m<sup>3</sup>/day) must be fenced and a notice posted alerting people of the presence of a drinking water well. Within the immediate protection area, activities, facilities or deposits of materials or objects likely to contaminate groundwater are prohibited, except equipment necessary to operate a well when installed safely. Hydrogeological studies must be conducted to define 200 and 550 day time of travel; vulnerability of the aquifer in these areas and microbiological contaminant inventory is required and documentation must be signed by a licensed engineer. Minimum radii of 100 m and 200 m are used if more than 20 people are supplied by the well. There are restrictions on new barns or storages, spreading manure (30 m) and biosolids (100 m), or infield manure storage. Where nitrate is elevated, there may be further restrictions in the immediate well head area.

Most European groundwater protection standards are based on a zoned system. The inner most zones may be based on either distance or time of travel to account for short-lived microbial contaminants while the outer zones may include the entire well capture zone to account for persistent chemical contaminants. The European Union has formed an International Consortium to set uniform standards for the delineation of groundwater protection zones within the member countries. In the US, the EPA has developed detailed guidelines covering all aspects of groundwater protection. The states are charged with implementing groundwater protection on the basis of these guidelines. The United States *Safe Drinking Water Act*, introduced well head protection in 1986. It is achieved through voluntary programs encouraging states to develop programs to protect land areas around water supply wells. More detail on New York's source protection program is provided in Appendix C.

England, like the United States, has national legislation and mandatory drinking water standards. The *Water Resources Act* administered by the Environment Agency is concerned with overall water resources management. The Act includes duties to achieve and maintain water quality objectives; the prohibition of certain discharges; requirements to take precautions against pollution; and the power to define certain areas as nitrate sensitive areas or water protection zones with greater controls on pollution. Nitrate Vulnerable Zones are designated in areas where surface water or groundwater exceeds or is at risk of exceeding the European Commission nitrate concentration limit of 50 mg/L. In England and Wales, Nitrate Vulnerable Zones have been designated which have required farmers to reduce nitrate leaching from their land beginning in December 1998, following codes of good agricultural practice.

#### **6.4 Water Quantity Legislation**

Water in Ontario has historically been allocated through common law according to riparian rights. In a riparian system, allocation is based on ownership of riparian land. Upstream users can not divert nor interfere with the water supply of another riparian; and riparian landowners do not have to make use of the water to keep riparian rights. The rule of capture is used for groundwater rights. The capture rule allows the landowner to withdraw as much percolating water as they wish without liability for interference created by this taking. These common law rights assume an abundant if not inexhaustible water supply.

MOE plays a key role in managing groundwater through administration of the Ontario Water Resources Act. This Act which places a requirement for a Permit To Take Water (PTTW) on anyone drawing more than 50,000 litres of water per day from any source. The Ontario Water Resources Act, Permit to Take Water (PTTW) was enacted in March 1961. The OWRA states that the Minister of the Environment has the supervision of all surface waters and groundwater in Ontario (R.S.O. 1990, c. 0.40, s.29), and authorises the MOE director to regulate the actual taking of groundwater and surface water (R.S.O. 1990, c. 0.40, s.34). It also provides for fair sharing and resolving of disputes among water sharers.

In Ontario, permits are provided for a variety of uses including irrigation (agricultural crops and golf course); commercial (plazas, restaurants, motels, municipal potable and non potable uses); industrial (power generation and quarries); communal (private water supply, bottling, recreational, wetlands, fishponds, snowmaking); and other (construction, dewatering, aquifer testing). The permits specify a maximum daily withdrawal with exemptions for domestic and livestock uses and for firefighting. Permits for different uses or sources are provided for different lengths of time. For example, water bottlers renew every two years, surface water every five years and all others are every ten years. The Director has the ability to prohibit water taking where it adversely interferes with another person's interests in water.

The Water Taking and Transfer Regulation (O. Reg. 285/99) was issued under the OWRA in May 1999 and replaced in December 2004 by a new Water Taking and Transfer regulation December 2005 (O. Reg. 387/04). The primary purpose of this legislation is to provide for the conservation, protection, use and management of water in Ontario. This regulation provides details on issues the Director must consider when issuing a Permit to Take Water including the protection of the natural functions of the ecosystem; surface water taking effects on groundwater; groundwater takings on surface water; availability of water in the watershed; the use of the water; concerns of others who have an interest; and the Great Lakes Charter. The main purpose of this regulation is to prohibit bulk transfer of water between water basins. Bulk transfer of water prohibition only applies to volumes packaged in containers larger than 20 L. Water used to manufacture or produce a product is also exempted.

In Ontario, the most common form for public notification of PTTW applications and approvals consists of the electronic Environmental Registry postings as required under the Environmental Bill of Rights Act (EBR). Water taking permits are Class 1 prescribed instruments under the EBR and as such must be posted on the Registry for a minimum of 30 days. Current exceptions include proposals for short term (<1 year) increases in water taking for crop irrigation, for other short term uses such as hydrostatic testing or construction site dewatering, or where the taking is deemed environmentally insignificant or is covered by alternative consultation mechanisms. All Ministry decisions relating to the granting of PTTW approvals and the conditions attached to those approvals are also posted on the Environmental Registry and may be appealed within 15 days of posting.

### **6.5.1 Other Influences on Water Taking**

The Ministry of Environment has the primary responsibility over water takings through the OWRA PTTW, however other agencies may also be influential in water quantity issues. Where

fish habitat may be impacted, the Ministry of Natural Resources or the Department of Fisheries and Oceans may require an additional approvals through Lakes and Rivers Improvement Act or the Fisheries act. OMAF provides guidance to rural landowners on wells and encourages farming practices that minimizes the impacts on both groundwater quality and quantity through the Environmental Farm Plan program and the Nutrient Management Act. It also administers the Drainage Act.

In fact, there are 30 pieces of legislation that could impact a permit administered by many different groups including Ministries of Natural Resources, Agriculture and Food, and Municipal Affairs and Housing and the federal government Departments of Environment, Fisheries and Oceans, Natural Resources and Transport. At the watershed and local level, conservation authorities and municipalities are involved in a number of regulatory, operational and planning activities pertaining to water resource management. Municipalities influence water demand and usage through land use planning decisions and also through their role in providing and managing water services to residential, commercial, industrial, and institutional customers. Finally, the individual water user can contribute to the effective management and use of water through decisions regarding conservation and efficient use.

In addition to regulatory tools, the Ontario Water Director's committee has developed a drought planning approach. The Ontario Low Water Response framework encourages the formation of local water response teams which include representatives of water users in a watershed along with officials from local and provincial government departments, and conservation authorities. The low water response is a management tool for drought planning and is discussed in more detail in later sections of this report.

In the general absence of imposed monitoring and reporting requirements and regular government inspections of water taking operations, Ontario's water taking permit system relies heavily on good faith that individual water users will respect their permit conditions as well as the needs and rights of others sharing the resource. Compliance assessment initiatives and any subsequent enforcement actions typically arise because of interference complaints involving other water takers or instream interests. Evidence from Local Water Response Teams in the Long Point and other areas indicates that a significant number of water users competing for limited water resources may have been operating without having applied for and obtained the necessary permit or may be in violation of their permit conditions and of s. 34 of the OWRA.

### **6.5.2 Proposed Changes to the Permit to Take Water Program**

In April 2003, the MOE posted proposed modifications to the Permit To Take Water (PTTW) process, undertook consultations on the proposed changes and posted draft legislation for comment on the EBR for 60 days (June 18 – August 17, 2004). The new Water Taking and Transfer regulation was posted in December 2004. The changes included:

1. Reporting: Reporting was always a condition of many permits; however, a coordinated approach to providing this information had not been developed and as a result, reports were not been requested regularly. Many permit holders reported that after several years of diligent documentation of their takings and no inspection of the records, the quality of

documentation deteriorated. The Ministry is phasing in, by sector, a requirement for records of daily volume of water taken to be reported annually. All permit holders will be reporting by 2008.

2. Notification: Permit applicants will have to provide notification of application to neighbours, municipalities and conservation authorities. Prior to changes there was a requirement for most permits to post their application on the Environmental Bill Registry for public comment but no local notification. This led to concern that parties informed of local water conditions and potential impacts of new users are not provided with an adequate opportunity to address these concerns. The Director will notify affected municipalities and conservation authorities of PTTW applications. The Director can also require an applicant to report on measures taken to resolve concerns raised by those notified or consulted.
3. Annual Fee: Fees ranging from \$750 - \$3000 were introduced. The variation in fee reflects time investment to review technical aspects of the application. Many jurisdictions impose an annual fee and some impose fees proportionate to the volume of water used or the water use. An analysis by Renzetti and Dupont (1999) of an annual permit fee and a volumetric charge showed that charging for withdrawal permits can encourage water conservation and bring in new revenues without disrupting industry greatly. The issue of non-permit holders lingers in Ontario. There are limited resources to enforce permits; some have expressed concern regarding whether adding a fee may further deter non-participants from enlisting. Another issue is the expense that some users already incur for water. Kreutzwiser et al. (1999) examined costs involved with irrigation and measures to mitigate water shortages and found that some farmers pay \$125/acre/day to irrigate. This expense reduces a very limited profit margin and alone would encourage conservation. Ontario has joined a number of other jurisdictions waiving the permit fee for agricultural permits.
4. Impact assessment: A requirement for Ministry of Environment staff assessing permit application is "consideration of natural functions of the ecosystem". High water use watersheds have been defined based on summer low flow conditions and the annual average conditions in a watershed. A limited area has been designated a high water use area. The Director will reject new permits for new or expanding water takings that remove water from the watershed in these areas. Exceptions may be granted to these users in some watersheds if they do not intend to withdraw during the 6-week period coinciding with annual low flow. In order to ensure consistency and fairness to permit holders, MOE must provide specific, clearly defined assessments to be conducted for every permit application. The information from the applicant must support existing local studies and not replace them. Relevant studies must be conducted by local or regional groups and be available for public consideration in permit applications. This process is similar to the process used by Oxford County for Nutrient Management plans.

### **6.5.3 Water Quantity Protection in Other Jurisdictions**

The volume used as a trigger for a permit is lower in some jurisdictions (Alberta, Delaware River Basin, England, Wales, Manitoba, Minnesota and Susquehanna River Basin). In some cases, these lower levels (as low as 20,000 L/day) apply only to certain uses and/or within certain watersheds or regions, which have been designated because of known occurrences of water shortages.

**Allocation:** Most jurisdictions were found to support prioritizing water use for domestic use, livestock watering and firefighting (Connecticut, England, Wales, Georgia, Iowa, Manitoba, Minnesota). Similarly, most jurisdictions place least priority on less essential or discretionary uses such as lawn and garden watering; golf course irrigation; car washing; and outdoor recreational uses. Some assign lowest priority to uses involving conveyance of water to locations and uses out of state/province (British Columbia, Iowa). In Minnesota, priorities have been legislated with agricultural water use for irrigation and processing of agricultural products being third behind domestic water supply; emergency power production; and uses consuming less than 10,000 gallons (37,854 L)/day.

British Columbia is trying to eliminate stresses on aquatic ecosystems including meeting the needs of fish and other aquatic life. Alberta has a regulation on the South Saskatchewan River Basin focusing on the supply of water for irrigation with other needs also recognized. In Manitoba, the policy intent is to ensure that water needed for ecosystem functions is not allocated for uses that would threaten environmental sustainability. Newfoundland and Labrador have a precedence for water use with domestic, municipal, then commercial and industrial listed as the top 3 priorities.

In Alberta, existing water rights are protected under the *Water Act*. Water for household use is protected giving it top priority and no license requirement (maximum of 1250 m<sup>3</sup>/day). Traditional agriculture is distinguished and prioritized for water allocation. This applies to water historically used for watering livestock and pesticide application to crops. Users can register up to 6,250 m<sup>3</sup> of water per year (3,767 gpd). The registration protects the user's right to water by assigning the registration a priority number "grandfathered" back to the date when the water was first put to use. Registration is voluntary but unregistered use is not protected.

Most jurisdictions declare a state of emergency when available supplies fall below prescribed levels. In some areas all non-essential use is prohibited during a declared emergency (Pennsylvania, Guelph by-laws). This would include lawn watering, washing cars, filling swimming pools etc. Under drought emergency situations, Iowa restricts water irrigation of farm crops to no more than one inch (2.5 cm) per irrigated acre per week and may impose more severe restrictions as necessary. In the case of public supplies, Iowa recognizes municipalities and other users who have voluntarily implemented comprehensive routine and emergency conservation measures in making decisions over allocation restrictions.

**Fees:** Many jurisdictions have administration fees and some also have volume or use related fees. Minnesota applies a water-conserving increasing block rate fee for water taken. Large users pay proportionately more for permitted withdrawals than users withdrawing smaller

volumes. The fees are capped according to type of water use with the maximum annual fee for agricultural irrigation at \$750 USD while large municipalities and large industrial water users are capped at \$175,000 USD. In Nova Scotia, an annual fee is calculated based on water allocated by license; agricultural licenses are exempted from paying the fee at this point but may be required to do so in the future. The fee is not related to volume but does reflect the size of the allocation. Quebec requires fees for large water users and municipal supplies. Rates vary from \$1,500 - \$4,000 depending on the use and amount of water used. In England and Wales, annual charges on individual users vary according to water supply, region, type of use, consumptive component and time of year.

In terms of public consultation, some jurisdictions offer longer consultation times; more direct information exchange (mail-outs); more opportunity to proceed towards a public hearing; and a process for continued involvement and information exchange. The EBR electronic postings are easily accessible by the public; however, the posting of these notices should be accompanied by directed notification to key stakeholders or other interested parties as well. For example, the proposed changes to the PTTW were posted without MOE staff alerting colleagues or interested groups, and as a result the posting period had to be extended to allow sufficient time for interested parties to comment once the posting was inadvertently discovered by different groups. Some concerned citizens habitually scan the EBR for any relevant postings. This however, is an onerous, time consuming way to ensure that interested parties have opportunity to provide comment.

**Long Term Water Supply Plans:** As is the case in Ontario, many jurisdictions now require municipal/public water supply permit applicants to prepare a long-term water supply plan (Connecticut, Delaware River Basin Authority, England, Wales, Georgia, Iowa, Minnesota, Pennsylvania). Such plans provide detailed documentation of anticipated water supply needs out to a period of 20 years or longer and describe the intended sources of supply. They also require documentation of intended and committed efforts and targets for promoting and improving overall water-use efficiency and conserving water in times of shortages. In Ontario, the regional municipalities of Durham, Halton, Peel, Waterloo and York have all completed these long term water supply plans that consider each municipality's long-term needs in the context of available supplies and competing uses.

Many jurisdictions also require other large volume users such as industry and irrigators to complete water conservation plans as part of the permit/license application process. Minnesota requires conservation planning by all public suppliers serving more than 1,000 people and may require irrigation permit applicants to submit conservation plans for approval by the county soil and water conservation district.

## **6.5 Conclusions**

1. Source protection is the first line of defense in any municipal water works. The Panel recognizes that the Watershed Based Source Protection Planning Technical Experts Committee (TEC) established by the MOE has undertaken a commendable effort in establishing a blueprint for source protection planning in Ontario. These efforts are focused primarily on municipal level wells.
2. Different types of aquifers may require different wellhead protection zones. In some cases, vulnerable aquifers have been chosen over equally accessible secure aquifers.
3. The Source Protection TEC identified wells as pathways for contaminants and a direct threat to municipal water supplies.
4. There are several recommendations that have implications for private water supplies in the Source Protection report. Although private wells are not the focus of the report, the TEC and this Panel agree that these pose a risk to the aquifer and well owners if poorly constructed or maintained. TEC Recommendation 123 suggested use of source protection planning committees to develop and implement “private well programs”.
5. The Nutrient Management Act is evolving towards a risk-based approach to align with source based protection planning.
6. Amendments to Ontario Water Resources Act (Water Taking and Transfer) will provide for more rigorous assessment and documentation of the impact of water taking on Ontario watersheds. This approach will lead to more sustainable management of the water supply.

## **6.6 Recommendations**

1. New and evolving water resources legislation should be developed with science-based arguments such as risk-based approaches.
2. Where a jurisdiction chooses to locate a municipal well in a more vulnerable location, the responsibility to protect these supplies should lie with the public consuming the water and not unduly penalize those within the wellhead protection zone.
3. Source protection for private wells should be managed through existing partnerships such as the partnership established between the OGWA, APGO and Green Communities to expand and continue existing education and outreach programs that are proven to be effective such as Well Aware, Well Inspection and Well Discovery.
4. The Ontario government should continue to fund a subsidy program similar or equivalent to the Ontario Ministry of Agriculture and Food (OMAF) Healthy Futures Upgrade and Decommissioning program. The Panel recommends that such programs provide greater than two-thirds cost-sharing and include an educational component.

5. The MOE also needs to ensure coordination and communication with all their programs and related programs from other Ministries i.e. integration of the source protection planning program.

## 6.7 References

Christensen, R.L., and Christie, E. 2001. Regulatory Approaches to Drinking Water Used in Canada and, Selectively Abroad. Prepared for Walkerton Inquiry. Prepared by Sierra Legal Defence Fund.

Conboy, M. J. and M. J. Goss. 2000. Natural Protection of Groundwater Against Bacteria of Fecal Origin. *Journal of Contaminant Hydrology* 43(1): 1 – 24.

Drinking Water Systems Regulation O. Reg. 170/03

Drinking Water Services: A functional review of the Ontario Ministry of the Environment, Walkerton Inquiry Commissioned paper 5, 2002.

Case for groundwater protection in Ontario: Results of the Workshop held at the University of Waterloo, May 1, 2001. Frind, Rudolph and Molson, 2001

Goss, M. J., D. A. J. Barry and D. L. Rudolph. 1998. Contamination in Ontario Farmstead domestic wells and its association with agriculture: 1: Results from drinking water wells. *Journal of Contaminant Hydrology*. 32: 267 - 293.

Ontario Environmental Protection Act, R.S.O. 1990

Ontario Ministry of the Environment. 2003. Proposed Amendments to Ontario Regulation 286/99 under the Ontario Water Resources Act.. April 2003. [http://www.ene.gov.on.ca/envision/env\\_reg/er/documents/2003/RA03E0009.pdf](http://www.ene.gov.on.ca/envision/env_reg/er/documents/2003/RA03E0009.pdf)

Ontario Ministry of the Environment. 2003. Protecting Ontario's Drinking Water: Toward a Watershed-based Source Protection Planning Framework. Advisory Committee on Watershed-based Source Protection Planning.

Ontario Ministry of the Environment. 2004. 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. Queens Printer for Ontario. <http://www.ene.gov.on.ca/envision/techdocs/4935e.pdf>

Ontario Ministry of the Environment. 2004. Watershed-Based Source Protection: Implementation Committee Report to the Minister of the Environment. Queen's Printer for Ontario. <http://www.ene.gov.on.ca/envision/techdocs/4938e.pdf>

Constitutional jurisdiction over the safety of drinking water, Walkerton Inquiry commissioned paper 2, R.Foerster, 2002.

Kreutzwiser, R., de Loe, R. and Benninghoff, B. 1999. Agricultural and Rural Water Allocation in Ontario: A report to the Agricultural Adaptation Council.

O'Connor, D. 2002a. Report of the Walkerton Inquiry. The Events of May 2000 and Related Issues. Part One. Ontario Ministry of the Attorney General. Queen's Printer for Ontario.

O'Connor D. 2002b. Report of the Walkerton Inquiry. A Strategy for Safe Drinking Water. Part Two. Ontario Ministry of the Attorney General. Queen's Printer for Ontario.

Ontario Ministry of the Environment. 2004. White Paper on Watershed-based Source Protection Planning. Integrated Environmental Planning Division, Strategic Policy Branch. Queen's Printer for Ontario. <http://www.ene.gov.on.ca/programs/3585e01.pdf>

Ontario Water Resources Act, R.S.O. 1990, c. O.40

OPSEU. 2001. Renewing the Ministry of the Environment. Submission to Walkerton Inquiry.

R.R.O. 1990, Regulation 903

Renzetti, S., and Dupont, D. 1999. An assessment of the impact of charging for provincial water use permits. *Canadian Public Policy*. Vol. 25.

Ritter, L., and Gore, \_\_\_ 2002. Sources, pathways, and relative risks of contaminants in water. Walkerton Inquiry Commissioned Paper 10.

Safe Drinking Water Act, 2002. Ontario Regulation 169/03

Wordsworth, Anne. 2001. Tragedy on tap: Why Ontario needs a Safe Drinking Water Act - Overview Submissions of the Concerned Walkerton Citizens And Canadian Environmental Law Association to Part II of the Walkerton Inquiry Date: May 15, 2001.

## **7.0 Location and Construction of Wells**

The majority of wells in Ontario are constructed for farms or rural homes. Most private wells exist without treatment systems and are reliant upon properly construction and a protected environment to ensure their safe water supply. Municipal wells have mandatory treatment but are also assessed holistically (source to tap) as part of a multi-barrier approach to safe drinking water. It is essential to take a precautionary approach with well construction to ensure that all wells are constructed in a manner that minimizes risk of contamination even where this threat is not apparent.

Understanding how wells have been constructed in the past, in addition to a review of current practices, helps in identifying what problems may exist in Ontario. The revisions to Regulation 903 have required some changes to past construction practices. The most significant changes relate to the casing length, ensuring a good seal to the annular space, the requirement for vermin proof well caps and a longer pumping test.

### **7.1 Locating Water Wells**

Determining the location of water wells has traditionally been the responsibility of the driller, the homeowner and for larger municipalities, hydrogeologists. There are excellent descriptions of the general methods used for locating large wells intended to supply communities (e.g. Johnson Division, 1975; Fetter, 2001; Todd and Mays, 2005) and those will not be repeated here. The practise of locating domestic wells is not as well documented; although, there have been several manuals published in recent years that are specific to the locating of domestic wells in Ontario (MOE, 1988; AAFC-OMAFRA, 2003).

#### **7.1.1 Practices in Ontario**

Reg. 903 presently governs locating water wells in Ontario for rural supplies and the Environmental Assessment process governs location of larger municipal wells. The clauses in Reg. 903 that pertain to locating a well include 12(1)-12(5) which specify that the site of the new well:

- Either be separated by the clearance distance specified in the Ontario Building Code;
- or for wells that have six metres of water-tight casing, be located at least 15 m from a potential source of pollution (i.e. leaching bed);
- or for wells that do not have a water-tight casing to six metres (i.e. a bored or dug well), be located at least 30 m from a potential source of pollution.

In general, the location of a water well on a small rural property has very little to do with hydrogeology and more to do with the practicalities of manoeuvring the drilling rig, the required setbacks and the aesthetics of the location. During construction in rural settings or even some urban settings, wells are often located based on local experience. In some areas, water well quality in deeper aquifers is poor and shallow dug or bored wells are used by tradition.

A very good primer on locating water wells for domestic supply can be found in the document “Best Management Practices, Water Wells” published by Agriculture and Agri-Food Canada and the Province of Ontario (AAFC-OMAFRA, 2003). With respect to well location, this primer recommends identifying the direction of groundwater flow and avoiding locating a new well in the flow pathway emanating from any obvious contaminant source. In rural/urban settings where neighbours are in close proximity, this means identifying sources on neighbouring property as well.

Clearly the most obvious source of contamination on almost any property is the septic system used to manage household waste water. In very detailed studies conducted in sandy aquifers by the University of Waterloo (e.g. Robertson et al., 1991; Robertson and Harman, 1998), narrow plumes of contamination were found to travel many tens of metres downgradient from the septic system source. Locating a domestic well anywhere along the pathway even far beyond the required setback, will lead to the potential for contamination in that well. It is important to note that septic systems in fractured rock have not received the same attention as those in porous aquifers; although, the impact in this setting may be higher as a result of low porosity and high groundwater velocities.

For municipal wells, the process of locating a well is much more complex and considerable hydrogeological information is often utilised. The Environmental Assessment Act (EAA) mandates the development of a specific Terms of Reference and procedure to be utilised for each new well or well field. Although individual municipalities approach this process in independent ways, the scrutiny and approval provided by the Environmental Assessments and Approvals Branch is the same for all.

Some municipalities that rely heavily on groundwater for their water supply have become very proactive with respect to locating and identifying their aquifers. The Regional Municipality of Waterloo, for example, developed a Long Term Water Strategy beginning in 1991 to accommodate developing water needs until the year 2041 (a 50 year plan). As part of the strategy, the identification of new groundwater sources, and the development of an aquifer storage and recovery system were required. The identification of new resources initially targeted approximately 5 million imperial gallons per day (migd) for potential production. Through the review of Ministry of Environment well records and other hydrogeological information, aquifers having the potential production of approximately 20 migd were identified. The Region has thus chosen to select new sources for development from those identified that are nearest to existing water distribution infrastructure. At the present time, capture zones for these new wells are not determined in advance of the well construction, although this will likely change with revisions to the water taking regulations.

### **7.1.2 Historical Perspective on Well Construction Practices**

In the early days when a well was constructed, the only concerns were the adequacy of the supply, cost, proximity to where it would be used and the structural soundness of the well. No thought was given to reducing contaminant migration into the well. A study by Hamill and Bell

(1986) found that most cases of contamination in wells were related to the construction of the well and not from a contaminated aquifer. As surface water moves through the soil and geological profile, impurities present are removed by adsorption, filtration, oxidation and reduction reactions and biological decay. Adequate well construction ensures that the well does not provide any shortcuts for the percolating water as reduced time for attenuation through the soil column can result in contaminants impacting aquifers.

There are a number of different methods to constructing wells in Ontario. Wells can vary in diameter with research, monitoring or test wells having a diameter of 2 – 6 inch; to private drilled wells with a diameter between 4 – 6 inches; and dug or bored wells with much larger diameters varying from 1 – 2 m. The smaller diameter wells have been more secure in the past because the materials used for casing these wells was a continuous material such as PVC piping, or metal casing generally available in 6 m lengths. This ensured that the first joint was well below ground surface, somewhat isolated from the effects of surface material. Larger diameter wells were cased with wood, field stones, brick, concrete tiles and more recently with galvanized steel and fibreglass. The casing material used in the past to case and finish large diameter wells was not watertight. This allowed surface water and materials to enter the well directly. It was not uncommon for homeowners and well contractors to find snakes, frogs or rodents had fallen into the well, contributing to deteriorating water quality.

In some cases, these older wells have been properly decommissioned. More commonly however, the wells are still open and may still be in use. Well water best management practice (BMP) guidelines (AAFC-OMAFRA, 1997) discuss wells that should no longer be used, such as cisterns for drinking water, wells with cracks or chips in concrete; wells lined with field rock or brick; wells in pits; and wells in barns. However, these types of wells are still being used for drinking water. Many wells more than 60 years old are still in use with no regular maintenance. There are also very degraded wells or manure pits that are no longer in use, but have not been retired properly, if at all. Examples of all these have been observed in the field (Conboy, 1998).

It is difficult for those unfamiliar with rural water supplies to understand the reasoning behind retaining these water supplies despite their vulnerability to surface influences and potential contamination with bacteria and nitrate. Many who have lived on rural properties understand the “attachment” some people form to their well. Many rural wells are the original well built sometimes one hundred years previous by a now deceased relative. The workmanship that is evident in some of the brick lined wells; tales of woe from neighbours tapping into deeper more mineralized aquifers; and the reliability of the water supply for such an extended period of time often causes well owners to diminish concern over the presence of bacteria.

### **7.1.3 Dug Wells**

The use of dug wells as a means of extracting groundwater was developed thousands of years ago by early settlers in China, Greece, Italy and other European countries. These dug wells were the dominant construction method during the first half of the 1900s and remain pervasive in many parts of northern and eastern Ontario, where the cost of drilling through bedrock can be onerous for a private well owner or where shallow aquifers exist. This type of construction was most accessible to early farmers and rural residents as early wells were often hand-dug and lined

with materials that were abundant onsite. The earliest wells were generally located in natural wetlands, or low-lying terrain to reduce the digging effort. The depth of the well depended on the yield of water-bearing sand deposits encountered at the site. The well liner material of the pioneer well depended on the available materials. In stoney glacial till areas, the wells would be lined with stone. In sandy areas, the wells would be lined with brick or timbers. The purpose of the liner was to enhance structural integrity with consumers overestimating the capacity of the soil to filter contaminants from the water prior to it entering the well. As time progressed, the wells were lined with concrete tiles. Joints were not sealed or sealed with a black petroleum-based sealant. The annular space was not addressed and as a result, some bored wells in clay soils have been observed to have an open annular space 30 or more years after construction.

#### **7.1.4 Cable Tool Drill Rigs**

The first mechanical drilling machines were used in the early 1900s. The cable tool percussion drill rig, which was developed in China about 4,000 years ago, was the first commercial drilling rig. These rigs operate by lifting and dropping a heavy drill bit into a borehole.

The bit hangs from a wire cable, which is raised repeatedly by the rig equipment. The earliest municipal wells and all pre-1950 drilled wells in rural areas in Ontario were drilled with cable tool rigs. They are still in use today in many parts of the Province, since they can be operated by one person, are relatively inexpensive, and require no make-up water for the building operation.

#### **7.1.5 Rotary Drilling Rigs**

Rotary drilling methods were first utilized for large capacity municipal wells in the 1930s and 1940s. These machines could drill faster and deeper than the cable tool rigs. The well borehole is drilled with a rotating bit and the cuttings are continuously removed by the circulation of a thick drilling fluid.

The rotary drilling method enable open, uncased boreholes to be drilled to examine the aquifer conditions before installing the casing and well screen. The rotary rigs are able to drill to depths of 200 m or more in either overburden or bedrock formations. This allows rural property owners in areas of deep aquifers to obtain adequate well supplies.

### **7.2 Current Well Construction Practices**

Well construction has evolved from two or three available methods to a variety of drilling methods and rig designs available for each geologic condition. Currently, there are three main types of wells in Ontario: hand-dug or bored; driven or jetted sand points; and drilled wells. The first two methods have gradually been replaced by drilled wells in all parts of the Province except a few local areas where the geologic conditions preclude drilling.

#### **7.2.1 Dug or Bored Wells**

Dug or bored wells are constructed either through hand digging; use of a backhoe; or a boring machine and can be constructed in areas of limited access by large drilling rigs. They are limited

mainly to geologic conditions where only small yields of groundwater are available in near-surface formations such as thin glacial tills overlying impermeable bedrock.

Backhoes cannot be used for deep large diameter wells due to the length of the boom. Boring machines were used where a good shallow aquifer was present, but where water quality at greater depths was poor, or low yielding wells. This method of excavation consists of shaving or cutting material from the bottom of the hole by the rotation of a cylindrical tool with one or more cutting lips. The process is similar to boring a hole in wood or metal with an auger or drill. The excavated earth normally feeds upward and is contained in the body of the auger and/or digging bucket where it remains until it is emptied. Boring machines can be used up to a depth of around 45 m. This type of well is best for overburden wells and is not as suitable for areas with very large boulders or bedrock. In an area with larger boulders and sand with hydrostatic pressure, a large diameter well may be very difficult to seal. The liners for larger diameter wells are set into a larger hole and the annular space is filled with bentonite grout.

Large diameter wells have some inherent disadvantages compared to smaller diameter wells including greater effort and longer construction time, greater safety hazards during and after construction. The well itself can be a dominant factor affecting water quality. Shallow dug or bored wells, located in sites where there is a shallow soil profile and/or a high water table can be very vulnerable to contamination (Conboy and Goss, 2000). Dug or bored wells are most affected by the soil and geological setting of the well location.

In many jurisdictions a choice has been made to prohibit new construction of these larger diameter wells because of the vulnerability of the liners. If larger diameter wells were prohibited in Ontario, there are areas where residents would not be able to obtain a reasonable water supply, due to poor quality water in deeper aquifers and poor flow rate of water requiring the storage that larger diameter wells provide.

In Ontario, efforts have been made to reduce the vulnerability associated with dug or bored wells. New legislation requires casing have a permanent watertight bond, and a continuous seal for 3 m. Cured concrete is still permitted as a construction material; however, the new regulations prohibit any joints that do not achieve a permanent watertight bond. Welded joints are considered permanent watertight bonds. It is much more difficult to achieve this type of bond in larger diameter construction materials. Despite this, many contractors are still using concrete tiles but are taking greater care to use (environmentally friendly green sealant) and grout the annular space. Other casing materials include fibreglass or galvanized steel culverts.

Larger diameter wells generally tap more shallow aquifers than drilled wells. Even where the well casing is suitably sealed, this type of well is more subject to surface influences especially if located in areas where there is shallow, fractured bedrock. This type of well is a poor selection in areas where properties are close to neighbouring properties and other potential contaminating influences exist (landfills, chemical storage, septic, etc).

A further issue is implementation of Best Management Practices. Many of the wells that do not meet standard building requirements are not found in Ministry records. A little under half of the 300 wells surveyed in a recent study (Conboy and Goss, 1999), were not documented in any

fashion in Ministry records. This makes it challenging to begin to solve the province-wide problem of contaminated well water when the only person who is aware of the presence of some of these wells is the landowner.

Regulation 903 requires that dug wells be at least 3 m deep (Section 14 (1)) and the top 2.5 m of the annular space around the well casing be filled with a sealant (Section 5 (10)). This sealing procedure is intended to prevent direct entry of surface contamination into the well. It will not, however, prevent shallow contaminated groundwater from seeping into the well below the seal.

### **7.2.2 Driven or Jetted Sand Points**

Sandpoint wells are shallow, narrow (one to two inches wide) wells. They are placed by driving a small-diameter pipe fitted with a sandpoint into the ground. The pipe with pointed well screen is driven into place in much the same way a nail is driven into wood. Sand points are usually less than 50 mm in diameter and as a result, they usually yield small supplies. A number of driven wells may be coupled together and pumped with a single shallow well pump.

The materials to construct a sandpoint well are readily available at local hardware stores and as a result, many do-it-yourself types have installed this type of well without any sealants. These wells are often used by cottagers or for irrigation.

Because driven wells are quick to construct, they may be used as a temporary source of water and then be pulled up when no longer needed. Driven well points may be installed and used for dewatering an excavation during construction. Unlike other well construction methods, material is merely forced aside and not excavated by the driving process. This means that little is learned about the material through which the well pipe passes. This type of well can, however, be used for exploratory purposes to determine static water level and rate of inflow versus drawdown. Hard formations cannot be penetrated by this process; these are used mainly in shallow sand aquifers. This type of well is very difficult to get a good seal that would allow it to be constructed to regulatory requirements.

The only geological conditions that are suitable for driven or jetted well points are those where permeable sand and gravel outcrops at the surface and the water table is less than about 4 m deep. These conditions occur in a number of areas in both southern and northern Ontario.

The shallow sand and gravel aquifers tapped by sand points provides minimal protection to surface contamination. If deeper, protected aquifers exist in the areas of shallow sand, drilled wells would provide a safer source of potable groundwater.

### **7.2.3 Drilled Wells**

Drilled wells were initially only used for municipal sources because of the requirement for specialized drilling equipment and drill rigs. By 1955, water well drilling exceeded 10,000 new wells per year and current estimates indicate closer to 20,000 new wells are drilled each year. Major advancements in drilling technology over the past 50 years have resulted in numerous specialized drilling equipment and well installation methods. An overview of well drilling

procedures is provided in Appendix D. Only the most commonly used drilling methods will be described and only those methods which apply to water well construction are included.

**Cable tool:** The cable tool method is versatile, allowing all types of materials to be penetrated. There are no depth limitations; the cable tool can drill up to 2,000 – 3,000 foot gas wells. This method is very slow and the annular space is too small to put a proper grout tube down to seal the well properly. In order for a proper seal to be constructed for this type of well, a larger diameter hole would need to be drilled to accommodate a temporary casing that would allow the proper seal. This would take the driller much longer and cable tool operators have argued that this would unduly interfere with their profitability. As a result, MOE has made concessions to permit a smaller annular space for this type of construction.

Cable tool drilling systems are much cheaper to operate, maintain and repair compared to rotary drilling methods. They may be used in places where rotary rigs may not be taken as they are light and mobile and do not require a large water truck, mud pump or air compressor. They produce easily identifiable drill cutting samples and are less likely to pass up a water-producing zone because they usually do not plug up geological formations as mud circulation rigs can.

**Jetted wells:** This method makes use of a high velocity stream of water to excavate the hole and to carry the excavated material out of the hole. This method depends on the erosive action of water; extremely hard materials cannot be penetrated. However, semi-hard materials may be penetrated by a combination of hydraulic and percussion effects. These wells are feasible up to 6 m, but casing is harder to install beyond a 20 to 40 foot length. The casing needs to be installed without pause to reduce the effects of sanding in the casing, which would create friction and make it more difficult to regain circulation.

**Mud rotary:** This technology became available in Ontario during the 1930s. A borehole is drilled by rotating a bit at the end of drill pipe. Borehole cuttings are removed by continuous circulation of a drilling fluid as the bit penetrates the formation. Drilling fluid is pumped down through the hollow drill pipe using a mud pump to a drill bit. The fluid flows upward in the annular space between the drill pipe and the borehole to the surface. When the cuttings reach ground level, they can be settled out in a small mud pit or tank and the "mud" recirculated. If the reverse flow path is used ("mud" pumped to the surface through the hollow drill pipe) the system is called reverse circulation. The reverse circulation system allows a larger diameter hole to be drilled and larger particles of cuttings to be brought to the surface, because the upward flow velocity inside the pipe is greater than that through the annular space. Reverse circulation drilling is used for larger diameter and greater depth production wells such as those used for irrigation or municipal wells. This method is only used in overburden and can be very costly and slow.

**Air rotary:** This technique is very quick and efficient in bedrock formations with shallow overburden. This method allows the use of many different techniques; use of only air; a casing driver; or a down the hole hammer. This method is used frequently in Northern and Eastern Ontario where the bedrock formations are close to the surface.

### 7.3 Issues in Well Construction

#### 7.3.1 Variation in Hydrogeology

The biggest challenge to water well contractors in Ontario is the extreme variation in hydrogeology within relatively small geographic areas. There are dozens of different geologic formations and a wide variety of water producing rocks and sediments. The aquifers' depths may range from a few metres to hundreds of metres and may or may not be protected from surface contamination by clayey materials with low permeability. A driller should be knowledgeable about local soils and formations to anticipate potential problems. Contractors may encounter challenges that they are not experienced or equipped to handle when drilling in non-familiar regions. The following conditions require specialized techniques that are often gained through several years of experience:

*Incompetent or fractured bedrock near surface:* This requires drilling deeper into solid rock formation and more grout into the annular space. A permanent casing is always used, the depth of which is dependent on shallow overburden and fracturing conditions. In the past, there were a number of wells where there was very little casing installed because of shallow bedrock. Contractors didn't realize that surface contamination could enter the well from the shallow, fractured bedrock. Different drilling techniques offer different cues to presence of incompetent bedrock. For example, when drilling with a cable tool rig, one can tell visually from outcroppings and the feel (pressure required); whereas with rotary drilling, the pressure gauge may provide evidence of heavily fractured bedrock.

*Situations requiring a double-liner:* A double liner is used to shut off the impact of an undesirable area, or to facilitate drilling. An example is drilling in a sand and gravel formation on top of bedrock. One may need to drill 6 – 12 m into bedrock if the rock is incompetent, or large voids are found, then a smaller casing is installed to shut off the void that may be receiving surface water. The presence of a salt seam may also require a double liner. The driller would drill past, install another casing, grout into place to shut off the salt seam.

*Natural problems:* high sulfur, hard formation, high mineral content, natural gas, boulders, artesian wells – case of poor quality aquifer.

*Other problems that may be encountered, especially if a driller is not familiar with the regional issues where they are drilling:*

- Drilling in conditions beyond equipment capability;
- Unsuitable Drilling Mud and Borehole Caving;
- Failure to get casing to bottom of borehole;
- Poor gravel pack;
- Inadequate well development;
- Excessive fluid;
- Drill bit jamming;
- Resistant beds encountered;

- Flowing wells - The well will have to be shut off and the driller needs to know how to do this as the flowing well can be very erosive causing unstable ground and creating sinkholes; and
- Marginal aquifer encountered – experience allows a more informed decision regarding whether the aquifer will meet intended needs.

### **7.3.2 Well Location**

Casual observation, anecdotal evidence along with reports from people in the field observing private wells regularly shows a serious deficit exists in private well source protection. This includes wells located adjacent to obvious sources of contamination, with some buried beneath driveways, roads or manure piles. Wells for residential homes have historically been sited close to a building, either a barn or home to limit the length of pipe required to service the client. As the home changes hands or the needs of the owner changes, the proximity of the well to these structures can become a problem. Wells have been observed in the middle of a driveway,; in a garden; buried underneath a lawn that is treated with fertilizers and pesticides; under interlocking patio stones; in basements; steps away from a septic system or old well; or in barns and barnyards. The presence of the well in these locations makes the security of the water supply suspect and presents many challenges when the well needs to be serviced.

*Wells constructed inside an old well.* This practice is not uncommon, but is extremely unsafe. The client has an existing well with either an inadequate supply or poor quality water. Often the poor quality water is a result of surface water entering the water supply directly through breaches in the old casing. The client's desire, or a suggestion provided to them, is to use the same location. The advantage that this could offer is the ability to use existing water line pipes. The new well is drilled through the bottom of the old well and is either finished near the bottom of the old well or is brought near to surface. The old well is left open. The integrity of the old well has never been secured. This situation allows a contaminated shallow aquifer a route to a deeper aquifer. This practice is becoming less common, but some wells constructed in the last year used this practice.

### **7.3.3 Annular Space**

The annular space is the area between the soil and rock formations and the casing. The importance of applying an adequate seal was not always understood (OFA, 2004). Wells were constructed and the annular space was either sealed with cuttings that tended to bridge and leave large voids, or in many cases this space was not sealed at all. This provided a preferential flow path along the exterior of the casing allowing surface materials to impact the well. New regulations have addressed the need for an adequate annular seal by requiring the diameter of the borehole be at least 7.6 cm greater than the proposed diameter of the finished well. This space is to be filled from the bottom up (or at least 6 m) with an appropriate sealant.

### **7.3.4 Pump Installation**

The pump may be installed by a MOE licensed pump installer, or by the homeowner. Proper pump selection and installation is critical to the efficient functioning of the well. A well can be

ruined by installing the incorrect pump size. An over-pumped well could migrate fines into the formation and restrict the flow. Pump placement is also critical; for example if there is a lot of fines, the pump may need to be placed higher to avoid restriction of flow. The well yield determines the adequate pump size. The well record indicates the well yield and will allow a proper size of pump and proper storage capacity. The record will also indicate the pumping rate and pump depth. A pump should not be placed inside the well screen area as it may induce sand bridging, cascading water and unnecessarily introduce oxygen into the system. It should be either above or below the screen, but not at the level of the screen.

### **7.3.5 Altering Wells After Construction**

Once the licensed well contractor leaves the site, there is often very little direction given to homeowners on how to protect their water supply. Wells inspected through the audit process of the Healthy Futures Upgrade and Decommissioning Program show that within a year, clients have used spray paint on the cap and casing; built elaborate wooden structures to encase the well head; built raised gardens; cut the casing to below ground level; loosened the cap for easy access (for excessive chlorination); backed up into it with a vehicle; and placed many other makeshift structures over the well for either protective function or decorative purposes. The Well Aware Phase II Guided Self Assessments (GSA) found roughly 20% of the wells observed were obscured by gardens or deep-rooted plants that could impact the integrity of the well seal. The connection between these alterations and the quality of the water is not made by many of the clients. The responsibility of well owners through Regulation 903 to keep their well accessible at all times for cleaning, treatment, repair and visual inspection is not understood.

### **7.4 Well Inspection Pilot Project**

This voluntary project, sponsored by MOE in partnership with the City of Ottawa and the Ottawa Septic System Office, ran from June 15, 2003 to January 15, 2004, offering rural homeowners in the Ottawa area free inspections of new wells, a water quality analysis and an inspection report. Prior to well construction, the inspector ensured that appropriate setbacks were respected. During construction the inspector observed that the well was constructed according to Regulation 903 standards by ensuring proper installation of casing and grouting of the annular space, proper installation of the pitless adapter and a final ranking when the plumbing system was complete. In instances of non-compliance, the well contractor was notified first and if resolution was not achieved, the local MOE office was notified.

### **7.5 Sustainability of Well Construction**

Construction materials and methods will have a major impact on longevity of wells; size of the annular space; the depth of joints; the methods of creating the joints; the caps that can be used; and the amount of fluctuation in the water level. All of these should be investigated in greater detail. Inspection and enforcement during construction is key to making sure that construction is done adequately. There should be resources allocated to having qualified professionals on site to monitor the construction methodology.

## **7.6 Conclusions**

1. Locating domestic water supplies is often based on practical considerations rather than on science-based best practice. Field studies conducted in Ontario have confirmed that this has resulted in well construction in inappropriate locations.
2. The Panel recognizes that the setback distances for potential contaminants provided in Reg. 903 are not adequate for all hydrogeological settings.
3. Large diameter wells are more vulnerable to contamination as it is difficult to achieve a permanent water-tight casing and cap.
4. Inappropriate alterations to well settings (i.e. wishing wells) that lead to lack of compliance with Reg. 903 can influence water quality.

## **7.7 Recommendations**

1. Guidelines for well location and construction should incorporate information regarding topography of the property, any structural problems that may be present due to the soil type or geology, and where possible, the local flow of groundwater should be known before a well is drilled. Wells should be positioned so that they are not located down-gradient from any pollutants.
2. Wells must be constructed to prevent contamination at all times. It is much more straightforward to use appropriate sealants during construction than to excavate and clean up a well once contamination is found.
3. Outreach, inspection and enforcement efforts should be aimed at ensuring that large diameter wells are constructed to reduce the potential points of entry. More research is needed to ensure that the best materials are being used in construction and to ensure that large diameter wells can also achieve a vermin-proof status.
4. The link between sustainability and construction materials and methods needs to be more fully explored. The Panel recommends that an investigation be facilitated by the MOE on what direction might be best to pursue a collaborative research/development process.

## **7.8 References**

Conboy, M. J. and M. J. Goss. 2000. Natural Protection of Groundwater Against Bacteria of Fecal Origin. *Journal of Contaminant Hydrology* 43(1): 1 – 24.

Conboy, M. J. and Goss, M. J. 1999. Contamination of Rural Drinking Water Wells by Fecal Origin Bacteria—Survey Findings. *Water Quality Research Journal of Canada*, 34(2): 281-303.

Conboy, M.J. 1998. Bacterial Contamination of Rural Drinking Water Wells. Doctoral dissertation. University of Guelph.

Fetter, C.W. 2001. Applied Hydrogeology. 4<sup>th</sup> Edition, Prentice Hall, Upper Saddle River, NJ.

Hamill, L., and Bell, F. G. 1986. Groundwater Resource Development. London: Butterworth.

Johnson Division, 1975. Ground Water and Wells. Johnson Division, UOP Inc., Saint Paul, MN.

AAFC-OMAFRA.1997. Best Management Practices: Water Wells. First Edition.

AAFC-OMAFRA 2003. Best Management Practices: Water Wells. Second Edition.

Ontario Federation of Agriculture (OFA). 2004. Healthy Futures Auditing Report. Submitted to OMAF as part of funding report.

Ontario Ministry of Environment. 1988. Water Wells and Groundwater supplies in Ontario.

Robertson, W.D., Cherry, J.A., and Sudicky, E.A. 1991. Ground-water contamination from two small septic systems on sand aquifers. Ground Water, 29, 1, 82-92.

Robertson, W.D., and Harman, J. 1998. Phosphate plume persistence at two decommissioned septic system sites. Ground Water, 37, 228-236.

Todd, D.K., and Mays, L. 2005. Groundwater Hydrology. 3<sup>rd</sup> Edition, John Wiley and Sons, Inc., Hoboken, NJ.

## **8.0 Operation and Maintenance of Wells**

Proper well maintenance is a critical aspect of ensuring the integrity and operational efficiency of the well and protecting the quality of the water supply. There has been an increased emphasis recently in Ontario on outreach and education activities to promote well stewardship and to inform well owners of best practices in well operation and maintenance. This chapter will provide an overview of best practice in well upgrading and preventive operating procedures and will discuss biofouling as a threat to well integrity. A variety of diagnostic techniques and rehabilitation measures are identified. Ontario government initiatives aimed at increasing adherence to proper well operation maintenance are also reviewed.

### **8.1 Aspects of Well Maintenance**

#### **8.1.1 Casing Integrity and Adherence to Best Practices**

Typical well casing can be made of metal, PVC or in the case of large diameter wells, it could be concrete, steel or fiberglass. The space between the casing and the sides of the hole provides a direct channel for surface water (and pollutants) to reach the water table. To seal off that channel, the space is filled with a mixture of bentonite clay and cement grout. To protect the inside of the casing, the driller installs a tight-fitting well cap. The primary objectives of ensuring casing integrity are:

- to provide suitable and safe operating conditions for the total measured depth proposed;
- to confine fluids to the well bore;
- to prevent migration of fluids from one stratum to another;
- to ensure control of well pressures encountered;
- to prevent contamination of freshwater; and
- to provide well control until the next casing is set, considering all factors relevant to well control including formation fracture gradients, formation pressures, casing setting depths, and proposed total depth.

Audits of well upgrading work to improve casing integrity conducted under the Healthy Futures Well Upgrade and Decommissioning project suggest a lack of adherence to best practices among many well contractors. The vast majority (78%) of the projects audited through Healthy Futures were projects involving drilled wells. Most of these projects were upgrades extending the well casing from a finish below ground either with or without a pit, to a finish above grade. The average price for a drilled well upgrade was \$1,600. Upgrading a large diameter well was generally more expensive than upgrading a drilled well because of the volume of material and labor time required to do the job properly. The average price for a large diameter upgrade was \$2,904. In general, a number of problems were observed with these projects as only 25% of the

drilled wells upgraded were ranked as using best practices. Twenty-eight percent of the drilled well upgrades were ranked as presenting major concerns; the remainder presented different problems that were ranked as minor concern (Table 8.1). If a well was upgraded without the use of the appropriate sealants and also lacked a vermin-proof well cap – the well was ranked as a major concern. If the well had these protections present, it was usually considered a best practice.

**Table 8.1 Summary of Healthy Futures Well Upgrade Audits**

|                       | <b>Upgrades</b> | <b>Best Practices</b> | <b>Major Concern</b> | <b>Average Price</b> |
|-----------------------|-----------------|-----------------------|----------------------|----------------------|
| <b>Dug/<br/>Bored</b> | 59              | 28                    | 8                    | \$2904               |
| <b>Drilled</b>        | 337             | 101                   | 104                  | \$1600               |

One of the most common problems observed in drilled well upgrades was the absence of sealants and the use of local soil, sand or gravel to fill excavated holes around a well that had been extended. Bentonite or concrete grout should be used to seal the annular space around the well casing. This sealant should be brought to the surface in the annular space and then a tapered wellhead area created with soil. The use of sand or gravel has the opposite effect of the sealants. The sealants protect the well from developing short-cuts at the edge of the casing and reduce water flow from the surface. Where sand or gravel is used, the infiltration of water is enhanced and this could allow contaminants to travel into the water supply. In a number of cases, the contractor did not fill the area surrounding the well at all but instructed the client to do so using sand. The use of vermin-proof well caps seemed to depend on the contractor or the particular region. Another concern seen on a limited number of well extensions was where the extension was fitted to the existing well by means other than a complete weld. These other methods, whether it be use of a press fitting coupler or a rubber sleeve attached with hose clamps are not a best practices and could allow leakage at the joint.

Of the large diameter well upgrade projects, 47% were ranked as using best practices and 17% were ranked as a major concern by auditors. A large diameter well is inherently more vulnerable to surface water contamination because it is a challenge to maintain a watertight casing with the materials that have traditionally been used for lining dug or bored wells. Well upgrades for this type of well should aim to ensure longevity of watertight seals to the casing and cap. Typical linings for older dug wells can range from field stone, brick or concrete tile. The field stone and brick have many cracks and crevices that need to be filled with a flowing and or expanding sealant during an upgrade. Concrete tile wells need to have any holes or gaps in the joints sealed, degraded tiles replaced and sealant placed between the joints, inside the well and outside the well to provide a multiple barrier to prevent surface water from entering the well. The cap should also be replaced if there are signs of deterioration. The quality of work observed in large diameter upgrades varied greatly. Some contractors appeared to have the expertise to reconstruct the well in a fashion that would ensure long-term water tight casing. Some used galvanized steel

culverts with concrete sealed annular space to replace brick-lined or field stone wells, some excavated the exterior of the well; replaced broken tiles; and sealed the well joints with the multiple barrier. Others applied grout on the interior of the well and some only sealed the top joint. Using grout on the interior of the well addresses the problem temporarily; it is unlikely however, to remain water tight for more than a year or two. One contractor who did a number of jobs sealing only the interior charged significantly less than the average for a large diameter upgrade (\$600 – \$900). This may require the client to repeatedly invest in short term upgrades rather than making one larger investment to repair the well for long term security. Other contractors who did insufficient work on the large diameter wells did not scale the price of the work down as much. One contractor even phoned one of the auditors to “explain” that the tile joints should not be sealed as this is where the water comes from for the water supply.

### **8.1.2 Preventive Operating Procedures**

Operational water levels in wells are dictated by pumping rate and well production efficiency. This efficiency can be calculated by noting operating water level change immediately outside the well expressed as a percent of the water level change inside the well at some rate of pumping. As long as operating levels inside the well remain above the depth of pump intake, production loss due to progressive loss in well efficiency is usually not identified nor of great concern until water level decline reaches to depths at or below the pump setting. At this point the loss in well production is abruptly interrupted when suction is broken and the well is deemed to have “failed”. Reasons for this failure, for even well managed municipal wells, are sometimes unknown and for the majority of rural wells, not investigated or documented. Provincial records have not traditionally archived preventative, rehabilitative or decommissioning information for such occurrences (Lebedin et al., 2000).

Post-construction water level monitoring provides the well owner with an extremely valuable means to assess the operational condition of the well. This consists of the minimum of a routine water level measurement while the well is pumping, then compared to the level while the well is at rest. The pumping rate divided by the difference in water levels is defined as the specific capacity expressed as the amount of water produced per unit of water level decline. Changes in this relationship parallel changes in well efficiency and imply changes to the operational condition of the well. This measurement can be used to forewarn of production loss and the need to look for a cause and, as necessary, allows the operator to consider appropriate preventative or rehabilitative measures to restore lost capacity. For many rural water well operators, this is not a normal operating procedure. Reasons for this vary but may include attitudinal aspects attributable to lack of knowledge, and understanding of the problem, or possibly related to the design of the well which may not have a monitoring or sampling port available to facilitate such observation without well disassembly. A sudden loss in capacity is often viewed as a normal and inevitable extension of well age or incorrectly dismissed as aquifer depletion - and actions taken may vary from lowering the pump setting or installing a new well. In a society that is accustomed to disposing of materials it no longer finds useful, the abandonment option is a typical outcome that, although presents a hardship, it is one that is rarely challenged. Operation and maintenance issues deserve much greater attention from the perspective of extending well

life. These issues are felt to be most within our ability to control with timely preventative maintenance or rehabilitation (Borch et al., 1993).

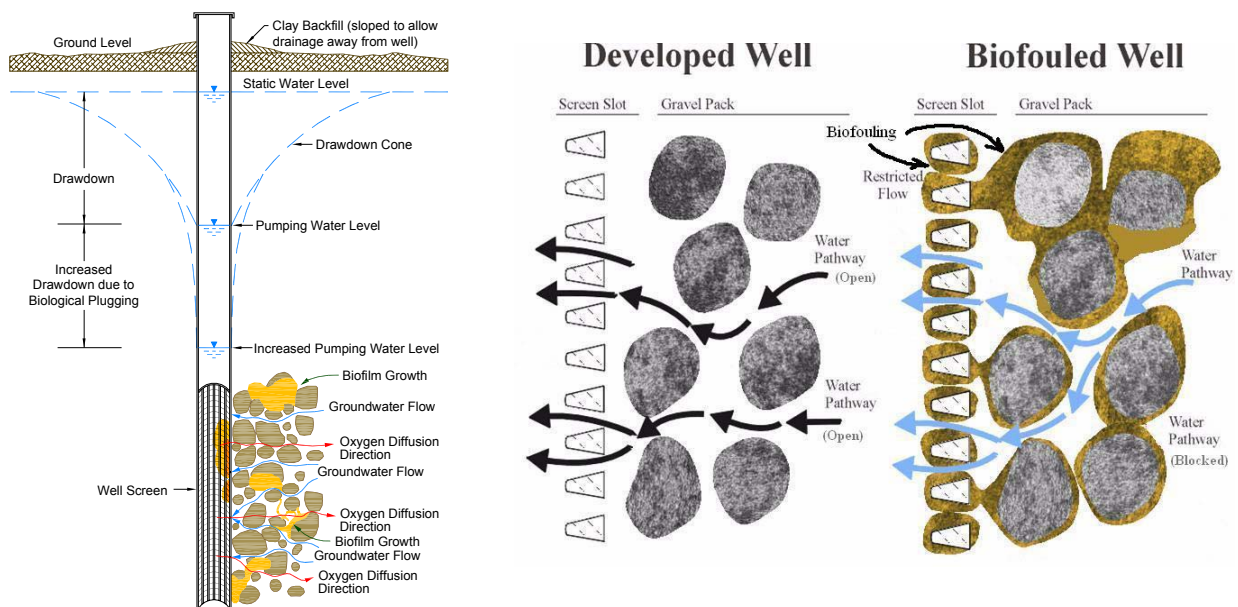
In a recent survey of rural well infrastructure in the Municipal District of Kneehill, Alberta where relatively abrupt well failures are fairly common at times of drought (Cullimore and Legault, 1997) it has been noted that loss in well productivity was caused not simply by over-extended groundwater pumping from depleted aquifers. Historical aquifer water levels were essentially unchanged. Rather, the cause was felt to be due to the added effect of an increased, but unnoticed loss in well efficiency beginning from the time the well was first constructed. This loss was attributed to a condition referred to as biofouling which also appeared to be independent of well depth or construction materials and seemed to be pervasive - in time affecting all wells to varying degrees.

The invisibility of this infrastructure problem is of concern because it is now recognized that, if detected early, substantial gains in well life are realizable through proper well design and operation, and through rehabilitative or preventative maintenance techniques on water wells.

## **8.2 Biofouling**

Water well deterioration caused by microbiological activity is termed biofouling. Installing and pumping a well increases the level of oxygen and nutrients in the well and in the surrounding aquifer along a redox front that is created by oxygen diffusing through the well into the adjacent aquifer - oxidative closest to the well and reductive farther from the well (Cullimore, 1999). The redox front encourages bacterial cells, which are naturally present in groundwater, to anchor themselves to surfaces along the front in the well and around the well intake. Once attached these bacteria quickly multiply and colonize these surfaces. The bacterial colonies will form a gel-like slime or biofilm that captures chemicals, minerals and other deposits such as clays and silts, which move to the well during pumping, forming biomasses (Figure 8.1). Biofilm is a complexly-structured hydrated substance, comprised of mostly bound water (Stoodley et al., 1999). The principle component of biofilm is a complex sugar molecule (polysaccharide) which is very insoluble and resistant to chemical/biocidal treatment (Shirliff et al., 2002; Donlan, 2002).

Some of the byproducts associated with bacterial growth, such as oxidized iron and manganese, will also become accumulated in these secretions. This leads to the production of the red or black slimes often found in toilet tanks or observed on pumps and discharge lines when they are pulled from a well and inspected (Figure 8.2). Biofouling of a water well occurs when biofilms accumulate a sufficient amount of debris to interfere with water flow and affect water quality.



**Figure 8.1 Biofouling on Water Well and in Adjacent Environment**

Source: L: Courtesy AAFC-AAC; R: Courtesy DROYCON Bioconcepts Inc.

If uncontrolled, well biofouling can affect well performance in various ways. Biofilms and the debris they collect can quickly coat, harden and plug the well screen, the sand pack, the surrounding aquifer material and may even plug water lines and affect the performance of household treatment systems. In addition, the bacteria living within the biofilm can increase the rate of iron oxidation and iron build-up in the well and distribution pipes, which leads to occasional discoloration of the well water. Biofouling can also result in the production of odours such as rotten egg or fishy smells, changes in taste, and corrosion of steel and iron casings and pipes. Once developed, a biomass can protect the bacterial cells from environmental changes such as changes in pH, changes in temperature and fluid movement and penetration which makes treatment chemicals less effective and removal of plugging material more difficult.



**Figure 8.2 Biofouling on Pumping Equipment**

Source: Courtesy AAFC-PRFA file photos; L: M.D. of Kneehills, Alberta; R: City of North Battleford, Saskatchewan

### **8.2.1 Diagnostic Procedures**

There are a number of field and laboratory tests that can be used to monitor water quality and biological activity in groundwater. An innovative and noteworthy technology for this purpose is the BART™ presence-absence (Biological Activity Reaction Test - Cullimore, 1999) (Figure 8.3). If performed on a regular basis, beginning immediately after the well is installed and then routinely every few months or so, these tests will indicate when water quality is changing or when biological activity is increasing (Cullimore, 1999).

Changes in water quality and increased levels of biological activity combined with a loss in specific capacity are indications that well maintenance is required. Ideally, appropriate well maintenance chemicals should be applied before well performance is significantly affected. Establishing a monitoring schedule, where pumping water levels and well pumping rates are recorded, is regarded to be the most simple and effective way to identify when preventative maintenance or rehabilitation measures are required.

Two of the main bacteria types that cause problems in water wells are iron related bacteria (IRB) and sulphate reducing bacteria (SRB) (Cullimore, 1999). These bacteria are not considered a health hazard, but can be quite a nuisance to well owners. A brief description of these bacteria is provided in the following:

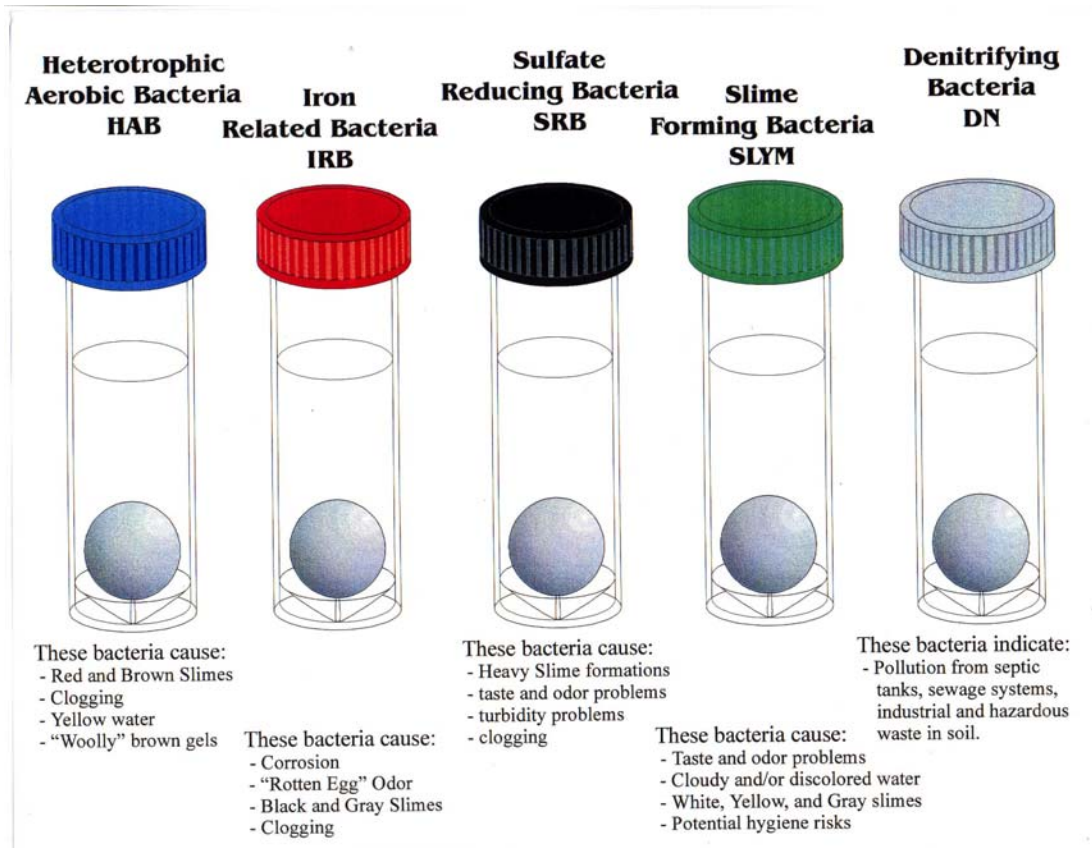


Figure 8.3 Standard Biological Activity Reaction Tests: Presence-Absence Monitoring Technology

Source: Courtesy DROYCON Bioconcepts Inc.

### 8.2.2 Iron Related Bacteria

Iron related bacteria (IRB) are a common nuisance in water wells because they favour the environment that these wells provide. Although IRB are generally considered as aerobic organisms requiring oxygen to survive, they have been found to grow in waters with very low oxygen content. These bacteria thrive in water which contains 0.5 to 4 mg/L of dissolved oxygen and will grow in water having iron concentrations as low as 0.01 mg/L. Some IRB are considered autotrophic (self-sufficient) organisms because of their limited ability to use dissolved iron/manganese in water as an energy source. They also prefer a temperature range of 5°C to 15°C, but are known to grow at temperatures ranging from 0°C to 40 °C. The optimum pH for their survival is around 6.5 pH units, but growth will occur in the range of 5.5 to 8.8 pH

units. IRB are not affected by light intensity and will grow in complete darkness or in areas fully exposed to light. The optimum ranges for the growth factors mentioned above are typical of the water well environment.

There are a number of visual indications of an IRB problem. These indications include: i) discoloured water (red, yellow, or orange); ii) slime/biofilm (red, brown, black) on the casing, pump, or well screen; iii) a smell resembling fuel oil, cucumber, or sewage; or iv) a sheen on the water surface that breaks up when disturbed (unlike a petroleum sheen). As the number of bacteria increases, the water may become more turbid; may turn reddish in colour; and may gain an unpleasant, sometimes metallic, taste. The deposition of iron and manganese salts in IRB biofilms results in its characteristic reddish-brown to black colour.

IRB are a diverse group and are difficult to enumerate. These bacteria function under different reduction-oxidation (redox) conditions and utilize a variety of substrates for growth. By routine (e.g. monthly) testing of a water or wastewater using the Biological Activity Reaction Test (BART) technique, the levels of aggressivity, possible population, and community structure of an IRB population can be determined.

### **8.2.3 Sulphate Reducing Bacteria**

Sulphate reducing bacteria (SRB) are more often found in systems with concurrent fouling problems. These organisms favour an anaerobic (oxygen free) environment. However, this does not mean that they will not grow in oxygen-rich environments. In fact, SRB can thrive under slimy deposits even though aerobic conditions exist in the main body of water. For instance, SRB will become established in a water well environment by locating under layers of aerobic bacteria such as IRB. If there is a layer of IRB biofilm on a casing, the IRB will use up all of the oxygen and the SRB will thrive in the anaerobic zone between the IRB and the casing surface.

Visual indications of SRB include a reddish or yellowish nodule on metal surfaces that exhibits black corrosion byproducts when broken open. When the complete nodule is removed, a bright metallic pit is often seen and severe localized pitting is evident. If hydrochloric acid is added to the black deposit, hydrogen sulfide will be released with its characteristic rotten egg odour.

SRB obtain their energy from the anaerobic reduction of sulfates. Even small amounts of oils and grease will provide nutrients for SRB growth. Stagnant water and low flow conditions will also increase the chance of growth. This bacteria type is also an agent of corrosion because it produces an enzyme, hydrogenase, that enables it to use elemental hydrogen generated at the cathodic site it thus creates to reduce sulfate to hydrogen sulfide. The electrolytic corrosion of iron by this process is very rapid and unlike ordinary rusting, is not self-limiting.

### **8.2.4 Emerging Microbiological Considerations: Biofouling and Hygiene Risk**

One of the least considered, yet most potentially important, hydrogeologic issues relates to the cause-effect relationship, hence increased vigil, between intensified development in rural areas and the occurrence of coliform bacteria within water wells. The reasons for elevated coliform bacteria in any water well varies according to a number possible contaminant pathways, but must

include some consideration that some coliform bacteria are indigenous to various soil and water environments and may naturally be there (Cullimore, 1999). However, coliform detection in the subsurface environment is regarded to be suspicious, and taken to indicate possible contaminant conditions, usually from a nearby source. (It should be noted that since many bacteria are smaller in size than the smallest aquifer interstitial pore space, natural filtration is not an effective barrier to their transport). In situations where coliform is present, caution is signalled for presence of enteric organisms, such as *E. coli* (and other smaller viruses), particularly if the bacteria occurs in the presence of nitrate. This leads to retesting for specific pathogens and, as necessary, disinfection.

Contrary to expectations, recent studies show that coliform bacteria are sometimes elevated in water wells which have become biofouled and which have consequently undergone rehabilitative or disinfection treatments (Oliphant et al., 2002). Evidence is growing that the development of a bioplume or biofilm around mature water wells may conceal coliform bacteria (and potentially other bacteria) in a complex association with heterotrophic, iron and sulphur related bacteria (IRB and SRB). In biofouled wells, some form of trauma or bioplume disruption is thought to be required to first loosen attached biofilm in order that the loosened masses be transported by the water stream into the well and discharged. Biofilm (and contained bacteria) can then be captured in samples collected from the pumped water stream. Since the current responsibility of water well sampling is largely left in the hands of well owners, random, intermittent sampling of biofouled wells may result in unrepresentative, i.e. false negative, results. Another complicating factor is that in the case of a positive result, the well owner will be required to disinfect the well, then immediately resample and re-disinfect the well until a negative result is returned. This practice, while comforting to the well owner, may not lead to a proper assessment, or ultimately to the proper disinfection of the well. Biofilm growth may also occupy distribution lines and other components in contact with the groundwater with similar concerns.

In some instances, the presence of coliform is natural and of little concern to human health. In other instances, confirmed pathogenic contamination (presence of *E. coli*) has occurred, perhaps as a result of a poorly located and/or designed project. False negatives and false positives appear to be inherent to current coliform survey or sampling methods for wells, and whether negative or positive, both are equally unacceptable. There is presently a need for the development of an effective sampling protocol based on a better understanding of the way microbiological conditions evolve in the typical water well environment (Cullimore, 1999). A biofouled well presents a challenge to both sample and disinfect and remains an area for further research with respect to the prevention and rehabilitation of such conditions.

Recently, a number of water well studies were performed on the Canadian Prairies to address concerns of declining well yield and water quality deterioration. These studies have led to the creation in AAFC (PFRA) of the Sustainable Water Well Initiative (SWWI, 1996 – present; see PFRA online [http://www.agr.gc.ca/pfra/main\\_e.htm](http://www.agr.gc.ca/pfra/main_e.htm)). One of the goals of this initiative is to work with rural communities, the water well industry, treatment specialists and researchers to investigate the causes of well deterioration and to provide improved advice to well owners on the methods used to diagnose, prevent and treat well problems. Such networks are valuable and a similar provincially supported initiative should be considered in Ontario's attempts to promote

research, pilot new technologies, provide training and extension on sustaining water well infrastructure within appropriate institutions.

Presently, a laboratory review and evaluation of well maintenance chemicals currently employed to restore well-aquifer efficiencies is being conducted by PFRA. In addition, field projects are under way to test the effectiveness of well rehabilitation technologies. The information gathered from these studies will be used to provide improved advice on the methods used to monitor, maintain and treat private water wells. Efforts are ongoing to address the significant knowledge gap concerning the extent of the well biofouling problem and to promote promising new rehabilitation and maintenance technologies that are available to counteract a major cause of water level decline and well abandonment and to maintain safe operating environments for wells and aquifers.

### **8.3 Well Rehabilitation**

Rehabilitation is usually taken to mean the efforts taken to restore lost well production capacity and much knowledge on this has been formally introduced and new technology is evolving and commercially available (Smith, 1995; Hackett, 1987). Currently, there are four classes of measures commonly in use: 1) structural; 2) physical; 3) chemical; and 4) disinfection. A fifth is electrical in application and has not yet developed sufficiently for commercial use but shows good promise (Globa et al., 2003).

**Structural:** Mechanical measures include re-installing and/or re-constructing casings and/or screen and riser pipes and, pumps and well caps, and to replace worn, corroded or otherwise deficient well components. This approach is most often taken although costs and incomplete well restoration may dictate well abandonment and replacement with a new well.

**Physical:** The most common method of rehabilitation consists of redeveloped, usually through the use of compressed air, sonic jetting, surge block apparatus and/or pressurized water to clean production zones. Most drilling contractors are well equipped to perform the servicing of wells with both structural and physical tools.

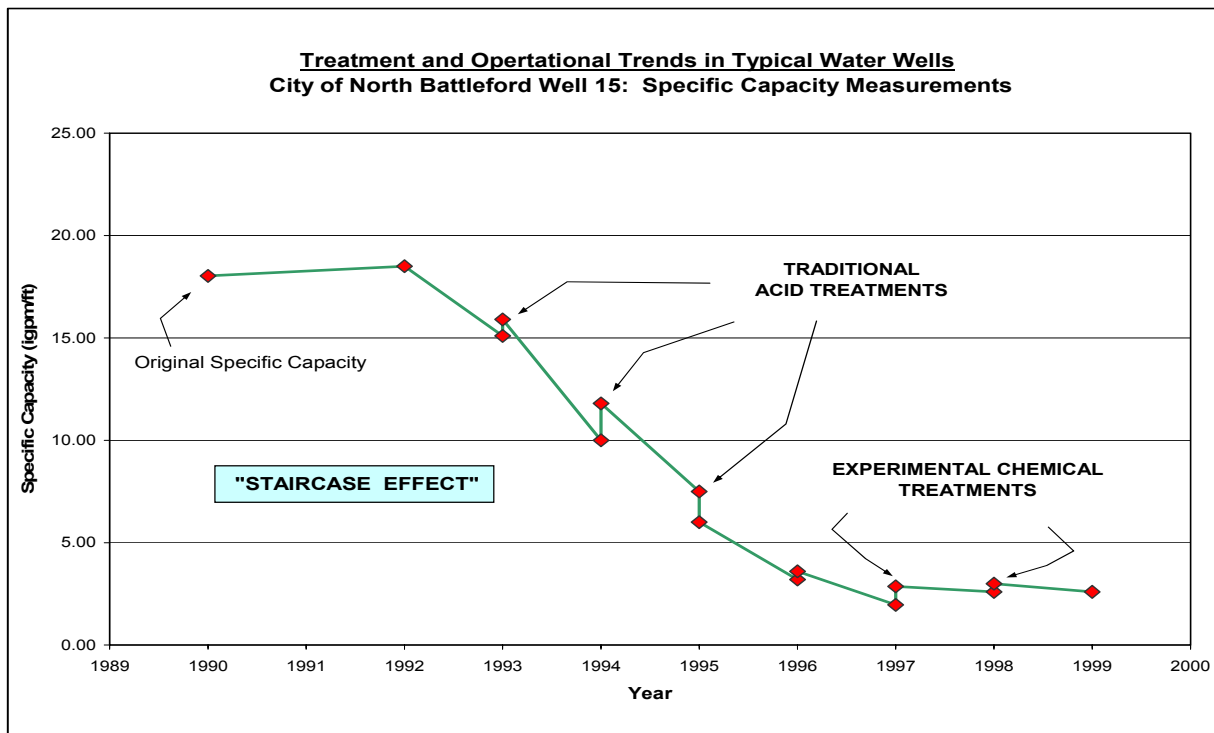
**Chemical:** The most common rehabilitation methods use acids, surfactants and disinfectants that are introduced into the well to remove deposits and encrustations which may occur over screen surfaces or accumulate in aquifer fractures or pore spaces around the intake portion of the well. There are numerous commercially available products in the market place but the majority consist of the application of hydrochloric acid together with a proprietary surfactant (usually optional and sold as a package commercially). Shock treatment (disinfection) is frequently applied either as a supplementary step with other chemical treatments or by itself. This involves use of a hypochlorite compound to produce hypochlorous acid as the effective disinfection agent. These methods are of varying success ranging from very good to poor. Other methods employ the use of cryogenic carbon dioxide.

Recently, a number of proprietary blended chemical heat treatment methods (BCHT, UAB) have been developed that show good results to restore lost production capacity (Cullimore, 1999). They involve the combined use of heated acids/bases and surfactants - noting that heat raises the

chemical activity, requiring lower concentrations (with reduced corrosivity through the use of corrosion inhibitors or through the use of organic acids) - but with good biocidal characteristics capable of removing both chemical encrustation and biofilm, and thus counteracting bioplugging as well. Acids used range from inorganic such as hydrochloric acid to a variety of organic acids such as acetic acid. The major drawback is the special equipment and training required on the part of the crew engaged in these applications.

There is clearly a cost with preventative/rehabilitative measures but considered by some experts to be less than the effects of uncontrolled deterioration of wells and water systems. Companies that provide these needed, but lacking services for wells, may find profitable new opportunities as stakeholder awareness improves and demands for such services increase (Smith, 2003).

It has been noted that in the case of biofouling, wells that show losses in specific capacity of 25 percent or more are very difficult to rehabilitate successfully (Scott and Keevil., 1997). This underlines the need for diligent monitoring and application of timely preventative treatments. With preventative maintenance, heated chemical treatments have been demonstrated to be very effective in maintaining well productivity. Further research is warranted to help deal with the “staircase effect” which appears as a downward trend in specific capacity with time in some repeat applications (Figure 8.4), and for cost-effective small scale applications for small private wells.



**Figure 8.4 Staircase Effect – Treatment and Operational Trends Typically Observed in Water Wells**

Source: Courtesy AAFC-PFRA

**Disinfection:** The use of chlorination in wells is becoming more restrictive in parts of North America and Europe because of the creation of undesirable chlorination byproducts. Because of these byproducts, and particularly because shock chlorination is seldom the most effective treatment alone, several other treatments are being used for biofouling control (Smith, 1995).

Chlorine tends not to fully penetrate biofilm or to dissolve polysaccharide (Payment, 1999; Momba et al., 1999). Biofilm may react to chlorine by expelling bound water and contracting and shearing into detached fragments, which protect bacterial consortia contained in the biofilm which are then free to migrate and re-establish new growth after the shock chlorination. Wells treated with chlorine compounds are noted to redevelop biofouled and clogged conditions a short time after treatment and wells eventually become more severely affected in the familiar stair case trend. Research into new methods of disinfection is needed into methods that are capable of penetrating biofilm.

**Electrokinetic:** Recent research suggests that biofilm growth and bacterial attachment to aquifer and screen surfaces can be effectively controlled through the use of impressed current systems similar to that used in cathodic protection (Globo et al., 2003). The principal component of biofilm is a complex sugar molecule (polysaccharide) which is extremely insoluble and biomasses are difficult to penetrate with chemical approaches once maturely established. Bacterial attachment is thought to be electrostatic in nature. Appropriately applied electrical current has been noted to cause biofilm shrinkage and shearing, demonstrating a potentially very effective control of biofouling. Further research is required into remote anode applications and well design and conductive materials that lend themselves better for electrokinetic applications.

#### **8.4 Well Maintenance and Awareness in Ontario**

All wells require regular maintenance to enhance their performance and longevity. Over time the well cap and casing can deteriorate and lose the water tight seal that was present when the well was constructed. This is especially true of large diameter wells as traditional liners have had many joints or were not water tight to begin with. This makes the older larger diameter well prone to influence from surface water.

The Ministry of Environment and the Ontario Ministry of Agriculture and Food have recently conducted outreach initiatives to improve homeowners' level of knowledge and awareness of the importance of well maintenance and to provide funding for well upgrading. These activities have included an assessment of homeowners' well maintenance practices and knowledge and attitudes towards well maintenance. The findings of these surveys, described below, indicate that comprehensive well stewardship is not widely practiced and identify a number of barriers associated with undertaking well maintenance and upgrading activities.

**Well Aware Phase I:** This Ontario Ministry of Environment sponsored initiative included a 15-20 minute survey of 400 Ontario well owners to determine their level of knowledge about wells and well water, and to gauge their willingness to take on active well stewardship roles. Six focus groups and extensive interviews were conducted with key informants from Ontario and other jurisdictions about the most effective way to make stewardship programs work. There were also

a number of pilot projects that were tested to determine effectiveness. Some of their findings were as follows:

- Well owners are very concerned about how the quality of their well water affects family health; this prompts 80% to test their well water at least once a year and 50% to test it two or more times a year. For comparison, an earlier survey of 8,869 well owners in Oxford County, Ontario, found that 68% of respondents had tested their water at least once a year, and 43% did so two or more times a year (Statistics Canada, 2001).
- Barriers to well stewardship were lack of information or understanding; cost; time; access to required goods and services; high level of comfort in current practices; and general guardedness towards government involvement in private wells.
- A common misconception among well owners is that well problems would become apparent from changes of water quantity and quality. Well owners are often more likely to seek assistance to resolve a quantity problem and less likely for quality issues.
- For many private well owners, the only information they recall receiving about their well is their water test results. Most well owners in Ontario report having good quality water. This was observed in a number of different programs; in some cases despite the fact that they were not testing their water regularly or testing for the required well quality parameters. Many indicate that they believe a broad screening of potential contaminants is conducted at the MOH even though only bacteria is reported.
- Water testing was the most commonly reported action that well owners can take to improve the quality of water from their well (43.5%). Only 12.5% indicated upgrading or repairing their well. Twelve percent of participants checked their wells for cracking, leaking, debris, and run-off issues annually. Some treated with Javex, inspected for vermin and cleaned out debris. Most maintenance or repair work was only undertaken if a problem was identified. Eighteen per cent said they did nothing and 29% said they didn't know what they did.

**Well Aware Phase II Campaign:** This program is funded through the Ministry of the Environment and partners including the Association of Professional Geoscientists, the Ontario Groundwater Association and the Green Communities Association. The Well Aware program includes:

*Well Aware Video:* This half hour video, distributed through the Ontario Ground Water Association, is aimed at providing information to well owners about their responsibilities in keeping their well safe.

*Well Aware Booklet:* This user-friendly guide for well owners is similar in content and approach as the video. 50,000 copies were printed and sent to various organizations in Ontario between May and September 2003 for distribution (including 25,000 to Ontario Ground Water Association for distribution via members). Requests for booklets exceeded demand and plans for a reprint were in progress (Green Communities Association, 2003).

*Well Aware Community Forums:* Sixty-two public information sessions were conducted over an eight-month period across Ontario to educate well owners on local groundwater issues and their well.

*Guided Self Assessment:* This program is similar to the Environmental Farm plan process but targets non-farm rural residents, and provides a one-on-one onsite assessment of well owners' risks and provides recommendations for improvement. This program is similar to the US Home\*A\*Syst program that conducted more than 21,000 assessments across 38 states in 1999-2000. Ontario's GSA pilot project participants were surveyed following the visits and found overwhelming support for the project. The guided self assessment is an excellent tool to educate and motivate action; 86% of the participants followed recommendations and the visit had a ripple effect with participants speaking to six or seven others regarding the visit and what they had learned about wells.

*Information Provider Workshops:* These sessions are aimed at people who are called upon by the general public to provide information on wells or well water. The sessions include staff from public health units, municipalities, OFA etc. The aim is to assess the level of knowledge among information providers and to ensure that consistent messages are provided to the public.

**Well Aware Phase II Guided Self Assessment (GSA):** This Ministry of Environment sponsored initiative found that the vast majority of wells observed were more than 20 years old, pre-dating the 1985 and 2004 revisions to Regulation 903, and in need of repair. Only 12 per cent of wells observed during the Guided Self Assessments conducted in the summer 2003 were deemed satisfactory. In the remainder of cases, upgrading or replacement was recommended for basic problems causing a breach in the watertight casing or cap.

Some wells over 100 years old had never had any maintenance performed, according to the well owners. In one circumstance, a well that was found to be contaminated in the early 1920s, causing eight of ten family members to die of dysentery, was still being used for household water for three homes. The cap and casing had never been upgraded. Well Aware Phase II GSA customers are typically environmental leaders in the community, including solar power users, organic farmers, conservation authority board members, etc. However, their general environmental awareness is not reflected in their well stewardship knowledge and behaviour. Only about a third of participants had drilled wells finished above grade – the rest are dug or bored, or have a well pit. Many of those wells finished above grade have various defects, including encumbrance by a garden or structure.

Many clients expressed a reluctance to have a well contractor assess their large diameter wells as they were concerned about being required to move to a deeper drilled well. Many well drillers do not have the expertise nor do they prioritize their time to perform rehabilitation work on wells. As a result, many well owners with older large diameter wells have been in a situation where they may have wanted to have work performed on their well, but either were unable to get an available contractor with the expertise to do the work, or were pressured to drill a new well. The well owner, feeling that they have limited options and often concerned about the cost and subsequent quality and quantity of water in a different water supply, often decides that the

philosophy “if it ain’t broke don’t fix it” applies, not recognizing that breaches in the seal are serious and in need of repair.

### Evaluation of Well Aware

Enviro-nics was commissioned to conduct an evaluation of the Well Aware Phase II Program in July 2004 (GCA, 2004). Participants in Well Aware activities were asked a number of questions about groundwater basics, common threats, and well stewardship best practices. When compared with non-participants, participants in Well Aware activities were more likely to understand basic well stewardship principles (see Table 8.2). Some of the questions were compared to the results of the Phase I survey conducted in 2002.

**Table 8.2 Evaluation of Well Aware Phase II (GCA, 2004)**

| <b>Participants are more likely to:</b>                          | <b>Phase II Participants</b> | <b>Phase II Non-Participants</b> | <b>Phase I</b> |
|--|------------------------------|----------------------------------|----------------|
| Understand they are responsible for taking care of their well    | 94%                          | 88%                              | 70%            |
| Visually inspect their well                                      | 81%                          | 56%                              | N/A            |
| Know that unused wells should be plugged and sealed              | 77%                          | 59%                              | 30%            |
| Hire a licensed contractor to plug and seal an unused well       | 41%                          | 28%                              | N/A            |
| Name common threats  | 95%                          | 71%                              | N/A            |
| Remove the source of contamination before resorting to treatment | 75%                          | 51%                              | N/A            |
| Talk to their neighbours about well stewardship                  | 55%                          | 35%                              | N/A            |

**Healthy Futures Upgrade and Decommissioning Project:** To address the cost barriers associated with undertaking well maintenance work, the Ontario Ministry of Agriculture and Food (OMAF) allocated \$5M towards the Healthy Futures Upgrade and Decommissioning project. This project provided subsidies to clients to assist them in performing well maintenance to improve the integrity of their well and secure their water supply or to securely decommission an old unused well. The response to the project was extremely positive. A total of 2,576 well upgrades funded. Funds for upgrading and performing well maintenance were used entirely by end of May 2003. Public demand for continuation of this portion of the project was so compelling that OMAF allowed funds from the decommissioning fund to be allocated for well upgrades if they were also decommissioning a well. Over 100 participants accessed these combined project funds over a four month period.

Clients communicated several reasons for deciding to have a well upgrade performed. The historical quality of the water in upgraded wells may or may not have been an issue in the client's decision. Well owners who already had reliable, good quality water often opted to perform the upgrade with the Healthy Futures incentive because they believed that the work would guard against future problems. Several clients indicated that a well contractor had informed them of the Healthy Futures Program, and the contractor had told them that the upgrade was a good precaution. Many clients also said that the monetary incentive to do the upgrade was a big motivator. Others commented they didn't want to take any chances with their water. The fact that people remained vigilant in maintaining good water quality reflects the high degree of importance many people place on their water in rural areas and the overall awareness of the importance of the source.

Through the Healthy Futures program, some private well owners were very frustrated by their interaction with some of the well contractors. OFA was not permitted to provide the names of licensed contractors who are qualified and willing to do well rehabilitation work. MOE did not have this information posted electronically. Clients would check local phone directories or call the MOE for a referral, but this process led to a list of a number of licensed contractors in the area, not necessarily contractors routinely performing this type of work. Not all well drilling contractors necessarily possess the expertise or the equipment to decommission or repair wells. Contractors who are qualified to do this work, but who also have drill rigs, have better economic return in keeping their rig running when there is demand. Reports from Ontario Ground Water Association (OGWA) indicated that there was consistent demand for new wells during the time of the project. Some private well owners became discouraged and were not able to have their projects completed before the deadline, in part due to this apparent shortage of licensed well contractors.

Many clients noted the large variation in quotes provided by contractors for upgrading work. In one case, three quotes for one project were approximately \$800, \$1,600 and \$3,000. The client expressed serious concern over the highest quote whereas someone familiar with the well and the appropriate materials required to do the job would be more concerned with the lowest price as it may not even cover materials costs. Other clients expressed surprise at the rapid completion time at a higher cost than they felt was reasonable for the length of time required for completion of the job by the contractor. These clients felt that the contractors were exploiting government funding whereas it may have actually reflected high materials cost.

Another barrier is lack of understanding of what a proper well looks like and associated risks that could impact a well. Part of the Healthy Futures program was the requirement for an Environmental Farm Plan for farmers and a self assessment for non-farm residents. The aim of this, and other similar programs offered through conservation authorities is to educate people regarding proper environmental practices and to assist with the implementation through subsidies.

Client surveys conducted as part of the audit suggested that many wells chronically contaminated with bacteria showed improvements with the upgrade. In some cases, however, this was not based on water testing results, but on the client's perception based on aesthetics of the water.

**Well Discovery Program:** This pilot project was initiated in June 2002 in Merrickville-Wolford among private well owners to georeference the coordinates of the well and affix a well tag to register or link the well with the Ministry of the Environment well records database. The project was funded by the Ontario Ministry of the Environment and Energy and carried out by the Green Communities Association as part of their “enhance well owner involvement” assignment. The approach showed great sensitivity in acquiring permission from the homeowner to access their property. The program was promoted and endorsed by the town in collaboration with the local media. The program was voluntary and the level of involvement was determined by the client. Some were very interested in learning more about the process and their well (10%), while others were accepting of the program (98% agreed to participate) but showed low interest in their well (33%). Two hundred wells were identified and most were georeferenced using GPS (90%). Only 24% of wells matched with well records and one third of the wells assessed were not visible, with roughly 10% of the homeowners not aware of the location of their well (Green Communities Association, 2002).

**Outreach to Drillers:** MOE has partnered with the Ontario Ground Water Association (OGWA) to educate drillers on revisions to Regulation 903. Outreach included regular communication in the OGWA newsletter and through information sessions entitled “Discover 903.” Four meetings were held in November 2003 throughout the Province. The meetings were well attended with about 450 contractors attending one of the four sessions. A number of concerns were raised regarding some of the new requirements of the regulation regarding large diameter well construction and decommissioning, the new pump test and grouting requirements. The overwhelming message conveyed by the drilling industry was the desire for a methodical and regular inspection and enforcement program to ensure to a level playing field. There are additional equipment and materials costs incurred by contractors in adhering to the new regulations. Contractors adhering to the new regulations must charge their clients these additional equipment and materials costs, while those not adhering to regulations often undercut the diligent contractor. Without regular inspection and enforcement, there is little incentive among contractors to comply with the new regulations.

**Subsidy programs for well work:** In addition to the OMAF Healthy Futures Upgrade and Decommissioning program, conservation authorities and municipalities have provided funding for work performed on private wells.

## **8.5 Implications for Sustainability**

Maintaining a private well is key to increasing the longevity of the well. Inadequate maintenance results in crisis intervention and may lead to irreparable, widespread problems. Consumers understand the need for routine maintenance with other complex, expensive items (cars, furnaces, etc.). Annual household budgets and tasks should be allocated accordingly and key indicators of deterioration identified through research.

Inspection and enforcement at this point of the life cycle should be focused on voluntary compliance, water testing, outreach and education, subsidy programs and preventative strategies.

To promote sustainable groundwater use, the number of replacement wells should be minimized. Wells should not be considered disposable goods.

## **8.6 Conclusions**

1. The Panel applauds the educational initiatives undertaken by the Ontario government. This appears to be the most efficient means to promote Water Well Sustainability. The Panel recognizes that continued funding for these initiatives in 2005 has not been forthcoming.
2. Many wells in Ontario require rehabilitation and upgrading and costs to well owners associated with undertaking repair work are often a barrier. Continued funding for well rehabilitation is a critical step in addressing deficient private wells. The Healthy Futures Upgrade and Decommissioning program was successful in improving the water quality of wells in Ontario and raising awareness among well owners of well stewardship issues and the importance of well repair and rehabilitation in enhancing well security.
3. The demand for qualified contractors to carry out well rehabilitation and maintenance work in Ontario exceeds the current supply. In addition, there appears to be a lack of adherence to best practice among some contractors who are currently carrying out this work
4. Field investigations have shown that best practices (e.g. annular fill around casing extensions) are not always followed. The requirements for upgrades are not clearly stated in Reg. 903.
5. Water well biofouling is a prevalent and universal problem that is not clearly understood and managed by water well owners, despite the availability of new diagnostic knowledge and rehabilitative technology. Changes in specific capacity and water quality characteristics are signals that preventative and/or rehabilitative action should be taken – preferably before production loss is greater than 25 percent.

## **8.7 Recommendations**

1. The Well Aware program, a provincial government funded province-wide effort to educate rural residents about well safety, is an effective tool for promoting well stewardship and should receive continued funding and support. Indeed, consideration should be given to expansion of this program into additional Ontario communities.
2. The Ontario government should continue to fund a subsidy program similar or equivalent to the OMAF Healthy Futures Upgrade and Decommissioning program. The Panel recommends that such programs provide greater than two-thirds cost-sharing and include an educational component.
3. The Ontario government should support and fund a new sustainable asset management training program at Sir Sanford Fleming College. The program should focus on the practices, tools and techniques necessary to develop life-cycle management strategies that will sustain the water well infrastructure in Ontario, and beyond. The program would

spawn a badly needed service industry aimed at maintaining, rehabilitating and decommissioning water wells. The new industry would meet the growing needs of the millions of Ontarians who rely on high quality groundwater supplies.

4. The Panel recommends that a proper well upgrade should include the following:
  - excavation around the well tiles;
  - replacement of damaged tiles;
  - application of non-toxic sealant between joints and tiles;
  - application of grout on the interior of the joint; and
  - use of impermeable materials on the exterior of the well.
  
5. Research is required in the following areas:
  - development of well designs that incorporate construction materials able to withstand treatment chemical applications and allow for well maintenance, rehabilitation and/or treatment without well disassembly (See also Recommendation 2.1);
  - development, evaluation and pilot testing of cost-effective treatments for wells that are able to safely and effectively serve as biocides to counter-act biofouling, as well as remove incrustative minerals from within water wells;
  - assessment of the role and properties of biofilm growth and biofouling in water wells;
  - development of reliable water sampling protocols for pathogens and for effective well disinfection; and
  - development of a decision-making tool that will provide clarification to determine when efforts should be placed on well upgrading versus replacement.
  
6. A knowledge/research network should evolve in Ontario similar to the Agriculture and Agri-Food Canada (AAFC) Sustainable Water Well Initiative (SWWI) to promote knowledge exchange; the development of extension materials; and sharing of research efforts on ways to diagnose and treat well problems. The network should also focus on sharing information on new technologies for maintaining and rehabilitating water wells. A website dedicated to sharing existing and future technology developments with water well stakeholders should be developed

## 8.8 References

- Borch, M. A., Smith, S. A., and Noble, L. N., 1993. Evaluation and Restoration of Water Supply Wells. Prepared for and Published for American Water Works Association Research Foundation. 271 p.
- Cullimore, R. 1999. Microbiology of Well Biofouling- Lewis Publishers- Sustainable Water Well Series; 435 p.
- Cullimore, R. and Legault, T. 1997. Microbiological Investigations of Water Wells in the Municipal District of Kneehill, Alberta: project report prepared in partnership with Agriculture and Agri-Food, Canada - PFRA. 28 p.
- Donlan, R. M. 2002. Biofilms: Microbial Life on Surfaces; Emerg. Infect 8(9) © 2002 Centers for Disease Control and Prevention (CDC).pp. 7-21.
- Globa, R., and Rohde, H. 2003. Application of Impressed Current Systems to Mitigate Water Well Biofouling: Presented at 56th Canadian Geotechnical Conference - 4th Joint IAHC-CNC/CGS Groundwater Specialty Conference, Winnipeg, Manitoba. 8 p.
- GCA (Green Communities Association) 2002. Report on the Well Discovery Pilot Project. Village of Merrickville-Wolford, Eastern Ontario. August 2002.
- GCA (Green Communities Association) 2003. Well Aware (Phase II) 2<sup>nd</sup> and 3<sup>rd</sup> Quarter Report. April through Sept. 2003. Interim Report to MOE/GCA Liaison.
- Hackett, G. 1987. A Review of Chemical Treatment Strategies for Iron Bacteria in Wells: Journal of Water Works, February, 1987. pp 39-42.
- Lebedin, J., Rohde, H., Jaques, D., and Hammer, M., 2000. Rural Water Well Infrastructure Assessment on the Prairies: An Overview of Groundwater Development and Reliance Trends. March 31, 2000. Agriculture and Agri-Food Canada -PFRA. 14 p.
- Momba, M. N. B., Cloete, T. E., Ventner, S. N., and Kfir, R., 1999. Examination of the Behaviour of Escherichia Coli in Biofilms Established in Laboratory-Scaled Units Receiving Chlorinated and Chloraminated Water. Journal of Water Resources Research. 33, 13, 2937-2940.
- Oliphant, J. A., Ryan, M. C., Chu, A and Lambert, T. W., 2002. Efficacy of Annual Bacteria Monitoring and Shock Chlorination in Wells Finished in a Floodplain Aquifer: Journal of Groundwater Monitoring and Remediation . 22, 4, 66-72.
- Payment, P. 1999. Poor Efficacy of Residual Chlorine Disinfectant in Drinking Water to Inactive Waterborne Pathogens in Distribution Systems: Canadian Journal of Microbiology. 45, 709-715.

Scott, P., and Keevill, B., 1997. City of North Battleford Well 15 1997 Field Test of UAB Water Well Treatment Technology - prepared in collaboration between Droycon Bioconcepts Inc and AAFC - PFRA, 26 p.

Shirtliff, M. E., Mader, J. T., and Camper, A. K. 2002. Molecular Interactions in Biofilms. *Journal of Chemistry and Biology*, 9, pp. 859-871.

Smith, S. A., 1995. *Monitoring and Remediation Wells. Problem Prevention, Maintenance and Rehabilitation*, Lewis Publishers. 182 p.

Smith, 2003. *Ground Water Science*. <http://www.groundwatersystems.com/index.html>.

Statistics Canada. 2001. *Survey on Internet Use and Selected Health Issues for Oxford County; Report SSDC-72*.

Stoodley, P., Boyle, J., D., and Lappin-Scott, H. M. 1999. *Microbial Biosystems: New Frontiers - Proceedings of the 8th International Symposium on Microbial Ecology, Halifax, Canada*, 7 p.

## 9.0 Decommissioning and Abandonment

In Ontario, wells that are not used or maintained for use are legally required to be decommissioned according to Regulation 903. Responsibility for the decommissioning falls on the well owner. The Ministry of Environment also requires decommissioning of i) wells containing salty, sulphurous or mineralized water; ii) wells that contain natural or other gas; iii) wells that produce water that is not potable; or iv) wells that do not meet Regulation 903, for example the required minimum separation distance to a potential source of contamination. In Ontario, the Ministry of Health (MOH) will not issue a clearance certificate to the building department unless there is a well in place with potable water for a residential home. A developer is unable to obtain either a demolition or building permit until any wells onsite are decommissioned and the MOH provided with the records.

The Ontario Ground Water Association (OGWA) estimates that there are more than 500,000 wells in Ontario that need to be decommissioned. Seventeen percent of the 450 non-farm rural residents visited under the Well Aware GSA program owned a well that required decommissioning. Some rural homes had more than one additional well. Many older wells in Ontario were constructed by the homeowner with the objective of structural stability as opposed to ensuring a watertight liner to protect the water supply. These wells became contaminated, stopped producing adequate water, or were no longer needed and new wells were built.

Abandoned wells must be addressed to protect the quality of water in our aquifers. Other benefits to the well owner would include improved health and increased property value. These old wells are direct avenues to aquifers and often are more permeable than the surrounding, intact soil and geological structures. Improperly retired wells can increase the risk of contamination entering nearby wells and provide a short-cut for contaminants to reach deeper aquifers.

Many areas of Ontario, especially rural areas located adjacent to expanding urban centers, have switched rural residents to a municipal water service but have not compelled the homeowner to retire their wells. This has resulted in many abandoned wells in close proximity. The old wells were then addressed as a structural problem or not all. In cases where the well was addressed for structural problems, the well was filled with native soil, gravel or in some cases garbage and debris. In other cases, only the top was secured with the remainder of the well left open. Many other wells were not addressed at all and continue to pose a serious risk of injury to people or animals unaware of their location. Figure 9.1 shows an old fieldstone lined well receiving contaminants. The new drilled well is deeper and not directly affected by the contaminants; however, because of the short-cut provided by the abandoned well, the newer well is also compromised.



**Figure 9.1 Fieldstone Lined Well Receiving Contaminants**

Abandoned wells are unlikely to have a well driller’s record filed with the Ministry of Environment, and if the property has changed hands since the well has ceased to be used, the new property owner may not know that the well exists. OGWA indicates that as a very general rule of thumb, if the rural property is over 50 years old, there is likely an additional well present. The most likely locations for old wells are near the homestead, barns or other outbuildings. Table 9.1 summarizes some of the signs that may indicate the presence of an unused well. One farmer involved in the Healthy Futures program used a small cement step in his barn for 30 years before the concrete collapsed under his weight to reveal an open well below this cap. In other circumstances, the remnants of the well remain – the old hand pump or windmill or the well covered with plywood or a deteriorating cap.

Surveys from Well Aware Phase I identified barriers to well abandonment, including expense and a lack of knowledge of the importance and requirements of de-commissioning. Only half of survey respondents mentioned sealing and plugging of abandoned wells; more than a quarter didn’t know or thought that nothing needed to be done.

**Table 9.1 Possible Indicators of an Unused Well (based on AGWT, 2000)**

|   |
|---|
| Pipe sticking out of the ground   |
| Small buildings that may have been the well house                         |
| Depressions in the ground   |
| Presence of concrete pit – may be covered by lumber or metal              |
| Old windmill (windpump)   |
| Additions to home – may be constructed over well to protect from freezing |

## 9.1 Decommissioning Practices

Each site will have its own particular characteristics that must be considered when planning how to decommission a borehole or well. There are however a number of commonalities that must be addressed. When a well is decommissioned properly, it should no longer permit vertical movement of water through or surrounding the well. The area should be as structurally sound as adjacent land, removing any physical risk.

The Healthy Futures program subsidized 835 well decommissions over an 18 month period in 2002- 03. Many clients had more than one well on their property. One client had 8 wells decommissioned through this subsidy program. 102 decommissioning projects were audited under Healthy Futures auditing requirement (see Table 9.2). The average price for decommissioning drilled wells was \$1 667. Drilled wells appeared to be decommissioned properly in most of the wells audited. Of the drilled wells that were decommissioned, 64% were ranked as using best practices and only 4% presented major concerns. In general, contractors used bentonite to seal the well and followed regulatory requirements that are fairly specific on the appropriate protocols for decommissioning small diameter wells.

Large diameter wells were seen less frequently overall but were more concentrated in some parts of Ontario (ex. South - east, north). Well surveys have shown about 1/3 of the wells in Ontario are dug or bored (see Chapter 2). Of all projects funded through Healthy Futures, 20% were dug/bored wells and a small number of projects were drilled wells inside open dug wells. The average price for decommissioning a large diameter well was \$ 1,461, less than the average price for decommissioning a drilled well. Large diameter wells require a large amount of materials to properly seal them; however, many drilled wells required large quantities of materials also due to the depth of the wells.

The audit program found that the price for decommissioning large diameter wells varied significantly and very low prices often reflected a lack of expertise and the use of inappropriate materials. Many contractors demonstrated an understanding of the selection of materials and methodologies. There were however many examples of contractors who accepted a job, were licensed to perform the work, but clearly did not know what they were doing. Of the large diameter wells, 70% were ranked as using best practices and 23% of the projects presented major concerns to the auditors. Most contractors used bentonite or cement grout, but those working on projects ranked as major concern did not use appropriate sealants, but filled the well with backfill, soil or sand. One large diameter well was filled to the surface with bentonite. This is not recommended as the clay does not firm up enough for future use, creating an unstable area where even a child would sink into the clay. In one of the worst situations observed, the well contractor had filled the well with unclean soil that contained manure.

**Table 9.2 Number of Audited Decommissioning Projects by Well and Project Type**

|                       | <b>Decommission</b> | <b>Best Practices</b> | <b>Major Concern</b> | <b>Average Price</b> |
|-----------------------|---------------------|-----------------------|----------------------|----------------------|
| <b>Dug/<br/>Bored</b> | 47                  | 29                    | 10                   | \$1,461              |
| <b>Drilled</b>        | 55                  | 32                    | 2                    | \$1,667              |

Source: OFA (2004)

Unused wells are viewed differently by the client than their production well. Investing funds in upgrading a well in use is seen as protecting the client’s health, improving their situation and an enhancement to their property. Unused wells are not viewed as a pressing concern requiring immediate action. The price for decommissioning the well, even with the Healthy Futures subsidy may deter clients from proceeding. In addition, many farms and rural properties have more than one unused well and the priority to take action diminishes further. In a number of jurisdictions, the recognition of the risk presented by unused wells has prompted the development of programs providing 100% subsidy to clients.

In Ontario, only the City of Hamilton developed a “top-up” program that would allow the client to see a greater subsidy than the 64% offered by Healthy Futures. Other decommissioning funds existed at the time of this project, but restrictions did not permit a “top-up” to enhance the Healthy Futures subsidy. Future programs to assist well owners in decommissioning wells should consider a higher subsidy rate. The well owner’s assistance in locating and properly decommissioning these wells is required in order to protect the wells currently in use.

## **9.2 Decommissioning Requirements**

Well decommissioning must ensure that any contaminants present in the well are removed, and that the aquifer is left clean. The flow of water in the aquifer must not be impeded, but vertical flow of water and contaminants must be stopped entirely.

Ontario decommissioning standards stipulate the materials and techniques to properly plug and seal wells according to well diameter. Instructions in the revised regulation are more specific than in previous versions to ensure consistency across the Province.

In Ontario, wells being decommissioned must be disinfected, filled with clean gravel in the water bearing zone and then filled coincidentally where the bentonite is placed 30 cm above the fill. A well must be filled the full length with impervious material. That material must be introduced into the well at the bottom and placed progressively upward to ground surface. All casing should be cut off and capped below ground. Where a well tag is available, it must be buried with the well. A well record must be completed and a copy provided to the well owner, one copy filed by the contractor and one copy provided to the Ministry of the Environment.

There is no stipulation in the present decommissioning standard which requires either assessment or management of a leak in an annular seal for a well. There are several means by which to deal with this in practice; however, the practicality and affordability of these methods has not been explored.

In the past, many contractors used native soil or fill. The use of sand or gravel has the opposite effect of sealants. The sealants protect the well from developing short-cuts and reduces water flow from the surface. Where sand or gravel is used, the infiltration of water is enhanced and this could allow contaminants to travel into the aquifer.

A properly decommissioned well should be as secure as the surrounding land. There should be no need to make considerations for the location of the decommissioned well if it was done properly. To ensure this is consistent, a conscientious contractor needs to investigate the future use of the site and take this into consideration when decommissioning the well. For example, if a new subdivision is planned for the site, then there is a need to account for the depth of the basements. If the well is cut off 1.8 m below ground, the integrity of the seal could be compromised during future construction. In this circumstance, the wells should be cut off far enough below ground to ensure that the seal remains intact during future usage. If water and sewer lines are going in then the well must be cut off below the lowest excavation point.

Appendix E provides a list of resources describing best practices for decommissioning water wells.

### **9.2.1 Decommissioning Large Diameter Wells**

As with all decommissioning procedures, the first steps involve removing the pump, and any debris or excessive piping etc. from in and around the well. The well is then chlorinated. The concentration of chlorine in the water must be 50 mg/L for 12 hours minimum. The contractor will typically leave the chlorine in the well overnight and then pump out the well or at least the volume contained in the water bearing zone. Clean filter material (washed pea stone or washed brick sand) is put in the water bearing zone to ensure water flow is not affected in the aquifer. In large diameter wells, the thickness of aquifer needs to be determined as there is usually no well record to assist in determining this.

Generally, using the static water level and the full depth of the well as the estimated thickness of the aquifer errs on the side of caution, but where the static level is less than 3 m from the surface greater scrutiny is required. After the filter media is in place, 0.5 m of bentonite is placed in followed by a bentonite grout mixture to 1 m below grade. All wells must be capped below ground to enhance the security of the seal. If a cap is present, then it may be used for the decommissioning but if it doesn't exist, one must be brought in. The cap for a large diameter well is usually concrete and it can be lowered into the grout mix. More grout mix is poured over the cap. This ensures that if there is settlement in the column, then the cap is still present for safety. The area around the well is excavated with the cap on so that no debris is knocked into the well and then more grout and concrete are poured on top and around the well to ensure the entire well and annular space are sealed. The top 1-2 m is filled with soil - clay is ideal but native soil is acceptable.

The liners on large diameters tend to be either concrete tile, culvert, brick or field stones. Generally the top few concrete tiles are removed and the area around the well is excavated. This process is similar for brick liners – the top 2 m are excavated and removed. It is critical to excavate around the well casing after the cement grout has been brought to the desired cut off elevation to ensure that any voids or older casings are addressed during the decommissioning process. Stone lined wells may have up to 3 layers of stone composing the liner. To block vertical migration of water and contaminants through these stones, the contractor must ensure that the voids are filled. Contractors use cement grout and concrete vibrator to allow the grout to flow into locations in behind the stones. The level of grout will decrease as the grout fills in around the stones. The contractor would continue to top up the grout until it equilibrated and then the well would be capped and finished as described above.

Decommissioning a large diameter well generally is a two person job taking 8 – 12 hours. On the first day, debris is removed and water is chlorinated and the second day water is pumped out, filter media is placed in the well and the opening is sealed and covered. The typical cost for this work is \$3,000 – \$5,000 for a 9 m well. The materials alone may cost \$1,200 – \$1,500 for washed filter media, bentonite and grout mix, cap and fill.

Section 5.4.5 provides a comparison of decommissioning requirements and incentives in other jurisdictions

### **9.2.2 Decommissioning Drilled Wells**

The decommissioning process for smaller diameter wells is articulated clearly in Regulation 903. The Regulation states what materials to use, layering requirements, etc. The Healthy Futures audit process found the vast majority of small diameter wells were decommissioned according to the regulations and well records were filed.

One issue that may have been overlooked in decommissioning small diameter wells is the sealing of the annular space that may be left from the casing shoe. In many circumstances the annular space of older wells was never adequately sealed during the construction process. As a result, the annular space may remain open and other voids may exist surrounding the well casing. It is essential to excavate around the well casing at least 0.5 m from either surface or in the bottom of the well pit to reveal any voids or gaps that may be present.

In Ontario, there are two main types of drilled wells – drilled wells finished in overburden and drilled wells seated into bedrock. The decommissioning procedure is slightly different for each well type. For a bedrock well, only a small fraction of the well may be cased. The bedrock wells may also have several aquifers present throughout the rock. To ensure that the flow is not blocked in these aquifers, filter media is used to fill the bedrock portion of well right up into casing. If there is no well record, the casing depth can be determined by down hole camera or a well casing detector (Solinst model 501), or in some circumstances, the casing depth can be determined using a hook along the side of the casing to determine where the casing diameter narrows at the base.

The bedrock may present a number of challenges for infilling filter material. There may be voids in the formation which would require a larger filter media; however, the larger the media introduced, the more likely that bridging could occur. In a circumstance where there is significant fracturing of the upper bedrock, the contractor may choose to grout 13 – 15 m into the rock to seal off fractures that could transmit surface material through the well hole. Where there is no fracturing, the filter material is filled until the casing is reached. Bentonite and grout are layered on top of the filter material to the predetermined cut off elevation below surface where the casing is cut and capped. The area surrounding the well is excavated and a liquid grout mix is poured over the well to seal the cap and to ensure that any gaps in the annular space are filled during the decommissioning process. The remainder of the area is filled with native soil.

In an overburden well, the casing extends the entire depth of the well and the base of the well has a screen. To decommission this type of drilled well, the screened area is filled with filter media, the remainder of the well is filled with layers of sealants. The depth of the screen can be determined as the casing diameter narrows at the top of the screen where the K-packer is situated. If the well has a nominal screen, the diameter may not differ from the diameter of the casing. An L-hook can be used to determine where the screen is located because the hook will bounce off the perforations in the screen. In some circumstances, a down-hole camera may be needed if there are exceptional circumstances making determination of screen height challenging.

### **9.3 Difficult Cases**

#### **9.3.1 Well Pit Decommissioning**

A well pit is finished 1-2 m below ground. It can be lined with concrete tiles, poured concrete or field stones. The base of the pit is often poured concrete, but may also be native soil. The Healthy Futures auditing program identified a number of poorly addressed well pits. The well pit must be decommissioned both when the well is upgraded to a finish above grade or when it is decommissioned. Some contractors filled the entire pit with concrete grout, but many used 2 – 5 bags of bentonite to seal the base of the pit (or nothing at all) and then added some type of fill – often sand or gravel, to fill the remainder of the pit. In some cases, the pit was removed entirely, in other cases the concrete was left in place and in a few situations, the concrete was broken into fairly large pieces and buried beside the well. The presence of the concrete chunks adjacent to the well would allow voids to exist resulting in rapid infiltration of surface water and any materials carried in the water.

Regulation 903 does not permit well pits, or wells finished below grade. Conversion of these wells should ensure that the area immediately surrounding the well head is not going to pool surface water. In some audited projects, wet screening materials were observed in the well pit indicating that water was pooling at about the level where the casing was extended. This pooled water would age the well casing to a greater degree and the presence of this water adjacent to a point of weakness is not a best practice. The best option to retire the well pit is to remove the well pit entirely, or to fill it with impermeable materials such as cement grout or clay.

The area around the metal casing must be excavated down .3 - .6 m either by breaking the concrete bottom adjacent to the well or by digging out the dirt bottom. The pit structure should be removed during the decommissioning process. There may be an appearance of a seal at surface level because the soil is packed from traffic or because of the concrete, but the contractor needs to establish that the full annular space will be sealed with the pit. Excavating the base of the pit will ensure that if there are any voids in the annular space below the pit base, they would be sealed properly when the pit is decommissioned. If an open annular space is encountered, a very liquid media such as Portland cement mix should be used to ensure that the grout travels the full length of the gap and to avoid bridging.

### **9.3.2 Flowing Well**

A flowing or artesian well presents challenges for decommissioning. This type of well must be decommissioned or flow controlled at all times. The flowing well conditions create pressure that must be mitigated to allow the sealants time to accumulate and set to create counter pressure. In some situations the pressure is relatively manageable; in other circumstances a flowing well can be somewhat like a geyser creating very challenging and risky situations for the well contractor. The flow of the aquifer must be confined to the aquifer where it originated to avoid loss of water resources to other formations.

The two biggest risks from an artesian well are that the pressure from the well becomes sufficient to jack the casing out of the ground if shut off too quickly, and that the flow of water is so great and erosive that the area around the well settles and drops creating sinkholes. In many circumstances, the flowing well can be addressed by using a pump that is stronger than the natural flow of the well. In other situations, more mitigation is required.

In a drilled well, a K-packer can be used to control the flow of the water. The packer is put in with a regulatory device that would permit the flow of the well to be turned off slowly. The packer does this by expanding and sealing off the rock. It is essential to proceed slowly to determine if there is going to be a reaction. If there is a reaction, the contractor may need to put in a series of packers to control the pressure from the well. Once the packers are in place, grout is placed on top and the well is sealed as described above.

A large diameter flowing well presents a different situation as there is no device like the K-packer that could be used to regulate the flow of water. In this situation the contractor needs to create a situation where there is no flow either by pumping or raising casing to above static level. If the contractor chooses to pump down, a stronger pump than the existing flow must be used to remove the pressure the flowing water creates. Once the pump is mitigating the pressure, small filter media is put into the base of the well and the well is grouted with a heavy aggregate mixture. The aggregate mixture creates opposing pressure but the well must be pumped to remove the pressure while putting in the grout.

If the well is flowing strongly then the contractor might put in 1 cm diameter pea stone as the water will not move the pea stone. Once the pea stone is in place, the tremie pipe is lowered. The tremie pipe is fitted with a device (like a ball) that will cover the pipe and keep the water

from entering the pipe. Once the tremie pipe is in the desired location, the grout is pumped into the well. The pumping of the grout will pop the ball off the pipe and it will float to the top of the water.

Another option to address flowing large diameter wells is to add a few tiles to the top of the well to stop the flowing situation. Adding the tiles allows the water to stabilize at a static level higher than the ground surface and creates a stable situation where the water is not flowing. When the water is flowing, it will disrupt the grout causing the aggregate to separate from the cement and make it impossible to properly decommission the well. If the flow can be stopped, then the concrete will remain intact as it is pumped through the tremie pipe. The concrete grout displaces the water out of the new tiles put in for the procedure. The grout is brought to 1-2 m below ground and the concrete sets while some displaced water sits on top of the grout. This creates opposing pressure while the concrete sets. Once the concrete has set, the stacked tiles are removed and the area is infilled.

In exceptional circumstances, for a very significant flow in a large diameter well, where it is not possible to pump off, or build up the casing high enough, the contractor may need to drill another 15 cm relief well beside the large diameter. The well would be drilled into the same aquifer. This well would be pumped vigorously to create drawdown in the local aquifer. This would allow the large diameter well to be closed off. Once the large diameter well is properly decommissioned, the relief well would also be decommissioned. The relief well would be constructed with extra precautions to reduce any chance of the well casing being forced out of the ground by the pressure in the aquifer. Generally the casing is installed with wings, the casing is excavated around top, where a grout pad is poured to assist in anchoring the casing. Dirt is placed on top of the pad for added counter pressure to ensure the casing remains intact. The small diameter well would be slowly turned off using a packer or a flow control valve.

### **9.3.3 Well Containing Existing Material**

In many situations, the contractor will discover a well that requires proper decommissioning, yet previous attempts to fill the well are evident. Regulation 903 specifies that any equipment or debris in the well must be removed before decommissioning begins. If the dug or bored well is accessible, then a drill rig may be set up to draw debris drawn out of the well, including any well cuttings. If the well is inaccessible, then the contractor may have to set up an A frame, or tripod with pulley to remove debris or where really restricted, the debris would have to be removed by hand.

A situation arose recently in which a contractor discovered a large diameter well filled with field stones. This was in an area where there were no other wells relying on an aquifer so there was limited potential for contamination. Attempts to remove the large rocks using the excavator bucket were unsuccessful. The contractor would either need to remove each stone by hand or devise a way to reduce contamination and fill in gaps. In consultation with the Ministry of Environment the contractor opted for the latter. The well was chlorinated, then with use of a tremie pipe cement grout mixed with bentonite was pumped into the well and a concrete vibrator was used ensure the grout moved into all the cracks and crevices.

Another unique situation arose with one of the wells audited through the Healthy Futures program. This well was a large diameter well lined with fieldstones. The material in the well had settled 1 – 2 m in less than 1 year. Investigation showed that the well was filled with loosely packed soil. The well had to be properly decommissioned. The fill was removed, but the location of property was sufficiently remote that the fill was removed one pail at a time by hand by the contractors. Grass, twigs, roots and even horse manure was discovered in this fill. Large voids in the rock liner were also observed. After 5 days of removing fill, pumping and chlorinating the well water, the well was finally decommissioned properly. These examples show how challenging and time consuming it is to rectify improper decommissioning work and how each well is different and must be managed to address the specific problems at that location.

#### **9.3.4 Well with Hydrocarbon Contamination**

Wells need to be assessed to determine if there is any evidence of oil or spills or chemicals. Where there is contamination, most of the time there will be visual cues for example, the M-scope that is used to check static level may come back up with oily residue. In other situations, there may be staining on the casing or a blue tinge to the water when pumped off. Other cues could be odors, or the location of the well compared to adjacent properties i.e. gas station, fuel storage.

Wells cannot be chlorinated if petroleum products are present because the chlorine reacts with the hydrocarbons. The petroleum products and any bacteria present must be addressed before the well can be decommissioned. The Ministry of Environment and the Health Unit must be contacted. The MOE will provide a permit generation number to allow the spill to be pumped off.

A licensed waste management company must be involved to pump water from the well to a tank. The water is then taken away and the waste management company separates fuels from water. This needs to be done until the level of contaminant is not detectable. Samples must be taken to an accredited lab for analysis. Once the contaminant is not detectable, the health unit requires the water to be free of bacterial contamination. The well must be pumped until a sample meeting ODWS for bacteria is achieved.

The well can be decommissioned after it has been demonstrated that the standards have been met. After the well is filled, the area around the well must be excavated to ensure that the soil surrounding the well is not impacted. The Ministry of Environment then takes samples of the soil and inspects the site.

#### **9.4 Implications for Sustainability**

Proper closure of the well is key to the long term sustainability of the groundwater resource. Methods that block the vertical migration of water, but do not interfere with aquifer flow, are essential to protect the aquifer and any other well tapping into the same source.

Inspection and monitoring at this stage of the life cycle should be focused on addressing the plugging of “known” abandoned wells. Entice and educate well owners into coming forward to act on unused, deteriorated wells.

## **9.5 Conclusions**

1. There are more than 500,000 abandoned wells in the Province of Ontario; the location of which are largely unknown. The presence of these wells poses a risk to the quality of aquifers and drinking water supplies.
2. Identifying the location of abandoned wells has proven to be a difficult undertaking. Often the location of abandoned wells is known only to the homeowner or has been lost due to property transfer or loss of records.
3. The present regulations for well decommissioning in Reg. 903 for drilled, small diameter wells are well articulated, reasonable and generally adhered to in the field with the exception of the issues related to the integrity of annular seals.
4. Large diameter wells present a special infrastructure challenge due to their construction methods and materials and their generally shallow nature. These conditions pose a potentially high vulnerability to contamination.
5. Case study evidence indicates that well decommissioning can have site-specific requirements.

## **9.6 Recommendations**

1. The MOE should introduce legislation aimed at disclosing the status of all used and unused water wells by the owner at the sale or transfer of property where they are located. The disclosure records should include well performance and quality of all operating water wells and the status and condition of all unused wells. The new legislation should include a phase-in schedule to allow time for trained water-well service companies to develop across the Province.
2. There is a need for more comprehensive identification of existing water wells in Ontario. This can be accomplished either by enlisting the assistance of homeowners through an awareness campaign that provides guidance on how to locate old wells or through the development of tools that detect the void left by the well.
3. The Panel recommends that the Province partner with municipalities and other government agencies to develop a subsidy program that completely covers the cost of decommissioning unused or abandoned wells that may lie in sensitive areas. Criteria for identifying potentially high risk wells that qualify for fully funded decommissioning need to be established.
4. Well decommissioning should be coupled with the installation of a new well unless a specific exemption has been granted. (See also Recommendation 5.7)

5. Well contractors should be required to upgrade or decommission deficient wells that they work on. The role of the contractor should be to inform the client and MOE of the required work and if the client declines to pursue it, then the MOE should follow up with the well owner as the legislation states that the well owner has responsibility to maintain their well. A clarification bulletin should be sent out to all contractors to clarify their roles and responsibilities when wells are found to be deficient.
6. The Ontario Ground Water Association (OGWA) should play an outreach role (via newsletter) in disseminating case studies of difficult decommissions to promote greater awareness of best practices among contractors who undertake this work.
7. There is a need for research in the following areas:
  - i) identification of effective methods to decommission large diameter wells followed by outreach to contractors to ensure the consistent application of best practices in the field; and
  - ii) development of criteria for identifying areas in which the proper decommissioning of abandoned wells is highest priority.

## 9.7 References

Ontario Federation of Agriculture (OFA). 2004. Healthy Futures Auditing Report. Submitted to OMAF as part of funding report.

Regulation 903 – Wells.

## 10.0 Emerging Issues in Water Well Infrastructure Sustainability

The scope of present, emergent and future risks to Ontario's water well infrastructure and implications for their management is indeed broad. Based on the Panel's experience and expertise and perspective gained through consultations with members of the public, the municipal sector and well drillers, this Chapter identifies risks to water well infrastructure sustainability. Table 10.1 identifies these risks along with concise explanatory notes on each risk issue. The Panel felt that this approach would best serve the purpose of pointing out the linkages between various risk elements and their jurisdictional/regulatory aspects and provide insight as to the manner in which these risks are related to sustaining present and developing future water well infrastructure.

Risks to water well infrastructure are very closely tied to the various hydrogeological settings found in uniquely different geographical locations of Ontario as described in Chapter 3. Perhaps the greatest of these risks are those which may appear to be indirectly related to other developments, and thus may be less than obvious and managed in a reactive fashion. Some examples include the growing risk issues associated with waste disposal; transportation corridors; improperly abandoned test holes and wells; and population density increases (septic system, buried utilities and sewer lines). Changing land uses from historical agricultural to industrial and urban present further challenges as these require anticipating uncertain implications for our present and future groundwater infrastructure development. It is evident that well capture zones have the potential to transcend several different land uses and involve multiple jurisdictional and regulatory considerations.

The Panel's investigation indicates that private wells in Ontario are in various states of disrepair. They have not been maintained proactively; they have not been decommissioned properly; construction has not been monitored by inspectors; and water quality has not been tested. Therefore, identifying risks to the sustainability of water wells in Ontario at the time of writing this document is somewhat similar to conducting a scientific experiment without any control. The lack of structural integrity and lack of regular monitoring are critical underlying factors affecting the vulnerability of the well and the surrounding aquifer to existing and emerging threats. Chapter 4 discusses some of the existing risks to private wells in Ontario identified in previous surveys.

To properly and effectively manage emerging groundwater/well sustainability issues will require establishing comprehensive groundwater strategies with specific initiatives and mechanisms for cross-sector cooperation and collaboration on infrastructure issues. Urban, industrial, agricultural, academic and both government and non-government sectors are all unique contributors and essential members of Ontario's community of groundwater practice in this effort. Hydrogeological and geographic targeting would appear to be an important aspect of any approach taken.

**Table 10.1 Example of Key Issues Affecting Water Well Infrastructure Sustainability**

| Issue                                 | Elements  | Impact:<br>Well (W), Aquifer (A)<br>Distribution Pipe (P)  | Legislative<br>Management  | Recommendations   |
|---------------------------------------|---|--|--|---|
| <b>Road Salt</b>                      | <ul style="list-style-type: none"> <li>• Identified as a toxic substance (impact on aquatic organisms)</li> <li>• Sodium chloride elevated in many wells</li> <li>• Quantity used on Ontario roads in winter</li> </ul>     | <ul style="list-style-type: none"> <li>• Shallow wells (W) located near roads and parking lots</li> <li>• (A)</li> </ul>             | <ul style="list-style-type: none"> <li>• Canadian Environmental Protection Act (CEPA)</li> <li>• Ontario Drinking Water Standards (O. Reg. 169/03) for chloride and sodium (aesthetic objectives)</li> </ul>   | <ul style="list-style-type: none"> <li>• Best management practices for salt application</li> <li>• Management for sensitivity of shallow aquifers</li> </ul>  |
| <b>Oil and Gas Wells</b>              | <ul style="list-style-type: none"> <li>• Improper abandonment</li> <li>• Lack of knowledge of location of oil and gas wells</li> <li>• Lack of accountability for well ownership</li> </ul>                                 | <ul style="list-style-type: none"> <li>• All wells (W) located in proximity to oil and gas producing areas</li> <li>• (A)</li> </ul> | <ul style="list-style-type: none"> <li>• Environmental Protection Act, R.S.O. 1990 c. E.19</li> <li>• Water Resources Act, R.S.O. 1990, c. 0.40</li> <li>• Oil, Gas, and Salt Resources Act, 1997</li> <li>• Ministry of Natural Resources Guidelines</li> </ul> | <ul style="list-style-type: none"> <li>• Identification of areas sensitive to impact from abandoned oil and gas wells</li> <li>• Locate and properly decommission abandoned oil and gas wells</li> </ul>  |
| <b>Municipal wastewater/landfills</b> | <ul style="list-style-type: none"> <li>• Municipal sewage by-passes</li> <li>• Aging sewage and landfill infrastructure</li> <li>• Cost of upgrade</li> </ul>   | <ul style="list-style-type: none"> <li>• Shallow wells (W)</li> <li>• Unconfined aquifers (A)</li> <li>• (P)</li> </ul>              | <ul style="list-style-type: none"> <li>• Environmental Protection Act, R.S.O. 1990 c. E.19</li> <li>• Ontario Water Resources Act R.S.O. 1990, c. 0.40</li> </ul>  | <ul style="list-style-type: none"> <li>• Survey of impacts on water wells from aging sewage and landfill infrastructure</li> <li>• Research into methods for identification of infrastructure problems</li> <li>• Coordination of existing programs dealing with infrastructure issues</li> </ul> |
| <b>Industrial contamination</b>       | <ul style="list-style-type: none"> <li>• Toxic chemicals</li> <li>• Number and properties of chemicals present</li> <li>• Nonaqueous phase liquid (NAPL)</li> <li>• Lack of disclosure</li> <li>• Accountability</li> </ul> | <ul style="list-style-type: none"> <li>• All wells (W)</li> <li>• Unconfined and deep aquifers (A)</li> <li>• (P)</li> </ul>         | <ul style="list-style-type: none"> <li>• Environmental Protection Act – O. Reg. 153/04, Brownfields Statute Law Amendment Act, 2001</li> <li>• Environmental Protection Act, R.S.O. 1990 c. E.19</li> <li>• Water Resources Act, R.S.O. 1990, c. 0.40</li> </ul> | <ul style="list-style-type: none"> <li>• Research into methods for monitoring, assessment, risk management and remediation of NAPL sites</li> </ul>   |

| Issue                            | Elements  | Impact:<br>Well (W), Aquifer (A)<br>Distribution Pipe (P)  | Legislative<br>Management  | Recommendations   |
|----------------------------------|---|--|--|---|
| <b>Emerging chemical threats</b> | <ul style="list-style-type: none"> <li>Length of time to address problem</li> <li>Unknown fate/mobility/toxicity /interaction with other substances in the environment</li> </ul>   | <ul style="list-style-type: none"> <li>All wells (W)</li> <li>Unconfined and deep aquifers (A)</li> <li>(P)</li> </ul>                             | <ul style="list-style-type: none"> <li>Existing legislation may not apply</li> <li>Water Resources Act, R.S.O. 1990 c. 0.40</li> <li>Environmental Protection Act, R.S.O. 1990 c. E.19</li> </ul>  | <ul style="list-style-type: none"> <li>Diversion initiatives should be undertaken in an environmentally sound manner</li> <li>Governments should be proactive in identifying managing and responding to new and emerging chemical threats</li> <li>Legislative exemptions (i.e. to EPA) should only be given after extensive studies/field trials have conducted.</li> <li>Land-based disposal of products with no benefit to the land should be prohibited.</li> </ul> |
| <b>Agricultural Activity</b>     | <ul style="list-style-type: none"> <li>Farm industry is changing (demographics, economic strategies for growth, etc.)</li> <li>Loss of farm land in recharge areas</li> <li>Point and non point sources of contaminants on farms</li> </ul> | <ul style="list-style-type: none"> <li>Shallow wells (W)</li> <li>Unconfined aquifers (A)</li> </ul>   | <ul style="list-style-type: none"> <li>Nutrient Management Act, 2002, O. Reg. 267/03</li> <li>Proposed Source Protection Act</li> <li>Water Resources Act, R.S.O. 1990 c. 0.40</li> <li>Environmental Protection Act, R.S.O. 1990 c. E.19</li> </ul> | <ul style="list-style-type: none"> <li>Ontario should remain committed to ensuring effective implementation of Nutrient Management Act through close collaboration between the provincial Nutrient Management Advisory Committee and Federal government initiatives in support of a stronger, national Environmental Farm Plan program</li> </ul>   |
| <b>Septics</b>                   | <ul style="list-style-type: none"> <li>Poor maintenance and performance</li> <li>Density of septic systems in rural areas</li> <li>Age/condition</li> <li>Presence of pathogens</li> </ul>  | <ul style="list-style-type: none"> <li>Shallow unconfined wells, and poorly confined bedrock wells (W)</li> <li>Unconfined aquifers (A)</li> </ul> | <ul style="list-style-type: none"> <li>Water Resources Act, R.S.O. 1990 c. 0.40</li> <li>Environmental Protection Act, R.S.O. 1990 c. E.19</li> <li>Building Code, O. Reg. 403/97</li> </ul>   | <ul style="list-style-type: none"> <li>Amalgamate legislation which governs septic systems and wells</li> <li>Mandate septic system pumping and inspection</li> <li>Research on relationship between septic system and wells in densely populated areas</li> <li>User- friendly tools to assess septic system function</li> <li>Develop a site-specific approach</li> </ul>   |

| Issue                                   | Elements  | Impact:<br>Well (W), Aquifer (A)<br>Distribution Pipe (P)   | Legislative<br>Management   | Recommendations  |
|---|---|---|---|--|
| <b>Indigenous bacteria</b>              | <ul style="list-style-type: none"> <li>Biofouling of wells and pathogen survival in biofilms</li> <li>Health impact of natural bacteria</li> </ul>  | <ul style="list-style-type: none"> <li>Shallow, unconfined wells (W) and bedrock wells,</li> <li>Aquifers (A)</li> <li>(P)</li> </ul> | <ul style="list-style-type: none"> <li>Water Resources Act, R.S.O. 1990 c. 0.40</li> <li>Safe Drinking Water Act 2002, O. Reg. 170/03 Drinking Water Systems</li> <li>Drinking Water Source Protection Act</li> </ul>   | <ul style="list-style-type: none"> <li>Encourage proper well maintenance programs through outreach and education</li> <li>Research on: <ul style="list-style-type: none"> <li>i) antibiofouling mechanisms</li> <li>ii) geochemical conditions in biofilms</li> <li>iii) survival of organisms</li> <li>iv) health risk presented by naturally occurring bacteria</li> </ul> </li> </ul> |
| <b>Microbial and pathogen transport</b> | <ul style="list-style-type: none"> <li>Preferential flowpaths allow greater mobility</li> <li>Fate of pathogens in aquifers is difficult to model and quantitatively predict</li> <li>Human health is impacted</li> <li>New pathogen discovery</li> </ul>   | <ul style="list-style-type: none"> <li>Shallow, unconfined wells (W) and bedrock wells,</li> <li>Aquifers (A)</li> <li>(P)</li> </ul> | <ul style="list-style-type: none"> <li>Water Resources Act, R.S.O. 1990 c. 0.40</li> <li>Safe Drinking Water Act 2002, O. Reg. 170/03 Drinking Water Systems</li> <li>Drinking Water Source Protection Act</li> </ul>   | <ul style="list-style-type: none"> <li>Enforce proper well construction techniques</li> <li>Proactively survey wells in high risk areas</li> <li>Identify emerging pathogens</li> <li>Research on <ul style="list-style-type: none"> <li>i) prediction</li> <li>ii) monitoring</li> <li>iii) disinfection</li> <li>iv) source identification</li> </ul> </li> </ul>                      |
| <b>Urban growth</b>                     | <ul style="list-style-type: none"> <li>Competition for resources</li> <li>Impacts on recharge both positively and negatively</li> <li>Sustainable environmental development</li> <li>Aging infrastructure</li> <li>Upgrade and development costs</li> </ul> | <ul style="list-style-type: none"> <li>All wells (W)</li> <li>Unconfined and deep aquifers (A)</li> <li>(P)</li> </ul>                | <ul style="list-style-type: none"> <li>Municipal Act, 2001</li> <li>Planning Act, R.S.O., 1990</li> <li>Building code, O. Reg. 403/97</li> <li>Water Resources Act, R.S.O. 1990 c. 0.40</li> <li>Environmental Protection Act, R.S.O. 1990 c. E.19</li> <li>Drinking Water Source Protection Act</li> </ul> | <ul style="list-style-type: none"> <li>Develop a long-term water needs and management plan</li> <li>Identify the point at which a sustainable water supply is no longer possible</li> <li>Prioritize sensitive watersheds for proactive management</li> </ul>  |

| Issue                | Elements   | Impact:<br>Well (W), Aquifer (A)<br>Distribution Pipe (P)  | Legislative<br>Management   | Recommendations   |
|----------------------|--|--|---|---|
| <b>Water Takings</b> | <ul style="list-style-type: none"> <li>• Local water shortages</li> <li>• Adequacy of permit database to provide information on water usage</li> <li>• Consumptive use which potentially impacts watershed supply</li> </ul> | <ul style="list-style-type: none"> <li>• All wells, but particularly shallow wells and those within the zone of influence of permitted water taking (W)</li> </ul> | <ul style="list-style-type: none"> <li>• Permit To Take Water program</li> <li>• Water Taking and Transfer Regulations, O. Reg. 387/04</li> </ul> | <ul style="list-style-type: none"> <li>• Need for accurate, watershed scale water budgets</li> <li>• Need for decisions on allocation in times of shortage</li> <li>• Use of conservation measures</li> </ul> |

## **11.0 Review of the Water Well Infrastructure Think-Tank Process**

As part of the Sustainable Water Well Infrastructure Project, the “Think-Tank process” developed by CRESTech was undertaken in the spring and summer of 2002. The Think-Tank brought together stakeholders from industry, government and the academic community to discuss information gaps and technology needs around the issue of water well infrastructure. Through a highly interactive process involving participants who, for the most part, rarely have an opportunity to interact, collaborative R&D opportunities were identified and prioritized.

The first Think-Tank on sustainable water well infrastructure was held on June 14, 2002 at CANWELL 2002 at the Toronto International Centre. The meeting objective was “...to explore research solutions on water well rehabilitation and optimizing water well construction materials and methods.” The second Think-Tank was held on August 14, 2002. The key objective of this meeting was to present proposals to participants and other potential partners and investors and agree on proposals to go forward for CRESTech review and investment.

The Panel’s assignment was to evaluate the findings of the Think-Tank process in terms of their potential to address the most pressing needs, knowledge gaps and emerging issues for water well sustainability.

### **11.1 Think-Tank Process and Outcomes**

The Think-Tank process reverses the traditional lecture and debate meeting and instead engages stakeholders in a dialogue that involves research professors in listening while industry and government “problem-owners” define their information and technology needs. Information gaps and technology needs are prioritized at the first meeting through a “voting process”: to vote for a project means that you will devote your resources (cash, in-kind, laboratory, time, students, etc.) to the R&D problem.

Research teams and two champions (from the academic community and from industry/government) are identified during the first meeting. These champions present a “two-page” proposal at the second meeting to a group of potential investors. Once investors have committed resources, proposals are prepared for CRESTech, peer-reviewed using ProGrid™ and are subject to a stage-gate process culminating in a deployable technology.

Thirty-six (36) representatives from industry, government and the academic community attended the June 14, 2002 meeting. The agenda included:

- identification of “info-gaps” by Industry and Government
- definition of R&D list (Industry/ Government/ Academia)
- setting of priorities (Industry/ Government/ Academia)
- creation of research teams and Academia & Industry/ Government champions

- Two-page proposal template.

The meeting deliverables were:

- a prioritized list of research projects
- establishment of 1 – 3 research teams who would commit to develop a research proposal.

The research priorities, identified during the Think-Tank are summarized in Table 11.1 (in rank order, the number of votes are indicated):

**Table 11.1 Think-Tank Research Priorities**

| <b>Rank Order</b> | <b>Topic</b>   | <b>Number of votes</b> |
|-------------------|--|------------------------|
| 1                 | Communications: public perception (reality vs. fiction), education and public educational models | 15                     |
| 2                 | Well Infrastructure Characterization and Assessment  | 14                     |
| 3                 | Microbial pathogens: transport pathways of water-borne disease                                   | 13                     |
| 4                 | Cost Effective Well Decommissioning and Abandonment Methods                                      | 10                     |
| 4                 | Well Monitoring Systems: tracer techniques, sensor development, etc                              | 10                     |
| 4                 | Well Maintenance and Rehabilitation Techniques   | 10                     |
| 5                 | Well Construction Materials and Methods: casing, screen, grout, etc.                             | 9                      |
| 6                 | Model Wellhead Protection Plan   | 4                      |
| 7                 | Energy Storage in Aquifers   | 3                      |
| 8                 | Microbes in Wells  | 0                      |
| 8                 | Data Management Models   | 0                      |
| 8                 | Well Monitoring and Testing (measurement indicators and standards)                               | 0                      |

It was agreed that communication was a priority; however, MOE indicated that current initiatives were addressing some of the gaps in this area. Further discussion, including what would attract CRESTech investment<sup>2</sup>, lead to the development of four research teams focused on the following research priorities.

<sup>2</sup> CRESTech asked the participants to consider whether the research would advance science/engineering, enlarge the pool of highly qualified personnel (graduate students), contribute to technology development, lead to technology transfer, deal with market factors, involve a problem owner (industry/government partner), lead to IP and involve a technology receptor.

- a) **Microbiological and Chemical Issues.** This includes operation and maintenance applications such as improved monitoring to better understand interactions between pathogens, nutrients and chemicals and impacts on the well system and human health; evaluation of existing and novel physical chemical methods of preventing and controlling fouling; strategies for remediation and reclamation of a well system; development of laboratory-based methods to employ in the field; and development of strategies and monitoring programs for abandonment and decommissioning.
- b) **Well Construction and Decommissioning Technology.** This includes the evaluation of materials for construction and decommissioning; and the development of low cost tools and protocols for construction, retrofitting, rehabilitating and prioritizing the decommissioning of wells.
- c) **Data Management Tools.** This includes the development of software tools for the collection, analysis and sharing of data on existing infrastructure.
- d) **Applied Research in Water Well Education.** This includes efforts to increase awareness among well owners and the public of well maintenance

The four teams prepared to present their research ideas at the second Think-Tank meeting held on August 14, 2002. The meeting involved 20 participants; the deliverables were two-fold:

- 1 – 3 quality research proposals and
- a commitment to prepare a detailed proposal for CRESTech review and investment.

The dialogue at this meeting lead to the development and submission of two quality proposals:

1. *“Ecology of the water well environment: well-screen interface”*, lead by Dr. Steven Liss, Ryerson University. Expected outcomes: (a) knowledge for the management of microbial processes in wells, including specific information on: microbial transport, pathogen survival, and interaction with natural and fouling films at the well screen; and (b) a “tool kit” to assess, track and minimize microbial transport into drinking water wells. Project Partners: Ontario Federation of Agriculture, Burnside Environmental, W.B. Beatty & Assoc. Ltd., and Malroz Engineering Ltd. Total Investment: \$1.15 M over 3 years.
2. *“Scientific development of devices to curtail bacterial movement into an aquifer along the axis of a water well”*, lead by Brian Gerry, Sir Sandford Fleming College. Expected outcomes: a well head protection device. Potential Partners: Terrafix, Ministry of Environment.

Following a peer review, CRES Tech has supported the Liss project. The Gerry proposal continues to seek partner support.

## **11.2 Panel Assessment**

The Panel considers the Think-Tank exercise to be valuable as it identified through a multistakeholder collaborative process, the critical need for communication, education and well infrastructure characterization to enhance water well infrastructure sustainability. These research priorities were also deemed critical by the Panel through the course of their deliberation.

The Panel also identified issues such as enforcement, well drilling industry issues, and consumer practices. The research needs identified through the Think-Tank process were all progressive; however, appear to be based on an assumption that diligence and best practices are currently the norm in the field. Clearly this was not always the case.

The first identified priority issue of communication is important given the critical role of the well owner in protecting well water sustainability. Although there were 36 participants, only one proposal of several became a fully supported project. The reasons for this may include institutional culture; interest and commitment of partners; timing (i.e. duration required for proposal development); and the constraints related to the eventual expenditure of funding.

At the time of writing this report, many of the initiatives undertaken by the Ministry were no longer funded.

## **11.3 Recommendations**

1. The number one priority identified in the Think-Tank exercise, namely education and communication, needs to have long term sustainable funding and effective partnerships. Results from the evaluation of the Well Aware program indicate that this program was very effective in increasing knowledge of the average private well owner.
2. It is critical for future progress on water well sustainability, to assemble the necessary research teams to investigate the priority areas identified in the Think-Tank exercise.

## 12.0 Conclusions and Recommendations

The task of the Expert Panel was to investigate the state of water wells in Ontario and determine the prognosis for improving well longevity. The Terms of Reference identified three principal objectives for the Panel: 1) to produce a “state of knowledge” document on Ontario’s water well infrastructure; 2) to identify emerging threats to water well infrastructure and assess Ontario’s ability to mitigate these; and 3) to provide peer review of the findings of two “Think-Tanks” conducted previously on the topic. This final chapter summarizes the conclusions and recommendations resulting from the Panel’s assessment and deliberations. The Panel identified 10 of the 43 recommendations as critical for promoting water wells sustainability in Ontario. These key recommendations are illustrated in Figure 12.1 and are indicated in bold font within the complete list below.

The text within ovals in the diagram identify influencing factors in water well management including training, monitoring and enforcement, consumer activities, consumer education, data management and legislative tools. Recommended initiatives to address each of these factors are also identified. The diagram shows influencing factors and tools at particular stages of the well life cycle where they may have an impact; however, in many cases the effects will span several phases of the life cycle.



Figure 12.1 Summary of Key Recommendations for Water Well Sustainability

## **Chapter 2: Life Cycle of a Well**

### **Conclusions**

1. Management of private water wells is usually not carried out in a proactive manner, due to limited operator knowledge, and an “install and forget” attitude among well owners. This attitude is reinforced by a non user-friendly well design.
2. Municipal wells are generally much better managed, although the longevity of these wells may also be at risk in some cases. Municipal wells are usually tested for chemical or biological parameters and yield on a relatively regular basis.
3. The present condition, age and life expectancy of private wells remains largely unknown as are the reasons for well failure.
4. The Panel recognizes that there is significant investment in water well infrastructure in Ontario. Sustainable asset management (SAM) is recognized as a possible means to protect this significant investment. The effort involved to investigate this approach in more detail was beyond the resources of the Panel.

### **Recommendations**

1. Collaborative research is required into the development of user-friendly well designs for new installations and retrofits on existing wells.
2. Continuing effort must be directed toward understanding water well infrastructure and how to extend well life and enable wells to function safely and reliably in their respective aquifer environments.
3. A technical consumer’s guide for private well owners should be developed to focus on improving technical knowledge of well construction and maintenance.
4. The Panel recommends that SAM (sustainable asset management) be investigated more thoroughly as a potentially cost-effective approach to extending the sustainability of private water wells. Therefore there is a requirement for data gathering that will support SAM. In addition, an affordable service program that provides for routine well maintenance should be set up similar to those available for furnaces or air conditioning systems.

## Chapter 3: Groundwater Resources in Ontario

### Conclusions

1. Diverse geological and climatic conditions in Ontario require a variety of approaches to well design, location, and construction. This presents unique challenges for well life cycle management.
2. Generally there is an abundant supply of groundwater in most parts of Ontario, however local shortages are likely to become more common due to demographic and environmental factors.
3. Competition for local groundwater constraints requires proactive groundwater management strategies.
4. The Panel commends the MOE for the development of the Provincial Groundwater Monitoring Network.
5. The Panel recognizes the significant expenditure of government funding in the development of groundwater studies across the Province. These documents currently exist as stand alone reports based on a common technical terms of reference.
6. At present there is no comprehensive description of natural groundwater quality. The Panel recognizes that the MOE has taken initial steps to address this issue by developing the Provincial Groundwater Monitoring Network.

### Recommendations

1. The Panel strongly encourages MOE to undertake integration (including province-wide maps of aquifers and municipal wellhead protection zones) of their groundwater study results.
2. The Provincial Groundwater Monitoring Network should be expanded to include more wells in sensitive and highly productive aquifers.
3. **The MOE should make available to the public a comprehensive, user-friendly, interactive groundwater website containing information such as results of comprehensive groundwater studies; water taking; groundwater monitoring network data; Water Well records data; and Ministry of Health and Long Term Care well water quality data.**
4. The Panel recommends that full water budgets be completed for all watersheds in Ontario in order to guide evidence-based decision-making on water taking and water allocation. The budget should include rates of recharge; water that is consumed versus water that is returned within the watershed; timing of water migration through the watershed; and the water needs of the entire community.

This is consistent with a sustainable asset management approach and will enhance water well sustainability in Ontario.

## **Chapter 4: Present Status of Water Quality in Wells in Ontario**

### **Conclusions**

1. The state of water quality in private wells in Ontario has not been surveyed comprehensively since the early 1990s.
2. Surveys of private wells in Ontario (i.e. the 1991-92 OFGWQ survey) have found bacteria and nitrate to be the most common contaminants in drinking water. Pesticides and industrial contaminants have been found to a much lesser degree.
3. Surveys have found that the geological setting, location, construction and maintenance of wells are the predominant factors associated with bacterial contamination.

### **Recommendations**

1. **A comprehensive province-wide survey of water quality in all private wells should be undertaken immediately. This should include all unregulated wells including rural wells, cottage wells, and private wells in urban areas in addition to farm wells. This survey should be repeated at least every ten years, allowing for ample time between surveys to investigate trends and findings in more detail.**
2. The Panel recommends that guidance be provided to homeowners to promote testing for more parameters than bacteria.
3. The availability of cost-effective bacterial and pathogen sampling and analysis tools for private well owners should be promoted through awareness raising initiatives.

## **Chapter 5: Regulatory Framework in Ontario and Other Jurisdictions**

### **Conclusions**

1. Ontario's Regulation 903 is well-written and comprehensive in addressing private wells, adding clarification to ensure proper construction, sealants and decommissioning techniques and materials are used, while allowing for some flexibility. Ontario does not have specific water testing requirements in the legislation but has encouraged water testing through a complimentary service offered through MOH.
2. The Panel believes that bacterial testing of private wells by well owners is presently inadequate.

3. Based on interviews with stakeholders, well inspection and enforcement of Reg. 903 is presently inadequate.
4. There has been a significant improvement in legislation addressing the construction and operation of municipal wells. The Panel considers the current level of inspection and enforcement to be rigorous.
5. The Ministry of Environment has collected groundwater data for a number of years through the Drinking Water Surveillance program, the Water Well Information System and the Groundwater Monitoring Network. This data remains difficult to access by the groundwater stakeholder community and therefore is a barrier to proper resource/infrastructure management.
6. The Panel recognizes that new privacy laws have impacted the ability of private well owners and practitioners to identify the location of wells. This may lead to safety issues if existing wells cannot be found.

### **Recommendations**

1. The Panel recommends that the process of collecting, compiling and disseminating the Water Well records data be more transparent and accessible to the groundwater stakeholder community (See also Recommendation 3.3).
2. **To build upon MOE's source protection and water taking permit initiatives, a stakeholder group should be established immediately to explore alternatives for managing the Water Well database. This stakeholder group should report to the Minister within 12 months of its formation.**
3. Ontario should clearly set out water quality testing requirements for private water wells. At a minimum bacterial content, nitrate, fluoride, iron, hardness, and turbidity should be measured immediately following new well construction. For this testing requirement to be implemented successfully, the testing must be legislated.
4. **Mandatory membership in an accredited professional groundwater association should be required for all workers engaged in water well activities. This action is needed to facilitate the transfer of knowledge from those on the cutting edge to the broader water well industry and to ensure that a highly skilled workforce is sustained throughout the Province.**
5. **To ensure due diligence and compliance with Reg. 903, a third party organization should be engaged to develop an outreach and education program for the drilling industry.**
6. **To support the objectives of Reg. 903, enforcement of the regulation should be provided by a third party organization who has qualified, experienced staff that are knowledgeable about the water well industry.**
7. The Panel recommends that the decommissioning requirements of Reg. 903 be strengthened by compelling more formal linkages between replacement well construction and decommissioning of the existing wells.

8. The Panel recommends that the Water Well record for decommissioning should state the reason for well closure (See also Recommendation 2.4).

## **Chapter 6: Evolving and Other Important Legislation Affecting Water Well Infrastructure Sustainability**

### **Conclusions**

1. Source protection is the first line of defense in any municipal water works. The Panel recognizes that the Watershed Based Source Protection Planning Technical Experts Committee (TEC) established by the MOE has undertaken a commendable effort in establishing a blueprint for source protection planning in Ontario. These efforts are focused primarily on municipal level wells.
2. Different types of aquifers may require different wellhead protection zones. In some cases, vulnerable aquifers have been chosen over equally accessible secure aquifers.
3. The Source Protection TEC identified wells as pathways for contaminants and a direct threat to municipal water supplies.
4. There are several recommendations that have implications for private water supplies in the Source Protection report. Although private wells are not the focus of the report, the TEC and this Panel agree that these pose a risk to the aquifer and well owners if poorly constructed or maintained. TEC Recommendation 123 suggested use of source protection planning committees to develop and implement “private well programs”.
5. The Nutrient Management Act is evolving towards a risk-based approach to align with source based protection planning.
6. Amendments to Ontario Water Resources Act (Water Taking and Transfer) will provide for more rigorous assessment and documentation of the impact of water taking on Ontario watersheds. This approach will lead to more sustainable management of the water supply.

### **Recommendations**

1. New and evolving water resources legislation should be developed with science-based arguments such as risk-based approaches.
2. Where a jurisdiction chooses to locate a municipal well in a more vulnerable location, the responsibility to protect these supplies should lie with the public consuming the water and not unduly penalize those within the wellhead protection zone.
3. Source protection for private wells should be managed through existing partnerships. The partnership established between the OGWA, APGO and Green Communities should expand and continue existing education and

outreach programs that are proven to be effective such as Well Aware, Well Inspection and Well Discovery (see Recommendation 8.1).

4. Continued funding for well upgrades and decommissioning subsidy programs should be secured by either MOE or OMAF (see Recommendation 8.2).
5. The MOE also needs to ensure coordination and communication with all their programs and related programs from other Ministries i.e. integration of the source protection planning program.

## **Chapter 7: Location and Construction of Wells**

### **Conclusions**

1. Locating domestic water supplies is often based on practical considerations rather than on science-based best practice. Field studies conducted in Ontario have confirmed that this has resulted in well construction in inappropriate locations.
2. The Panel recognizes that the setback distances for potential contaminants provided in Reg. 903 are not adequate for all hydrogeological settings.
3. Large diameter wells are more vulnerable to contamination as it is difficult to achieve a permanent water-tight casing and cap.
4. Inappropriate alterations to well settings (i.e. wishing wells) that lead to lack of compliance with Reg. 903 can influence water quality.

### **Recommendations**

1. Guidelines for well location and construction should incorporate information regarding topography of the property, any structural problems that may be present due to the soil type or geology, and where possible, the local flow of groundwater should be known before a well is drilled. Wells should be positioned so that they are not located down-gradient from any pollutants.
2. Wells must be constructed to prevent contamination at all times. It is much more straightforward to use appropriate sealants during construction than to excavate and clean up a well once contamination is found.
3. Outreach, inspection and enforcement efforts should be aimed at ensuring that large diameter wells are constructed to reduce the potential points of entry. More research is needed to ensure that the best materials are being used in construction and to ensure that large diameter wells can also achieve a vermin-proof status.
4. The link between sustainability and construction materials and methods needs to be more fully explored. The Panel recommends that an investigation be facilitated by the MOE on what direction might be best to pursue a collaborative research/development process.

## Chapter 8: Operation and Maintenance of Wells

### Conclusions

1. The Panel applauds the educational initiatives undertaken by the Ontario government. This appears to be the most efficient means to promote Water Well Sustainability. The Panel recognizes that continued funding for these initiatives in 2005 has not been forthcoming.
2. Many wells in Ontario require rehabilitation and upgrading and costs to well owners associated with undertaking repair work are often a barrier. Continued funding for well rehabilitation is a critical step in addressing deficient private wells. The Healthy Futures Upgrade and Decommissioning program was successful in improving the water quality of wells in Ontario and raising awareness among well owners of well stewardship issues and the importance of well repair and rehabilitation in enhancing well security.
3. The demand for qualified contractors to carry out well rehabilitation and maintenance work in Ontario exceeds the current supply. In addition, there appears to be a lack of adherence to best practice among some contractors who are currently carrying out this work
4. Field investigations have shown that best practices (e.g. annular fill around casing extensions) are not always followed. The requirements for upgrades are not clearly stated in Reg. 903.
5. Water well biofouling is a prevalent and universal problem that is not clearly understood and managed by water well owners, despite the availability of new diagnostic knowledge and rehabilitative technology. Changes in specific capacity and water quality characteristics are signals that preventative and/or rehabilitative action should be taken – preferably before production loss is greater than 25 percent.

### Recommendations

1. **The Well Aware program, a provincial government funded province-wide effort to educate rural residents about well safety, is an effective tool for promoting well stewardship and should receive continued funding and support. Indeed, consideration should be given to expansion of this program into additional Ontario communities.**
2. **The Ontario government should continue to fund a subsidy program similar or equivalent to the Ontario Ministry of Agriculture and Food (OMAF) Healthy Futures Upgrade and Decommissioning program. The Panel recommends that such programs provide greater than two-thirds cost-sharing and include an educational component.**

3. **The Ontario government should support and fund a new sustainable asset management training program at Sir Sanford Fleming College. The program should focus on the practices, tools and techniques necessary to develop life-cycle management strategies that will sustain the water well infrastructure in Ontario, and beyond. The program would spawn a badly needed service industry aimed at maintaining, rehabilitating and decommissioning water wells. The new industry would meet the growing needs of the millions of Ontarians who rely on high quality groundwater supplies.**
4. The Panel recommends that a proper well upgrade should include the following:
  - excavation around the well tiles,
  - replacement of damaged tiles,
  - application of non-toxic sealant between joints and tiles,
  - application of grout on the interior of the joint, and
  - use of impermeable materials on the exterior of the well.
5. Research is required in the following areas:
  - development of well designs that incorporate construction materials able to withstand treatment chemical applications and allow for well maintenance, rehabilitation and/or treatment without well disassembly (See also Recommendation 2.1),
  - development, evaluation and pilot testing of cost-effective treatments for wells that are able to safely and effectively serve as biocides to counter-act biofouling, as well as remove incrustative minerals from within water wells,
  - assessment of the role and properties of biofilm growth and biofouling in water wells,
  - development of reliable water sampling protocols for pathogens and for effective well disinfection, and
  - development of a decision-making tool that will provide clarification to determine when efforts should be placed on well upgrading versus replacement.
6. A knowledge/research network should evolve in Ontario similar to the Agriculture and Agri-Food Canada (AAFC) Sustainable Water Well Initiative (SWWI) to promote knowledge exchange, the development of extension

materials, and sharing of research efforts on ways to diagnose and treat well problems. The network should also focus on sharing information on new technologies for maintaining and rehabilitating water wells. A website dedicated to sharing existing and future technology developments with water well stakeholders should be developed.

## **Chapter 9: Decommissioning and Abandonment**

### **Conclusions**

1. There are more than 500,000 abandoned wells in the Province of Ontario; the location of which are largely unknown. The presence of these wells poses a risk to the quality of aquifers and drinking water supplies.
2. Identifying the location of abandoned wells has proven to be a difficult undertaking. Often the location of abandoned wells is known only to the homeowner or has been lost due to property transfer or loss of records.
3. The present regulations for well decommissioning in Reg. 903 for drilled, small diameter wells are well articulated, reasonable and generally adhered to in the field with the exception of the issues related to the integrity of annular seals.
4. Large diameter wells present a special infrastructure challenge due to their construction methods and materials and their generally shallow nature. These conditions pose a potentially high vulnerability to contamination.
5. Case study evidence indicates that well decommissioning can have site-specific requirements.

### **Recommendations**

1. **The MOE should introduce legislation aimed at disclosing the status of all used and unused water wells by the owner at the sale or transfer of property where they are located. The disclosure records should include well performance and quality of all operating water wells and the status and condition of all unused wells. The new legislation should include a phase-in schedule to allow time for trained water-well service companies to develop across the Province.**
2. There is a need for more comprehensive identification of existing water wells in Ontario. This can be accomplished either by enlisting the assistance of homeowners through an awareness campaign that provides guidance on how to locate old wells or through the development of tools that detect the void left by the well.

3. The Panel recommends that the province partner with municipalities and other government agencies to develop a subsidy program that completely covers the cost of decommissioning unused or abandoned wells that may lie in sensitive areas. Criteria for identifying potentially high risk wells that qualify for fully funded decommissioning need to be established.
4. Well decommissioning should be coupled with the installation of a new well unless a specific exemption has been granted. (See also Recommendation 5.7).
5. Well contractors should be required to upgrade or decommission deficient wells that they work on. The role of the contractor should be to inform the client and MOE of the required work and if the client declines to pursue it, then the MOE should follow up with the well owner as the legislation states that the well owner has responsibility to maintain their well. A clarification bulletin should be sent out to all contractors to clarify their roles and responsibilities when wells are found to be deficient.
6. The Ontario Ground Water Association (OGWA) should play an outreach role (via newsletter) in disseminating case studies of difficult decommissions to promote greater awareness of best practices among contractors who undertake this work.
7. There is a need for research in the following areas:
  - i) identification of effective methods to decommission large diameter wells followed by outreach to contractors to ensure the consistent application of best practices in the field; and
  - ii) development of criteria for identifying areas in which the proper decommissioning of abandoned wells is highest priority.

## **Chapter 10: Emerging Issues in Water Well Infrastructure Sustainability**

### **Conclusions**

1. Private wells in Ontario are in various states of disrepair. They have not been maintained proactively, they have not been decommissioned properly, construction has not been monitored by inspectors; and water quality has not been tested. Therefore, identifying risks to the sustainability of water wells in Ontario at the time of writing this document is somewhat similar to conducting a scientific experiment without any control. The lack of structural integrity and lack of regular monitoring are critical underlying factors affecting the vulnerability of the well and the surrounding aquifer to existing and emerging threats.
2. Risks to water well infrastructure are very closely tied to the various hydrogeological settings found in uniquely different geographical locations of Ontario. Perhaps the greatest of these risks are those which may appear to be

indirectly related to other developments, and thus may be less than obvious and managed in a reactive fashion. Some examples include the growing risk issues associated with waste disposal, transportation corridors, improperly abandoned test holes and wells, and population density increases (septic system, buried utilities and sewer lines).

### **Recommendations**

1. To properly and effectively manage emerging groundwater/well sustainability issues will require establishing comprehensive groundwater strategies with specific initiatives and mechanisms for cross-sector cooperation and collaboration on infrastructure issues. Urban, industrial, agricultural, academic and both government and non-government sectors are all unique contributors and essential members of Ontario's community of groundwater practice in this effort. Hydrogeological and geographic targeting would appear to be an important aspect of any approach taken.

## **Chapter 11: Review of the Water Well Infrastructure Think-Tank Process**

### **Conclusions**

1. The Panel considers the Think-Tank exercise to be valuable as it identified through a multistakeholder collaborative process, the critical need for communication, education and well infrastructure characterization to enhance water well infrastructure sustainability. These research priorities were also deemed critical by the Panel through the course of their deliberation.
2. The first identified priority issue of communication is important given the critical role of the well owner in protecting well water sustainability. Although there were 36 participants, by 2005 only one proposal of several became a fully supported project.

### **Recommendations**

1. The number one priority identified in the Think-Tank exercise, namely education and communication, needs to have long term sustainable funding and effective partnerships. Results from the evaluation of the Well Aware program indicate that this program was very effective in increasing knowledge of the average private well owner.
2. It is critical for future progress on water well sustainability, to assemble the necessary research teams to investigate the priority areas identified in the Think-Tank exercise.





## Sustainable Water Well Infrastructure

### Expert Panel

### Terms of Reference

#### Objectives

Sustaining water well environments is critical for more than three million Ontarians who depend on private and municipals wells to draw groundwater as their primary water source. As part of Operation Clean Water, the Ontario Ministry of Environment (MOE) launched the Sustainable Water Well Infrastructure (SWWI) Project in 2002 to investigate, plan and execute innovative approaches to well maintenance and monitoring in order to extend the integrity of water well infrastructure in Ontario. Collaboration with OCE-CRESTech has resulted in a) the establishment of a project Advisory Committee, b) the development of a Well Tag System for the Province (designed by Waterloo Hydrogeologic Inc.), and c) the identification of high-priority water well infrastructure research projects through a university/government/industry Think-Tank Process. Building on these initiatives, a five (5) member interdisciplinary Expert Panel will be convened. The panel's assignment will be:

- 1. To produce a “state of knowledge” document on Ontario’s water well infrastructure, including the identification of knowledge gaps and opportunities to improve water well infrastructure in Ontario.**

As illustrated in Figure 1, Infrastructure includes the full life cycle of a well including construction, operation and maintenance, and abandonment/decommissioning. The review will provide insight into the relationship between the distribution of water well infrastructure, the patterns of groundwater development, the major physical geographical influences and any patterns or trends of groundwater reliance in areas of drought/low water in the Province. Issues to be considered by the Panel may include, but will not be limited to the following:

- a) What is known about the location, status and condition of water wells and aquifer vulnerability in Ontario? What well siting and well design characteristics influence the vulnerability of wells? What are the expected future demands for groundwater in Ontario (considering urbanization, human and livestock population trends, and technological advances, i.e. in well construction and maintenance?)

- b) What innovations or best management practices are available to improve and extend the integrity of water wells (including proper well siting, well construction, preventive maintenance, rehabilitation, and monitoring techniques)?
- c) What parameters or indicators can be used to characterize and monitor well infrastructure in Ontario? What needs to be done in terms of data collection and the development of new technology for data management?
- d) Should the Sustainable Asset Management (SAM) approach be used to support water well infrastructure decisions in Ontario? What has been learned from various jurisdictions concerning the benefits and barriers associated with the implementation of this approach?
- e) What is known about abandoned wells (i.e. both those that are decommissioned and those not decommissioned) in Ontario and their associated risks?

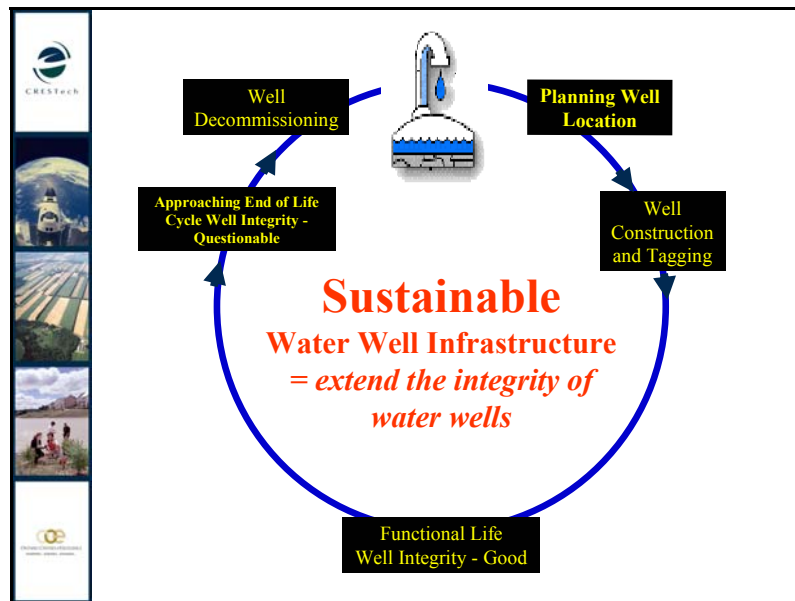


Figure 1: Life Cycle of a Water Well

**2. To identify emerging threats to well water sustainability and assess Ontario's capacity to mitigate these threats.**

Issues to be considered by the Panel may include, but will not be limited to the following (in no particular order):

- a) Pathways of contaminant movement through natural systems, including chemical and microbial interactions around the well, impacts of well construction on contaminant and microbial movement, and the extent of water well deterioration caused by microbiological activity.
- b) Impact of de-icing compounds on well infrastructure.
- c) Impact of biofouling on water well deterioration.
- d) Management of chlorine resistant microbes.
- e) Vulnerability of wells to climate change (higher temperatures, reduced rainfall, more frequent extreme weather, etc.).
- f) Cumulative impact of groundwater withdrawals on aquifers in Ontario.
- g) Effects of urbanization (building over recharge areas, population density, waste disposal, etc.).

|  |
|--|
| <p><b>3. To provide peer review of the findings of the Think-Tank Process.</b></p> |
|--|

The Water Well Infrastructure Think-Tank identified the following four priority areas of research. The Panel will evaluate the above research themes in terms of their potential to address the most pressing needs, knowledge gaps and emerging issues for water well sustainability identified in Tasks 1 and 2.

- a) **Microbiological and Chemical Issues.** This includes operation and maintenance applications such as improved monitoring to better understand interactions between pathogens, nutrients and chemicals and impacts on the well system and human health; evaluation of existing and novel physical chemical methods of preventing and controlling fouling; strategies for remediation and reclamation of a well system, development of laboratory-based methods to employ in the field, and development of strategies and monitoring programs for abandonment and decommissioning.
- b) **Well Construction and Decommissioning Technology.** This includes the evaluation of materials for construction and decommissioning; the development of low cost tools and protocols for construction, retrofitting, rehabilitating and prioritizing the decommissioning of wells.
- c) **Data Management Tools.** This includes the development of software tools for the collection, analysis and sharing of data on existing infrastructure.

- d) **Applied Research in Water Well Education.** This includes efforts to increase awareness among well owners and the public of well maintenance and risks to wells and to evaluate the effectiveness of existing education initiatives.

## Panel Process

The process will be consistent with the Expert Panel Manual of Procedural Guidelines developed by the Royal Society of Canada (RSC, 1998) ([http://www.rsc.ca/english/expert\\_manual\\_intro.html](http://www.rsc.ca/english/expert_manual_intro.html)). The following groups will have specified roles and responsibilities, in keeping with these guidelines:

The **Advisory Committee** will, among other tasks:

- Prepare the Terms of Reference for the work of the expert panel.
- Recruit expert panel members.
- Assist the expert panel in gaining agreement on the Terms of Reference.
- OCE-CREStech will provide logistical, administrative, and contractual support to the Expert Panel process, including the support of a technical writer.

The **Expert Panel** will:

- Follow the statement of work to which it has agreed.
- Hold a public meeting at the beginning of its deliberations.
- Present the results of its deliberations at a public meeting to be held at the Latornell Symposium on Thursday November 13, 2003.
- Deliver its observations and suggestions as per the established terms and timeframe.

Recognizing that the integrity and credibility of the Expert Panel, its composition, terms of reference and processes, are vital to the success of the expert review, the Advisory Committee is committed to ensuring that the Expert Panel and process be:

- Objective and independent.
- Unbiased and free of conflict of interest, real or perceived.
- Supported by proper structures and procedures consistent with established standards for such process.

## APPENDIX B: LIST OF PANEL CONSULTATIONS

### Public Forums (public feedback was encouraged)

Grand River Conservation Authority Water Forum - Sept. 12, 2003.

A.D. Latornell Conservation Symposium - Nov. 12-14, 2003.

Ontario Ground Water Association Annual Meeting - April 26-27, 2004.

The following individuals and groups provided input:

### Ontario Ministry of the Environment

Dr. David Neufeld, Manager Land Use Policy Branch/Water Policy Branch, Ontario Ministry of the Environment (Sept. 12, 2003; Jan. 23, 2004)

Deborah Brooker, Land Use Policy Branch/Water Policy Branch, Ontario Ministry of the Environment (Jan, 23, 2004)

Barbara Anderson, Senior Analyst, Land and Water Policy Branch, Ontario Ministry of the Environment (Sept. 12, 2003)

Deborah Conrod, Manager, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment (Sept. 12, 2003)

Ed Piche, Environmental Monitoring and Reporting Branch (Dec. 9, 2003)

Kim Yee, Environmental Monitoring and Reporting Branch (Dec. 9, 2003)

Fred Fleischer, Environmental Monitoring and Reporting Branch (Dec. 9, 2003)

Rachel Meltzer, Environmental Monitoring and Reporting Branch (Dec. 9, 2003)

### Drillers

Bill Davidson, President, Davidson Drilling Limited (Sept. 13, 2003)

Simon Smith, S.D. Smith Drilling Co. Limited (Sept. 13, 2003)

### Municipalities

Michael L. Murray, Commissioner of Transportation and Environmental Services, Region of Waterloo (Sept 13, 2003)

Eric Hodgins, Manager Water Resources Protection, Department of Region of Waterloo (Sept. 13, 2003)

Brian Stratton, City of Ottawa (Oct. 7, 2003)

Dave Belanger, Water Supply Program Manager, City of Guelph

### Conservation Authorities

Steve Holysh, Halton Region Conservation Authority (Oct. 7, 2003)

Asher Rizvi, Rideau Valley Conservation Authority (Oct. 7, 2003)

Rob Passmore, Rideau Valley Conservation Authority (Oct. 7, 2003)

### Consultants

Paul Martin, Waterloo Hydrogeologic Inc. (Sept. 24, 2003 by teleconference)

Tony Lotimer, Lotowater Inc. (Sept. 22, 2004 by teleconference)

Applegate Groundwater Consultants

### Other Groups

Wilmot Township Environmental Advisory Committee

Sustainable Peterborough, Environmental Committee for Federation of Ontario Cottagers' Association

The Canadian Geotechnical Society

Ontario Federation of Agriculture

## APPENDIX C: Source Protection Examples

The New York City Watershed, Oxford County groundwater protection program and the Region of Waterloo's protection program were all considered by the Advisory committee as examples to draw from. These programs all have strong science-based approaches to defining risk and potential mitigation and have taken a partnership rather than an enforcement type approach to addressing the problems. Aspects of two of these programs are described below.

### **New York City Watershed Agreement**

The Catskills and Delaware watershed cover 1900 square miles and supplies the city of New York with their drinking water. In 1989, EPA's Surface Water Treatment Rule (SWTR), issued under the federal Safe Drinking Water Act, required filtration of all surface water supplies (rivers and lakes) to protect against microbial contamination of drinking water. This requirement can be waived if a water system's treatment processes and natural conditions provide safe water and if the watershed is actively protected to ensure that safety in the future. Under the SWTR's authority, EPA has worked with New York City, New York State, and local communities on a program to implement this watershed protection requirement in the Catskill/Delaware watersheds.

The City of New York avoided a multi-billion dollar bill for a new filtration plant by investing money in improvements upstream – upgrading wastewater facilities, land acquisition, increase water quality monitoring, facilitating implementation of best management practices on farms upstream.

The New York City Watershed Agricultural Program is a voluntary watershed protection program funded by the New York City Department of Environmental Protection and administered by a farmer-led Watershed Agricultural Council. The dual goals of the Program are to protect New York City's water supply from potential agricultural pollutants, as well as enhancing the economic competitiveness and viability of farms within New York City's water supply watersheds.

Together, farmers and agency staff develop individual Whole Farm Plans which contain recommendations for management practices on the farm to prevent pollution without harming the farm business.

The Catskill Mountain portion of the watershed houses 300 dairy farms. The Whole Farm Planning process takes into consideration the priority pollutants within the watershed as well as the objectives and goals of the farmer. Pollutants from those farms include phosphorous and nitrogen from manure in barns, barnyards and fields, manmade fertilizers and soil sediment eroding off fields, petroleum fuels, and water-borne pathogens. Through the Watershed Planning Teams, cooperating farmers receive both small stipends and 100% financial support for implementing recommended changes.

Early in the Program, WRI introduced the concept of instituting multiple barriers to water pollution on farms. The three barriers are source, field, and stream margin. The

source barrier attempts to eliminate or minimize pollution at its source. For example, improved housing for calves not only leads to healthier animals with less risk of carrying pathogens, it reduces the risk of those pathogens travelling to and polluting the water supply. The landscape barrier, the second on-farm barrier, attempts to prevent or limit pollutants and minimize transport once a pollutant is released. A diversion ditch moves runoff away from pathogen-laden barnyard areas before running into a stream. The stream margin barrier is the final on-farm defense. A protected crossing such as a bridge is a simple example. It prevents cattle from walking in the stream and delivering pathogens directly into the watercourse. The Whole Farm Planning Teams select management practices within each barrier to provide protection to adjacent water courses.

This voluntary project started with 10 pilot farms and is now includes the majority of farms in the watershed. The budget for this program exceeds \$35 million and has a primary goal of the protection of drinking water quality.

### **Region of Waterloo: The Partners in Nitrogen Use Efficiency (PINUE)**

In the Region of Waterloo a unique approach has been taken to address non-point source pollution that resulted in elevated nitrate in municipal drinking water supplies. The objective was to reduce this non-point source nitrate from entering the groundwater by having local farmers adopt Best Management Practices that aim to maximize nitrogen use efficiency. This project started 6 years ago and has had students, technicians and professors from the Universities of Guelph and Waterloo, extension work through OMAF, coordination through OFEC, and funding from a number of sources with the main funding agencies being AAC, NSWCP and Region of Waterloo.

The idea behind this project is to look at impacting the farm-scale operation to provide an improvement in the local groundwater. The 5 farms in this project are 2 dairy, 1 swine, 1 beef and 1 cash cropper. The project helps farmers evaluate and adopt field and manure management BMP's.

A biophysical approach was taken to determine where the most nitrogen is lost. Everything that comes onto the farm is monitored as a nitrogen input and everything leaving the farms is monitored as an output and the efficiency is calculated as a percentage. With a few exceptions the inputs and outputs are measured and analysed for nitrogen content. For example to determine the amount of nitrogen in the feed, the feed bags are analysed – not just one or two, the purchasing records assessed and this is done every year. Nitrogen content is assessed for all inputs and outputs where possible and for some a book value is used to calculate the amount of nitrogen available. This is done for each farm, it has been done every year for the full 6 years. The first three years looked at the normal farm practices and had a lot of methodology development and kinks to work out because of the use of production farms with a need to not compromise their livelihood unnecessarily.

For the field BMP's nutrient management software program (N-MAN) was used to determine a recommended rate of nitrogen application for the given crop with the

consideration of the nitrogen content in the manure application. The first year this software was used, there was doubt from the farmers that their yields would not be impacted. The first year test strips with 0 N, the NMP rate and the normal rate were grown and the yields determined. The second year – the software had proven itself so well that all but a test strip of the normal rate had the NMP recommended rate of N application. At the end of the season, as the crop was being harvested, researchers would weigh the yields and also assess the quality of the crop and then take samples to determine nitrogen content. Yields were determined using weigh wagons, grab samples and comparing different experimental treatments.

Soil tests show that where the NMP recommended rate is used, there is much less nitrogen in the soil test – less available to move into groundwater. There was no difference in yield between the farmers normal application rate and the NMP rate. As a result, less fertilizer needs to be purchased and this results in a cost-savings to the farmer – in some cases the savings was over \$3 000/year.

Another aspect of PINUE is to address manure management issues. The impact of unlined manure piles has been debated. To address this issue, OMAF developed a field experiment to look at run-off and leaching potential from manure piles. They set up 5 manure piles, 2 lined, 2 unlined and 1 covered. 10 – 12 tons of solid manure and simulated rainfall. After 2 – 10 minutes of rainfall simulation, quite a significant amount of leaching was found. The leachate had high levels of nitrate, bacteria and phosphorous.

On a different farm, the farmer had a clay lined lagoon that had intermittent overflows. University of Waterloo installed a treatment system to handle this overflow. The system has a pump but mainly operates by gravity. It moves through a pre-filter system, then through the nitrogen and phosphorous treatment phases. The system was installed in 1 week and was fully functional within 2 weeks. It was functional most of the year, but may need some modifications for 100% of the year. The cost of the system was \$9000. When the material goes into this treatment system it has high levels of ammonia, nitrate, phosphorous, bacteria, and high BOD. The system removes almost all these concerns. With less than 1 mg of phosphorous, nitrate BOD and low levels of bacteria. Geophysical investigation confirmed the impact of the frequent overflow and showed the attenuation of this impact with the installation of the treatment system.

## APPENDIX D: WELL DRILLING PROCEDURE

### Overview of Well Drilling Procedure

Soil is logged during the drilling process, the change in soil material can be noted by the pressure required for drilling through a particular formation and the material observed in the drill cuttings and samples are taken.

Depending on the drilling method, the cable tool driller will know when a good water supply has been reached by noticing a change in the consistency of the cuttings or a change in the water level and cuttings. The driller will measure the volume and bail the water down and test the recovery. The air rotary driller will be blowing out with air and when water is hit, it will be blown out of the hole. The well is blown dry and recovery tested to assess if an adequate supply has been reached. Mud rotary and reverse circulation drillers use a bentonite slurry to sustain the drill hole. This method requires greater attention to the cuttings and the viscosity of the mud. Boring machines allow a visual assessment of the water in the well and the recovery rate can be monitored.

In general, boreholes should be completed as far as possible into aquifers to ensure a good yield. Once an adequate supply of suitable quality has been found, the well must be developed to remove cuttings, bring the well to a sand-free state, and stabilize the aquifer. The time required for development depends on the nature of the water bearing layer, the thickness of screen slots relative to aquifer particle size, the amount of material rinsed from the well prior to placing the filter pack, and the type of equipment and degree of development desired. Large amounts of development energy are required to remove drilling fluid containing clay additives (Driscoll, 1986); well development may be completed in 1 hour, but up to 10 hours may be required (Brush, 197?). Development is accomplished by causing the water to alternately flow into and out of the well. During inflow some small particles will be carried into the well through the screen, but other small particles will bridge between particles too large to pass through the screen. The reversal of flow will dislodge such particles and give them the opportunity to pass through the screen during the next period of inflow. The fine material entering the well is ultimately removed with the water. Removal of the fine material during development, in addition to increasing the capacity of the well, saves the pump from abrasion.

A newer development technique used in bedrock aquifers is hydrofracturing. This method causes pressure to build, splitting the seams in rock to allow in more water. It not only increases the size of the cracks and crevices present in the aquifer, but may also clean out or allow these fractures to become interconnected allowing greater water flow in the formation. This technique uses high pressure and works best in very hard granite formations. A packer is placed in the hole, water pressure build, the packer locks into rock and pressure goes into rock making small seams larger. This may be a poor technique if there are nearby wells in the same aquifer and in some cases the well

fracturing may redirect water that was originally feeding the well, thus reducing the water supply.

Once the well is developed, the well yield is tested using an M-scope. The well is pumped and recovery rate observed. When the well is completed the well is chlorinated, a well tag is attached, GPS locations are taken and all pertinent data is entered into the well record. Three copies of the well record are produced with one copy sent to the MOE, one retained and filed with the driller and a copy provided to the homeowner.

The well tag was introduced in August 2003 with the revised regulation 903. All new wells must have a tag permanently affixed to the well, preferably with a strapping device. This tag displays the well's alpha numeric identifying code and helps link the well's physical structure with the documentation filed with the Ministry of Environment.

### **References**

- Brush, R. 1979. Wells Construction: Hand Dug and Hand Drilled, US Peace Corps, Washington DC.
- Driscoll, F. 1986. Groundwater and Wells, St. Paul: Johnson Division

## APPENDIX E RESOURCES ON BEST PRACTICE FOR WATER WELL DECOMMISSIONING

<http://ianrpubs.unl.edu/water/g1471.htm>

### **Decommissioning Water Wells: An Owner's Guide (Nebraska)**

Includes basic techniques and background information as well as an outline of Nebraska's legislation and regulations for decommissioning.

[http://www.dcnr.state.pa.us/topogeo/groundwater/Well\\_Abandonment\\_Guidelines.PDF](http://www.dcnr.state.pa.us/topogeo/groundwater/Well_Abandonment_Guidelines.PDF)

### **Water-Well Abandonment Guidelines (Pennsylvania Dept. of Conservation and Natural Resources)**

A detailed description of well abandonment techniques, description of materials, summary of procedures, as well as a brief outline of legislation, regulations and standards.

[http://www.dec.state.ny.us/website/dow/well\\_decommish.pdf](http://www.dec.state.ny.us/website/dow/well_decommish.pdf)

### **Water Supply Well Decommissioning Recommendations (Dept. of Env. Conservation, New York)**

General recommendations as to procedure.

<http://www.deq.state.or.us/wmc/tank/documents/monwell.pdf>

### **Groundwater Monitoring Well Drilling, Construction and Decommissioning (Department of Environmental Quality, Oregon)**

Very detailed description of techniques and specifications for decommissioning (including diagrams). I'm not sure if this is the type of well that you are looking for though.

[http://www.environment-agency.gov.uk/commondata/105385/decommissioning\\_boreholes.pdf](http://www.environment-agency.gov.uk/commondata/105385/decommissioning_boreholes.pdf)

### **Decommissioning Redundant Boreholes and Wells (UK National Groundwater and Contaminated Land Centre)**

Seems to be fairly good and detailed information about decommissioning techniques, explanation of science behind the matter, and some legal framework.

<http://www.lapublichealth.org/eh/docs/ehmtruralwellreq.pdf>

### **Requirements for Well Construction/Decommissioning (California Bureau of Environmental Protection)**

Brief description of required techniques.

[http://www.geoexchange.org/regulations/pages/states/or/or\\_wells.html](http://www.geoexchange.org/regulations/pages/states/or/or_wells.html)

### **Oregon Water Well Standards**

A technical and detailed outline of State regulations.

### **Plugging Abandoned Water Wells (Mississippi State University)**

Good description of abandonment technique. Includes a chart on the amount of fill material and chlorine needed for various diameter wells.

<http://www.centalsupplyinc.com/statenh/ws-1-10.htm>

### **Well Abandonment and Decommissioning (New Hampshire)**

Well decommissioning procedure, necessary materials, etc.

[http://www.agr.gc.ca/pfra/water/wells\\_e.htm](http://www.agr.gc.ca/pfra/water/wells_e.htm)

**Water Well Abandonment and Decommissioning (Agriculture and Agri-Food Canada)**

. <http://www.gov.on.ca/OMAFRA/english/environment/water/publications.htm#Recommended>

**Recommended Methods for Plugging Abandoned Water Wells (OMAF)**

Summarized requirements under Regulation 903 and procedure for abandoning wells.

<http://www.ghiaa.net/15-WATERWELL/15-water-well.htm>

**How to Safely Seal Old Wells (American Groundwater Trust)**

Various articles on techniques, procedures, reasons for and indications of abandonment.

[http://www.hingham-ma.com/html/well\\_regulations.html#DeCom](http://www.hingham-ma.com/html/well_regulations.html#DeCom)

**Well Regulations (Hingham, Massachusetts)**

Outlines town's water supply regulations; a fair amount of information regarding decommissioning.

General introduction regarding the importance of abandoning unused wells, procedures, materials, etc.

**American Ground Water Trust** in *THE AMERICAN WELL OWNER*, 2000, Number 1

## APPENDIX F GLOSSARY<sup>3</sup>

- annular space** - open space between the casing and the side of a well and includes space between overlapping casings within the well
- aquifer** - a waterbearing formation that is capable of transmitting potable water in sufficient quantities to serve as a source of water supply
- aquitard** - a geological formation that prevents the significant flow of water, e.g., clay layers or tight deposits of shale
- baseflow** - the groundwater contributions to a stream or river
- bedrock** - the solid rock underlying unconsolidated material such as sand, gravel or clay
- bentonite** - commercially produced sealing material to be used in well construction or abandonment that, (a) consists of more than 50 per cent sodium montmorillonite by weight, (b) has the ability to swell in the presence of water, (c) does not provide nutrients for bacteria, and (d) does not impair the quality of water with which it comes in contact
- biofouling** - water well deterioration caused by microbiological activity
- bored wells** - A well that is excavated by means of a soil auger (hand or power) as distinguished from a well which is drilled, driven, dug, or jetted
- casing** - pipe, tubing or other material installed in a well to support its sides
- consumptive use** - water abstracted which is no longer available for use
- denitrification** - the conversion of nitrate in soils and sediments by either biological or chemical mechanisms
- discharge** - when groundwater empties into surface water or the ground surface
- dug well** - large-diameter, shallow, wells often constructed by hand
- evapotranspiration** - the transformation of water (liquid) from both the earth's surface (evaporation) and from the surfaces of plants (transpiration) to the atmosphere
- flowing well** - a well that has a static water level above the surface of the adjacent ground, causing the well to flow
- formation** - bedrock (e.g., granite) or overburden deposits (e.g., sands and gravels) with pores containing water and air
- fracture** - breaks in rocks or soil due to folding or faulting
- hole stabilizer** - may be a steel casing, a concrete tile, or an open hole in solid bedrock
- infiltration** - movement of water from the earth's surface into formations
- jetting** - propulsion of water under high pressure into sandy aquifers to create a hole for a well point
- Karst topography** - water moving through fractures in limestone has dissolved the rock, enlarging fractures and creating caverns
- overburden** - the loose soil, clay, silt, sand, gravel or other unconsolidated material overlying the bedrock, whether transported or formed in place
- pathogen** - an agent that causes disease, especially a living microorganism such as a bacterium or fungus
- permeability** - the property of porous rock, sediment, or soil for transmitting a fluid: it is a measure of the relative ease of fluid flow under an energy gradient
- pitless adapter** - device designed to replace the need for well pits and pumphouses — usually a metallic (brass) fitting that is attached to the casing below the frost line to connect the in-well water line to the buried water line leading to point of use
- plume** - a trail of dissolved contaminants in groundwater issuing from a contaminant source and spreading out as the trail travels in the direction of groundwater flow
- pore** - small openings filled with air or water
- porosity** - the amount of pore space in a formation

---

<sup>3</sup> Source: Agriculture and Agri-Food Canada. Ontario Ministry of Environment. 2003. Water Wells. Best Management Practices. Revised Edition 2003.

**private wells** – for the purpose of this report the Panel defines these as all non-municipal water supply wells e.g. residential, institutional, and industrial wells

**pumping water level** - the water level in a well being pumped

**recharge** - replacement of moving aquifer water with water infiltrating from the surface and percolating through unsaturated formations to the water table

**recharge area** - area of land beneath which there is a measurable downward driving force below the water table: rolling or steep land-forms with coarse-textured deposits (e.g., sand plains, end moraines) are particularly important recharge areas because of their high vertical flow rates

**saturated** - pores filled with water

**shock chlorination** - involves adding a large amount of chlorine to the water in the well and pumping it through the system: the chlorinated water is left in the system long enough to ensure complete disinfection

**specific capacity** - result of dividing the pumping rate by the drawdown

**spring** - discharge area where groundwater moves from a shallow aquifer to the surface or surface waters: wetlands, ponds, lakes, streams and rivers can be wholly, or in part, spring-fed

**static water level** - the level in a well attained by water at equilibrium in a well when no water is being taken from the well

**unsaturated** - pores containing air or a mixture of air and water

**water cycle** - continuous movement of water from the atmosphere to the earth's surface (precipitation), through (infiltration, percolation) formations to aquifers (recharge), back to the earth's surface (discharge, capillary rise, plant uptake) and to the atmosphere (evaporation, transpiration, evapotranspiration)

**water table** - depth below which all the pores are saturated

**well** - a hole made in the ground to locate or to obtain groundwater from an aquifer, and includes a spring around or in which works are made or equipment is installed for collection of water and that is or is likely to be used as a source of water for human consumption

**well screen** - slotted or perforated cylinder that is attached to the bottom of the solid casing of a drilled well to keep formation particles out and let water in

## APPENDIX G ACRONYMS

|             |   |
|-------------|---|
| AAFC- PFRA  | Agriculture and Agri-food Canada - Prairie Farm Rehabilitation Administration               |
| AAFC-OMAFRA | Agriculture and Agri-food Canada – Ontario Ministry of Agriculture, Foods and Rural Affairs |
| ADM         | Assistant Deputy Minister   |
| APGO        | Association of Professional Geoscientists of Ontario  |
| BMP         | Best Management Practice  |
| BART        | Biological Activity Reaction Test   |
| BOD         | Biological Oxygen Demand  |
| CEPA        | Canadian Environmental Protection Act   |
| CRESTech    | Centre for Research in Earth and Space Technology   |
| EAA         | Environmental Assessment Act  |
| EBR         | Environmental Bill of Rights  |
| EMRB        | Environmental Monitoring and Reporting Branch   |
| EPA         | Environmental Protection Act  |
| GPS         | Global Positioning System   |
| GUDI        | Groundwater Under Direct Influence  |
| GSA         | Guided Self Assessments (Well Aware Program)  |
| IMAC        | Interim Maximum Acceptable Concentration  |
| IRB         | Iron Related bacteria   |
| ISI         | Intrinsic Susceptibility Index  |
| MDH         | Minnesota Department of Health  |
| MOH         | Ministry of Health and Long Term Care (Ontario)   |
| MOE         | Ministry of Environment (Ontario)   |
| NMP         | Nutrient Management Plans   |
| OCE         | Ontario Centres of Excellence   |
| ODWO        | Ontario Drinking Water Objectives   |
| OMAF        | Ontario Ministry of Agriculture and Food  |
| OFGWQ       | Ontario Farm Groundwater Quality survey   |
| OGWA        | Ontario Ground Water Association  |
| OSTAR       | Ontario Small Town and Rural Development Infrastructure Program                             |
| OWRA        | Ontario Water Resources Act   |
| PEO         | Professional Engineers of Ontario   |
| PTTW        | Permit To Take Water  |
| PINUE       | Partners in Nitrogen Use Efficiency   |
| PDWO        | Provincial Drinking Water Objectives  |
| SRB         | Sulphate Reducing Bacteria  |
| SWTR        | Surface Water Treatment Rule  |
| SWWI        | Sustainable Water Well Infrastructure   |
| US EPA      | United States Environmental Protection Agency   |
| WHPA        | Wellhead Protection Area  |

**APPENDIX H Ontario Water Resources Act  
Loi sur les ressources en eau de l'Ontario**

**R.R.O. 1990, REGULATION 903**

*Amended to O. Reg. 128/03*

**WELLS**

**Notice of Currency:**\* This document is up to date.

\*This notice is usually current to within two business days of accessing this document. For more current amendment information, see the [Table of Regulations \(Legislative History\)](#).

*This Regulation is made in English only.*

[SKIP TABLE OF CONTENTS](#)

**CONTENTS**

|   | Sections |
|---|----------|
| <a href="#">DEFINITIONS</a>                             | 1        |
| <a href="#">SHALLOW WORKS</a>                           | 1.1      |
| <a href="#">WELL CONTRACTOR LICENCE</a>                 | 2-4      |
| <a href="#">WELL TECHNICIAN LICENCE</a>                 | 5-7      |
| <a href="#">EXAMINATION</a>                             | 8        |
| <a href="#">CONTINUING EDUCATION - WELL TECHNICIANS</a> | 8.1      |
| <a href="#">ASSISTANT WELL TECHNICIAN</a>               | 9-10     |
| <a href="#">CONSTRUCTION REQUIREMENTS</a>               | 11       |
| <a href="#">WELL CLUSTERS</a>                           | 11.1     |
| <a href="#">LOCATION OF WELLS</a>                       | 12       |
| <a href="#">CASING</a>                                  | 13       |
| <a href="#">ANNULAR SPACE</a>                           | 14       |
| <a href="#">DISINFECTION</a>                            | 15       |
| <a href="#">APPLICATION</a>                             | 16       |
| <a href="#">PUMP INSTALLATION</a>                       | 17       |
| <a href="#">VENTING</a>                                 | 18       |
| <a href="#">TESTING OF WELL YIELD</a>                   | 19       |

|  |    |
|--|----|
| <a href="#">WELL MAINTENANCE</a>       | 20 |
| <a href="#">ABANDONMENT</a>            | 21 |
| <a href="#">PROTECTION OF WELL TAG</a> | 22 |

## DEFINITIONS

### 1. In this Regulation,

- "air vent" means an outlet at the upper end of the casing that allows for equalization of air pressure between the inside of the casing and the atmosphere and for the release of gases from the well;
- "annular space" means an open space between a casing and the side of a well, and includes space between overlapping casings within the well;
- "aquifer" means a water-bearing formation that is capable of transmitting water in sufficient quantities to serve as a source of water supply;
- "assistant well technician" means a person who works at the construction of wells as an employee or agent of the holder of a well contractor licence under the supervision of the holder of a well technician licence;
- "ASTM" means ASTM International;
- "AWWA" means the American Water Works Association;
- "bedrock" means the solid rock underlying unconsolidated material such as sand, gravel and clay;
- "bentonite" means a commercially produced sealing material to be used in well construction or abandonment that,
- consists of more than 50 per cent sodium montmorillonite by weight,
  - has the ability to swell in the presence of water,
  - does not provide nutrients for bacteria, and
  - does not impair the quality of water with which it comes in contact;
- "casing" means pipe, tubing or other material installed in a well to support its sides;
- "dewatering well" means a well that is not used or intended for use as a source of water for agriculture or human consumption and that is made,
- to lower or control the level of ground water in the area of the well, or
  - to remove materials that may be in the ground water;
- "flowing well" means a well that has a static water level above the ground surface;
- "mineralized water" means water containing in excess of 6,000 milligrams per litre total dissolved solids or 500 milligrams per litre chlorides or 500 milligrams per litre sulphates;
- "overburden" means unconsolidated material overlying bedrock;
- "sealant" means,
- a slurry consisting of clean water and at least 20 per cent bentonite solids, or

- (b) other material that is equivalent to a slurry described in clause (a) with respect to the ability to form a permanent watertight barrier;
- "static water level" means the level attained by water at equilibrium in a well when no water is being taken from the well;
- "subsurface formation" includes an aquifer;
- "suitable sealant" means a sealant that is compatible with the quality of the water found in the well;
- "test hole" means a well that,
- (a) is made to test or to obtain information in respect of ground water or an aquifer, and
  - (b) is not used or intended for use as a source of water for agriculture or human consumption;
- "tremie pipe" means a pipe or tube with an inner diameter that is at least three times the diameter of the largest particle of material to pass through it and that is used to conduct material to the bottom of a hole, including a hole containing standing water;
- "well owner" means the owner of land upon which a well is situated and includes a tenant or lessee of the land and a person who enters into a contract to have a well constructed;
- "well record" means a form supplied by the Ministry for recording information about a well during construction or abandonment of the well. R.R.O. 1990, **Reg. 903**, s. 1; O. Reg. 128/03, s. 1.

#### SHALLOW WORKS

**1.1** (1) A test hole or dewatering well that is made to a depth of not more than 3.0 metres below the ground surface is exempt from sections 36 to 50 of the Act and from this Regulation, unless,

- (a) it is constructed in a contaminated area;
- (b) it is constructed in an area with conditions likely to result in flowing wells; or
- (c) it penetrates through a formation that is not an aquifer. O. Reg. 128/03, s. 2.

(2) Despite subsection (1), a person who constructs a test hole or dewatering well described in that subsection shall ensure that the major horizons of soil are excavated separately, stored separately, kept free from contamination and backfilled in the same relative positions that they originally occupied. O. Reg. 128/03, s. 2.

(3) If it becomes apparent during construction, use or abandonment of a test hole or dewatering well that subsection (1) does not apply, the person who caused it to be constructed shall, unless subsection (4) applies, retain the services of the holder of a well contractor licence. O. Reg. 128/03, s. 2.

(4) If construction of a test hole or dewatering well is complete, the well owner has assumed control over the operation of the test hole or dewatering well, and it becomes apparent during use or abandonment of the test hole or dewatering well that subsection (1) does not apply, the well owner shall retain the services of the holder of a well contractor licence. O. Reg. 128/03, s. 2.

(5) The holder of a well contractor licence who is retained under subsection (3) or (4) shall ensure compliance with the Act, this Regulation and the *Environmental Protection Act*. O. Reg. 128/03, s. 2.

(6) Subsections (3) and (4) do not apply if the person who would otherwise be required to retain the services of the holder of a well contractor licence has an employee who is the holder of a well technician licence and who ensures compliance with the Act, this Regulation and the Environmental Protection Act. O. Reg. 128/03, s. 2.

#### WELL CONTRACTOR LICENCE

2. (1) An application for issuance of a well contractor licence shall be on a form supplied by the Ministry and shall be submitted along with the required fee. O. Reg. 128/03, s. 3.

(2) An application for renewal of a well contractor licence shall be on a form supplied by the Ministry and shall be submitted along with the required fee. O. Reg. 128/03, s. 3.

(3) If the applicant is a corporation or partnership, the application shall be completed and signed by the official representatives referred to in paragraph 1 of section 4. O. Reg. 128/03, s. 3.

3. (1) It is a requirement that an applicant for a well contractor licence or renewal thereof or, where the applicant is a partnership or a corporation, a partner or director thereof, be eighteen years of age or older. R.R.O. 1990, **Reg. 903**, s. 3 (1).

(2) An applicant for a well contractor licence or renewal thereof shall submit such information and material as the Director may reasonably require to satisfy the Director as to the character, qualifications and financial responsibility of the applicant or its directors and officers. R.R.O. 1990, **Reg. 903**, s. 3 (2).

(3) Every holder of a well contractor licence shall notify the Director in writing of any change in the information submitted under section 2 or subsection (2) within 10 days after the date of the change. O. Reg. 128/03, s. 4.

4. The following are prescribed as conditions attaching to every well contractor licence:

1. If the licensee is a corporation or partnership, it shall ensure that,
  - i. at least one director, officer or partner is designated as the official representative of the licensee at all times, and
  - ii. the official representatives have been assigned the responsibility of ensuring that the Act and this Regulation are complied with.
2. The licensee shall maintain insurance in a form approved by the Superintendent of Financial Services of the Province of Ontario for every well construction business carried on by the licensee, with respect to the liability of the licensee and the licensee's employees arising out of the well construction business,
  - i. in an amount not less than \$2,000,000 for property damage arising out of any one incident, and
  - ii. in an amount of not less than \$2,000,000 for the death of or bodily injury to any person not an employee of the licensee, for each such person, but the contract of insurance may,
    - iii. limit the insurer's liability under the contract of insurance arising out of any one incident to \$5,000,000, and
    - iv. provide that the insured shall be responsible for a stated amount, up to \$1,000, for each claim for which coverage is required.

3. The licensee shall not do work or cause any work to be done with respect to the construction of wells except by or under the supervision of a holder of a well technician licence acting within the authority granted by his well technician licence who is,
  - i. the licensee,
  - ii. where the licensee is a partnership, one of the partners,
  - iii. where the licensee is a corporation, an officer or director, or
  - iv. an employee of the licensee.
4. Revoked: O. Reg. 128/03, s. 5 (2).
5. The licensee shall comply and shall ensure that employees and agents comply with the requirements of the Act and this Regulation. R.R.O. 1990, **Reg. 903**, s. 4; O. Reg. 128/03, s. 5.

#### WELL TECHNICIAN LICENCE

**5. (1)** The following classes of well technician licence are prescribed:

1. Well Drilling being a licence authorizing the holder to construct and supervise the construction of wells by means of well drilling equipment including,
  - i. rotary drilling equipment (standard, reverse, air, mud and air percussion),
  - ii. cable tool (churn and percussion), and
  - iii. diamond drilling equipment.
2. Well Digging and Boring being a licence authorizing the holder to construct and supervise the construction of wells by means of digging with non-powered equipment or with a back-hoe or power shovel and by means of boring or augering equipment.
3. Other Well Construction being a licence authorizing the holder to construct and supervise the construction of wells, or a type of well described in the licence, by only the methods or equipment specified in the licence.
4. Pump Installation being a licence authorizing the holder to install or supervise the installation of pumps and related equipment in or connected to a well. R.R.O. 1990, **Reg. 903**, s. 5 (1); O. Reg. 128/03, s. 6 (1).

(2) An application for a well technician licence shall be on a form supplied by the Ministry and shall be submitted along with the required fee. O. Reg. 128/03, s. 6 (2).

(3) An application for renewal of a well technician licence shall be on a form supplied by the Ministry and shall be submitted along with the required fee. O. Reg. 128/03, s. 6 (2).

(4)-(8) Revoked: O. Reg. 128/03, s. 6 (2).

**6. (1)** It is a requirement that an applicant for a well technician licence be eighteen years of age or older. R.R.O. 1990, **Reg. 903**, s. 6 (1).

(2) An applicant for a well technician licence or renewal thereof shall submit such information and material as the Director may reasonably require to be satisfied as to the character, qualifications and physical health and ability of the applicant. R.R.O. 1990, **Reg. 903**, s. 6 (2).

(3) The following are prescribed as qualifications for an applicant for any class of well technician licence:

1. Successful completion of a course of study, of at least 30 hours, that is approved by the Director for the class of well technician licence applied for and that addresses the following topics:
  - i. The Act and this Regulation.
  - ii. Licensing of well contractors and well technicians.
  - iii. Water quality health and safety considerations.
  - iv. Choosing the location of a well and assessing site conditions.
  - v. Geologic conditions and soil types.
  - vi. Construction requirements, including,
    - A. casing,
    - B. annular space,
    - C. disinfection,
    - D. pump installation,
    - E. venting,
    - F. testing of well yield, and
    - G. maintenance.
  - vii. Abandonment, including plugging and sealing.
  - viii. Workplace safety.
  - ix. Case studies.
2. Four thousand hours of work experience helping at or doing the activity that would be authorized by the licence applied for, or a combination of work experience and other qualifications that the Director considers equivalent. O. Reg. 128/03, s. 7 (1).

(4) Every holder of a well technician licence shall notify the Director in writing of any change in the information submitted under section 5 or subsection (2) within 10 days after the date of the change. O. Reg. 128/03, s. 7 (2).

7. The following are prescribed as conditions attaching to every well technician licence:

1. The licensee shall not supervise the operation of more than two pieces of well construction equipment at one time.
2. The licensee shall work or supervise work in connection with the construction of a well only as specifically authorized by the well technician licence he or she holds.
3. The licensee, while doing or supervising work related to the construction of wells, shall carry a copy of his or her licence and shall produce it upon the request of an employee or agent of the Ministry.
4. The licensee shall comply and shall ensure that every person under his or her supervision shall comply with the requirements of the Act and this Regulation.

5. The licensee shall, promptly after receipt of his or her licence, return to the Director any assistant well technician identification card previously issued to the licensee under this Regulation. R.R.O. 1990, **Reg. 903**, s. 7; O. Reg. 128/03, s. 8.

#### EXAMINATION

8. (1) Every applicant for a well contractor licence or a well technician licence shall take an examination set by the Director. R.R.O. 1990, **Reg. 903**, s. 8 (1).
- (2) If the applicant for a well contractor licence is a corporation or partnership, the examination required under subsection (1) shall be taken by each of the official representatives referred to in paragraph 1 of section 4. O. Reg. 128/03, s. 9.
- (3) An application for an appointment to take an examination shall be on a form supplied by the Ministry and shall be accompanied by the required fee. O. Reg. 128/03, s. 9.
- (4) Revoked: O. Reg. 128/03, s. 9.
- (5) An applicant who has paid the fee shall be given at least seven days notice of the date, time and place appointed for his or her examination. R.R.O. 1990, **Reg. 903**, s. 8 (5).
- (6) No applicant may try an examination for the same licence more than four times in any period of twelve months. R.R.O. 1990, **Reg. 903**, s. 8 (6).
- (7) For the purposes of subsection (6), an applicant who had an appointment for an examination that he or she did not try shall be deemed to have tried the examination. R.R.O. 1990, **Reg. 903**, s. 8 (7).

#### CONTINUING EDUCATION - WELL TECHNICIANS

**8.1** (1) If a well technician licence expires after December 31, 2005 and an application is made to renew it, it is a qualification of renewing the licence that the applicant must have successfully completed continuing education courses approved by the Director that consist of a total of at least 21 hours of instruction in the period that ends on the date the application is submitted and began on the later of the following dates:

1. January 1 of the third calendar year preceding the calendar year in which the licence expires.
2. The last day of instruction in a continuing education course that was previously relied on by the applicant for the purpose of this subsection and that ended in the third calendar year preceding the calendar year in which the licence expires. O. Reg. 128/03, s. 10.

(2) If a well technician licence is renewed during a calendar year in accordance with subsection (1), that subsection does not apply to a further renewal that occurs during the following two calendar years. O. Reg. 128/03, s. 10.

#### ASSISTANT WELL TECHNICIAN

**9.** (1) An assistant well technician without an identification card issued under this section is exempt from section 43 of the Act when working at the construction of wells if he or she is supervised by a holder of a well technician licence who is present at the site. O. Reg. 128/03, s. 11.

(2) An assistant well technician to whom an identification card has been issued under this section is exempt from section 43 of the Act when working at the construction of wells on behalf of the licensee named on the card if,

- (a) the expiry date on the card has not yet been reached;
- (b) he or she carries the card with him or her and produces it on the request of an employee or agent of the Ministry; and
- (c) he or she is supervised by the holder of a well technician licence who is available to be called to the site within one hour. O. Reg. 128/03, s. 11.

(3) A holder of a well contractor licence may, not earlier than four months after an assistant well technician begins to work as an employee or agent of the holder of the licence, apply to the Director on a form supplied by the Ministry for an identification card for the technician. O. Reg. 128/03, s. 11.

(4) A holder of a well contractor licence may, when the identification card for the assistant well technician is about to expire, apply to the Director on a form supplied by the Ministry for a new identification card for the technician. O. Reg. 128/03, s. 11.

(5) An identification card issued under this section for an assistant well technician shall bear an expiry date that is not more than 36 months after the date of issue. O. Reg. 128/03, s. 11.

(6) A person for whom an identification card is issued shall return the card to the Director promptly after ceasing to be the employee or agent of the licensed contractor named on the card. O. Reg. 128/03, s. 11.

**10.** Revoked: O. Reg. 128/03, s. 12.

#### CONSTRUCTION REQUIREMENTS

**11.** (1) Every person constructing a well shall comply with the requirements set out in sections 12, 13, 14, 15, 17 and 18. R.R.O. 1990, **Reg. 903**, s. 11 (1).

(2) Every person constructing a well shall make and have available for inspection, at the well site during construction or testing, an up-to-date record, including a geological log, of the construction and testing of the well. R.R.O. 1990, **Reg. 903**, s. 11 (2).

(3) When the construction of a well is completed or when a well under construction is left unattended, the person constructing the well shall cover the upper open end of the well securely in a manner sufficient to prevent entry into it of surface water or foreign materials. R.R.O. 1990, **Reg. 903**, s. 11 (3).

(3.1) Before the construction of a cased well is completed, the person constructing the well shall obtain a well tag from the Ministry and shall affix it permanently to the outside of the casing at a point where it will be visible and will not be obstructed by the well cap or other components of the well or by equipment associated with the well. O. Reg. 128/03, s. 13 (1).

(3.2) If an alteration is made to a cased well that already has a well tag, the person constructing the alteration shall safeguard the well tag during construction and shall reaffix it in accordance with subsection (3.1). O. Reg. 128/03, s. 13 (1).

(3.3) Despite subsection (3.2), if an alteration is made to a cased well that already has a well tag and the well tag is broken, defaced, illegible or otherwise unusable, the person constructing the alteration shall,

- (a) remove the well tag and dispose of it; and
- (b) obtain a new well tag from the Ministry and affix it in accordance with subsection (3.1). O. Reg. 128/03, s. 13 (1).

(3.4) Despite subsections (3.1) to (3.3), if one well record is prepared for a cluster of wells in accordance with section 11.1, it is not necessary to affix a well tag to a well in the cluster if a well tag is already affixed to at least one other well in the cluster. O. Reg. 128/03, s. 13 (1).

(4) On the day the construction of a well is completed, the person constructing the well shall, unless the well owner otherwise directs,

- (a) provide the well owner with a water sample from the well of at least one litre for visual examination; and
- (b) measure the depth of the well in the presence of the well owner. R.R.O. 1990, **Reg. 903**, s. 11 (4).

(4.1) Subsection (4) does not apply to a test hole or dewatering well. O. Reg. 128/03, s. 13 (2).

(5) On completion of construction of a well, the person constructing the well shall,

- (a) test the yield of the well in accordance with section 19;
- (b) deliver a copy of an information package about wells obtained from the Ministry to the well owner before the well construction equipment is removed from the site;
- (c) complete the well record for the well, including the record of Global Positioning System coordinates for the well location;
- (d) deliver a copy of the well record to the well owner within 14 days after the date on which the well construction equipment is removed from the site;
- (e) forward a copy of the well record to the Director within 30 days after the date on which the well construction equipment is removed from the site; and
- (f) retain a copy of the well record for two years. O. Reg. 128/03, s. 13 (3).

(5.1) Subsection (5) does not apply to a person who installs pumping equipment in a well for which a well record has already been completed. O. Reg. 128/03, s. 13 (3).

(5.2) Subsection (5) does not apply to a person who installs equipment of any of the following types in a well if a well record has already been completed for the well and the equipment installation does not involve substantial alteration of the well:

1. Equipment to determine the water level.
2. Equipment to sample the water.
3. Equipment to test a quality or characteristic of the water. O. Reg. 128/03, s. 13 (3).

(5.3) Subsection (5) does not apply in respect of a test hole or dewatering well that,

- (a) is constructed as an uncased well and is not required by this Regulation to be cased;
- (b) is abandoned within 30 days after completion of its construction; and
- (c) is abandoned in accordance with section 21. O. Reg. 128/03, s. 13 (3).

(5.4) Clause (5) (a) does not apply on completion of construction of a test hole or dewatering well if the person constructing it measures the static water level in the well by means of a plastic or metal tape, an air line or an electrical device, and ensures that any part of the tape, line or device that comes into contact with water in the well is clean. O. Reg. 128/03, s. 13 (3).

(5.5) Clauses (5) (b) and (f) do not apply to a test hole or dewatering well. O. Reg. 128/03, s. 13 (3).

(5.6) Subsections (2), (3), (4) and (5) do not apply to a person who installs water sampling or monitoring equipment in a well if the person is present at the well throughout the entire period that the equipment remains installed in the well. O. Reg. 128/03, s. 13 (3).

(6) Where construction of a well is completed but the well is not developed to a sand-free state, the person constructing the well shall notify the well owner of this condition and shall make note of it on the well record. R.R.O. 1990, **Reg. 903**, s. 11 (6).

(6.1) Subsection (6) does not apply to a test hole or dewatering well. O. Reg. 128/03, s. 13 (4).

(7) If a flowing well is constructed, the person constructing the well,

(a) shall construct the well to accommodate and be compatible with an appropriate device that controls the discharge of water from within the well casing, is capable of stopping the discharge of water from within the well casing, and is capable of withstanding the freezing of water in the well casing;

(b) shall install a device described in clause (a);

(c) shall construct the well and install the device described in clause (a) in a manner that prevents any flow of water from the well or at the well site, other than the flow through the device; and

(d) shall construct the well and install the device described in clause (a) in a manner that prevents backflow of water into the well or well casing. O. Reg. 128/03, s. 13 (5).

(8) Clauses (7) (b), (c) and (d) do not apply if the well is abandoned in accordance with section 21. O. Reg. 128/03, s. 13 (5).

(9) Every contract for the construction of a well shall be deemed to contain a term that makes the person undertaking construction of the well responsible for,

(a) the cost of complying with subsection (7); and

(b) if clauses (7), (b), (c) and (d) do not apply pursuant to subsection (8), the cost of abandoning the well. O. Reg. 128/03, s. 13 (5).

(10) Subsection (9) does not apply to a written contract that expressly releases the person undertaking construction of the well from the responsibility referred to in that subsection. O. Reg. 128/03, s. 13 (5).

(11) If a well casing extends above the ground surface, the person constructing the well shall ensure that the surface drainage is such that water will not collect or pond in the vicinity of the well. O. Reg. 128/03, s. 13 (5).

## WELL CLUSTERS

**11.1** (1) Despite clause 11 (5) (c), a person constructing wells may complete one well record for a cluster of wells instead of a separate well record for each individual well if all the following circumstances exist:

1. Every well in the cluster is a test hole or every well in the cluster is a dewatering well.

2. Every well in the cluster is located,

- i. on the same property as another well in the cluster,
  - ii. on a property that is adjacent to a property on which another well in the cluster is located, or that would be adjacent but for a road between the two properties,
  - iii. on a property that has only one or two intervening properties between it and a property on which another well in the cluster is located.
3. The construction of every well in the cluster is complete or, if the wells are being constructed in phases, the construction of every well in the relevant phase of construction is complete.
  4. The well owner of every well in the cluster has given written consent to the use of a single well record for the cluster and the water well record states that all the required consents have been given. O. Reg. 128/03, s. 14.

(2) For the purpose of subparagraph 2 iii of subsection (1), the following rules apply to the determination of the number of intervening properties between two properties on which wells are located:

1. The number of intervening properties shall be determined along a straight line joining the two wells.
2. If the straight line mentioned in paragraph 1 crosses a road, the road shall not be counted as an intervening property, unless one or both of the two wells is located on or inside the boundaries of the road.
3. If part of the straight line mentioned in paragraph 1 is on or within the boundaries of a road, the number of intervening properties shall be determined with reference to the properties adjacent to that portion of the road, on the side of the road that has fewer properties. O. Reg. 128/03, s. 14.

(3) A person constructing wells who completes one well record for a cluster of wells under subsection (1) shall,

- (a) include in the well record a detailed map showing all the wells in the cluster, all property boundaries, and measurements sufficient to locate all of the wells in relation to fixed points and Global Positioning System coordinates;
- (b) indicate in the well record, in a convenient, concise and comprehensive manner, which of the wells share common features, such as diameter, construction technique, casing, venting, pumping equipment and method of abandonment;
- (c) include in the well record a statement that the person constructing the well will promptly submit to the Director, on request, any additional information in the person's custody or control related to any well in the cluster that the person has constructed;
- (d) despite clause 11 (5) (d), deliver to each well owner a copy of the well record for the cluster of wells within 60 days after the commencement of construction of the first well or, if the wells are being constructed in phases, within 60 days after the commencement of construction of the first well in the relevant phase of construction; and
- (e) despite clause 11 (5) (e), forward a copy of the well record for the cluster of wells to the Director within 75 days after the commencement of construction of the first well or, if the wells are being constructed in phases, within 75 days after the

commencement of construction of the first well in the relevant phase of construction. O. Reg. 128/03, s. 14.

(4) If one well record is completed for a cluster of wells under subsection (1), a person who does any subsequent construction that affects any of the wells in the cluster may complete one new well record in respect of the subsequent construction, as long as the new well record refers to the number of the original well record and identifies which of the wells in the cluster are affected by the subsequent construction. O. Reg. 128/03, s. 14.

(5) A person constructing wells who completes a new well record under subsection (4) shall,

(a) despite clause 11 (5) (d), deliver to each well owner affected by the subsequent construction a copy of the well record within 60 days after the commencement of the subsequent construction or, if the subsequent construction is done in phases, within 60 days after the commencement of the relevant phase of the subsequent construction; and

(b) despite clause 11 (5) (e), forward a copy of the well record to the Director within 75 days after the commencement of the subsequent construction or, if the subsequent construction is done in phases, within 75 days after the commencement of the relevant phase of the subsequent construction. O. Reg. 128/03, s. 14.

#### LOCATION OF WELLS

**12.** (1) The site of a new well shall be separated by at least the clearance distance required by Ontario Regulation 403/97 (Building Code) from a leaching bed system or other sewage system as defined in that regulation, including a sewage system that has not been constructed but for which a building permit has been issued. O. Reg. 128/03, s. 15.

(2) The site of a new drilled well that has a watertight casing that extends to a depth of more than six metres below ground level shall be at least 15 metres from a source of pollution other than one mentioned in subsection (1). O. Reg. 128/03, s. 15.

(3) The site of,

(a) a new drilled well that does not have a watertight casing that extends to a depth of more than six metres below ground level; or

(b) a new well that is not a drilled well,

shall be at least 30 metres from a source of pollution other than one mentioned in subsection (1). O. Reg. 128/03, s. 15.

(4) The site of a new well shall be chosen so that the well is accessible for cleaning, treatment, repair, testing, inspection and visual examination at all times before, during and after completion of construction of the well. O. Reg. 128/03, s. 15.

(5) The site of a new well shall be at an elevation higher than the immediately surrounding area. O. Reg. 128/03, s. 15.

(6) Subsections (1) to (5) do not apply to a test hole or dewatering well. O. Reg. 128/03, s. 15.

(7) A well pit shall not be constructed at any location. O. Reg. 128/03, s. 15.

(8) Despite subsection (7), a well pit may be constructed for a well that is created by diamond drilling equipment in connection with mineral exploration. O. Reg. 128/03, s. 15.

- (9) The following requirements apply to a well pit constructed under subsection (8):
1. Section 13 applies as if the well pit were a well.
  2. The floor of the well pit shall be covered with a layer of suitable sealant at least 10 centimetres thick.
  3. The top of the well pit shall be covered with a solid, waterproof cover, sufficient to prevent the entry of foreign materials into the well pit.
  4. The cover on the well pit shall be fastened in place in a manner that will make it difficult for children to remove the cover.
  5. The well pit shall be kept dry by means of a sump pump.
  6. Despite paragraph 5, if the water table is substantially lower than the floor of the well pit, the well pit may be kept dry by means of drainage through a one-way valve that passes through the layer of sealant and that is located near the perimeter of the well pit.
  7. The top of the casing of the drilled well shall be at least 40 centimetres above the floor of the well pit.
  8. The top of the casing of the drilled well shall be sealed with a commercially manufactured sanitary seal and shall be provided with a length of air vent line sufficient to extend above the covering of the well pit. O. Reg. 128/03, s. 15.

(10) No person shall construct a well by penetrating through the bottom of a bored or dug well by means of drilling or by the use of a jetted point or driven point. O. Reg. 128/03, s. 15.

#### CASING

**13.** (1) Casing shall be new material. O. Reg. 128/03, s. 16.

(2) Subsection (1) does not apply to a test hole or dewatering well if abandonment of the test hole or dewatering well is scheduled to take place not later than 180 days after completion of construction. O. Reg. 128/03, s. 16.

(3) Casing shall be clean and free of contamination. O. Reg. 128/03, s. 16.

(4) Casing shall not impair the quality of water with which it comes in contact. O. Reg. 128/03, s. 16.

(5) Casing shall be watertight. O. Reg. 128/03, s. 16.

(6) Any seams in casing shall achieve a permanent watertight bond. O. Reg. 128/03, s. 16.

(7) Cement casing shall be fully cured before installation. O. Reg. 128/03, s. 16.

(8) A well that obtains water from an overburden aquifer shall be cased from the water-producing zone to at least 40 centimetres above the highest point on the ground surface within three metres radially from the well, after the surface drainage conforms with subsection 11 (11), as measured at the time the well is completed. O. Reg. 128/03, s. 16.

(9) A well that obtains water from a bedrock aquifer shall be cased from the bedrock to at least 40 centimetres above the highest point on ground surface within three metres radially from the well, after the surface drainage conforms with subsection 11 (11), as measured at the time the well is completed. O. Reg. 128/03, s. 16.

- (10) Subsections (8) and (9) do not apply if,
  - (a) the well is made by the use of a jetted point or driven point;
  - (b) the well is cased, from the highest point on the ground surface within three metres radially from the well, after the surface drainage conforms with subsection 11 (11), to,
    - (i) the water-producing zone, if the well obtains water from an overburden aquifer, or
    - (ii) the bedrock, if the well obtains water from a bedrock aquifer;
  - (c) the top of the casing is completed by the use of a buried joint to a suction water line that leads to a pump; and
  - (d) a permanent marker identifies the location of the well and is visible at all times of year. O. Reg. 128/03, s. 16.
- (11) Subsections (8) and (9) do not apply to a test hole or dewatering well if,
  - (a) the well is located where vehicle traffic is likely to pass directly over the well;
  - (b) the well is completed with a flush-mounted watertight commercially manufactured well cover; and
  - (c) the well cover is sufficiently strong, durable and well-installed to protect the well from damage, or the well cover is covered with a metal plate that is sufficiently large and sufficiently strong, durable and well-installed to protect the well cover and the well from damage. O. Reg. 128/03, s. 16.
- (12) The casing of a well that obtains water from a bedrock aquifer shall be sealed into the bedrock with suitable sealant to prevent impairment of the quality of the water in the well and aquifer. O. Reg. 128/03, s. 16.
- (13) Subsection (12) does not apply to a test hole or dewatering well. O. Reg. 128/03, s. 16.
- (14) If a well is constructed with a well pit,
  - (a) subsections (8), (9) and (12) do not apply; and
  - (b) the well shall be cased from the bottom of the well pit to at least 40 centimetres above the highest point on the ground surface within three metres radially from the well, after the surface drainage conforms with subsection 11 (11), as measured at the time the well is completed. O. Reg. 128/03, s. 16.
- (15) A well to which subsection (8), (9) or (10) applies shall, despite that subsection,
  - (a) have at least six metres of casing below the level of the original ground surface, unless clause (b) applies; or
  - (b) have at least 2.5 metres of casing below the level of the original ground surface, if a casing that extended to six metres below the level of the original ground surface would not permit the use of the only useful aquifer. O. Reg. 128/03, s. 16.
- (16) The following are the minimum specifications for casing:
  1. The casing specifications for high yield wells in Table 2 of AWWA 100-97.
  2. The outer permanent casing in double walled casing constructions must be steel pipe that conforms to ASTM A252 or ASTM A500.

3. Steel casing with an inside diameter of more than 50.8 millimetres must have a nominal wall thickness of 4.78 millimetres and a minimum wall thickness of 4.18 millimetres and must conform to ASTM A-53 Grade B, ASTM A589 Grade B or ASTM A500 Grade B or C.
  4. Steel casing with an inside diameter of 50.8 millimetres or less must have a nominal wall thickness of 2.77 millimetres and a minimum wall thickness of 2.41 millimetres and must conform to ASTM A-53 Grade B, ASTM A589 Grade B or ASTM A500 Grade B or C.
  5. Galvanized steel casing that is corrugated and that is used in bored or dug wells must be 18 gauge and must conform to ASTM A-53 Grade B, ASTM A589 Grade B or ASTM A500 Grade B or C.
  6. Cement casing with an inside diameter of 60.96 centimetres or more must have nominal wall thickness of 5.08 centimetres.
  7. Plastic casing with an inside diameter of 10.16 centimetres or more must have a minimum wall thickness of 0.635 centimetres and must be ABS or PVC pipe approved for potable water use by the Canadian Standards Association, the Canadian Society for Testing and Materials, ASTM or NSF International.
  8. Fibre-reinforced plastic casing must be manufactured from virgin resin and virgin fibres and must be approved for potable water use by NSF International. O. Reg. 128/03, s. 16.
- (17) Subsections (15) and (16) do not apply to a test hole or dewatering well. O. Reg. 128/03, s. 16.
- (18) The casing used in a well shall be continuous casing. O. Reg. 128/03, s. 16.
- (19) Joints in casing are prohibited, except for joints that,
- (a) achieve a permanent, watertight bond, such as welded steel joints; and
  - (b) are made so that the jointed casing does not impair the quality of water with which it comes in contact. O. Reg. 128/03, s. 16.
- (20) The annular space between casings of different diameters shall be sealed with suitable sealant to prevent the entry into the well of any substance, including foreign materials and surface water. O. Reg. 128/03, s. 16.
- (21) No person shall ground a lightning rod by attaching it, directly or indirectly, to the casing of a well. O. Reg. 128/03, s. 16.

#### ANNULAR SPACE

- 14.** (1) If a well is constructed by any method, the well shall be at least six metres deep, unless the only useful aquifer available necessitates a shallower well, in which case the well shall be at least three metres deep. O. Reg. 128/03, s. 17.
- (2) Subsection (1) does not apply to a test hole or dewatering well. O. Reg. 128/03, s. 17.
- (3) If a well is constructed by a method other than the use of a driven point, the well shall be constructed with a diameter at least 7.6 centimetres greater than the proposed diameter of the finished well, from the ground surface to a depth of at least the full depth of the well or six metres, whichever is less. O. Reg. 128/03, s. 17.

(4) If a well is constructed by a method other than digging or the use of a driven point, the annular space shall be filled from the bottom of the well to the ground surface with suitable sealant in accordance with the following rules:

1. The water-producing zone shall be filled with clean, washed gravel or sand that is,
  - i. deposited after placement of the casing, or
  - ii. developed, after placement of the casing and sealant, by surging water through the intake zone to remove the adjacent fine grained soils.
2. The sealant must be continuously deposited so that it fills the annular space from the top of the water-producing zone upward by,
  - i. being forced through the bottom end of the casing, or
  - ii. being forced through a tremie pipe with the bottom end of the pipe immersed in the rising accumulation of sealant.
3. If the sealant used to fill the annular space contains cement,
  - i. it shall be allowed to set according to the manufacturer's specifications or for 12 hours, whichever is longer, and
  - ii. if, after setting in accordance with subparagraph i, the sealant has settled or subsided, it shall be topped up to the original level. O. Reg. 128/03, s. 17.

(5) Subsection (3) does not apply if,

- (a) the well is constructed by a method other than digging or the use of a driven point;
- (b) the well is constructed with a diameter at least 5.1 centimetres greater than the proposed diameter of the finished well, from the ground surface to a depth of at least the full depth of the well or six metres, whichever is less;
- (c) the suitable sealant used to comply with subsection (4) has a maximum particle size that will not be subject to bridging; and
- (d) proper alignment is ensured by,
  - (i) in the case of a well constructed using a cable tool rig, the use of a breakaway guide for centering the casing that does not impair the quality of the water with which it comes into contact and that is placed two metres above the bottom of the casing, or
  - (ii) in the case of a well constructed using a rotary rig, the use of centralizers located below a depth of six metres. O. Reg. 128/03, s. 17.

(6) Subsections (3) to (5) do not apply to,

- (a) a test hole or dewatering well if abandonment of the test hole or dewatering well is scheduled to take place not later than 180 days after completion of construction; or
- (b) a dewatering well constructed by the use of a jetted point. O. Reg. 128/03, s. 17.

(7) The person who constructs a well shall ensure that the annular space is sealed to prevent any movement of water, natural gas, contaminants or other material between subsurface formations or between a subsurface formation and the ground surface by means of the annular space. O. Reg. 128/03, s. 17.

(8) If a well, other than a test hole or dewatering well, is constructed with a well pit, subsection (4) does not apply to the well pit but does apply, with necessary modifications, from the bottom of the annular space to the bottom of the well pit. O. Reg. 128/03, s. 17.

(9) If a test hole or dewatering well, other than a test hole or dewatering well referred to in subsection (6), is constructed with a well pit, subsection (4) does not apply to the well pit but does apply, with necessary modifications, from the bottom of the annular space to the bottom of the well pit. O. Reg. 128/03, s. 17.

(10) If a well is constructed by digging, the annular space shall be filled to the ground surface in accordance with the following rules:

1. The annular space from the bottom of the well to a depth not closer to the ground surface than 2.5 metres shall be filled with clean, washed and disinfected gravel or sand.
2. The remainder of the annular space shall be filled with suitable sealant. O. Reg. 128/03, s. 17.

(11) Subsection (10) does not apply to a test hole or dewatering well. O. Reg. 128/03, s. 17.

(12) If a well is constructed by the use of a driven point, the annular space shall be filled to the ground surface using a material and a method approved in writing by the Director that, in the opinion of the Director, will ensure that there are no gaps or air spaces in the material placed in the annular space. O. Reg. 128/03, s. 17.

(13) Subsection (12) does not apply to a test hole or dewatering well. O. Reg. 128/03, s. 17.

(14) If a well is deepened, this section and section 13 apply, with necessary modifications, as if a new well were being constructed, but continued use of the casing in the existing well is permitted if the casing appears sound. O. Reg. 128/03, s. 17.

(15) This section does not apply to a well that is constructed with a casing surrounded by a permanent casing of larger diameter (sometimes referred to as a double walled casing), but,

- (a) subsections (1) to (7) and (14) apply, with necessary modifications, to the annular space outside the outer casing; and
- (b) subsections (4), (6) and (7) apply, with necessary modifications, to the annular space between the casings, unless there is no ground water leaking into the annular space between the casings. O. Reg. 128/03, s. 17.

#### DISINFECTION

**15.** (1) When the construction of a well is completed, the water in the well shall be chlorinated to a concentration of approximately 50 milligrams of chlorine per litre of water and maintained at that concentration for a period of at least 12 hours. O. Reg. 128/03, s. 18.

(2) If pumping equipment is installed in a well,

- (a) the chlorinated water shall be brought into contact and maintained in contact with all areas of the pumping equipment that will come into contact with the water in the well when the well is in use; and
- (b) at the end of the 12-hour period of chlorination, the chlorinated water shall be pumped from the well until no odour of chlorine remains in the well water. O. Reg. 128/03, s. 18.

(3) Subsections (1) and (2) do not apply if the Director gives written approval to another method of disinfection and the approved method is complied with. O. Reg. 128/03, s. 18.

(4) This section does not apply to a test hole, dewatering well or flowing well. O. Reg. 128/03, s. 18.

#### APPLICATION

**16.** Sections 12 to 15 apply only to the construction and putting into operation of a new well except as otherwise provided therein. R.R.O. 1990, **Reg. 903**, s. 16.

#### PUMP INSTALLATION

**17.** (1) If a connection to the casing of a drilled well is made below the ground surface, a well seal or pitless adapter shall be used and the connection shall be made watertight. O. Reg. 128/03, s. 19.

(2) A cutting torch shall not be used to make an opening in the casing wall to accommodate a pitless adapter. O. Reg. 128/03, s. 19.

(3) If a connection to the casing of a bored or dug well is made below the ground surface,

(a) the connection shall be made watertight with durable bonding material; and

(b) the outside trench excavation shall be filled with suitable sealant extending from the casing a minimum distance outward of 0.5 metres and extending from the bottom of the excavation to within 0.5 metres of the ground surface. O. Reg. 128/03, s. 19.

(4) If a pump is not located directly over a well, the top of the casing shall be sealed with a commercially manufactured vermin-proof well cap. O. Reg. 128/03, s. 19.

(5) If a pump is installed directly over a well,

(a) the casing shall be extended to at least 40 centimetres above the ground surface or, if a floor has been constructed around or adjacent to the casing, to at least 15 centimetres above the floor; and

(b) the top of the casing shall be shielded in a manner sufficient to prevent entry of any material that may impair the quality of the water in the well. O. Reg. 128/03, s. 19.

#### VENTING

**18.** (1) If pumping equipment is installed in a drilled well, other than a well in which the casing is used to transmit water out of the well,

(a) an air vent shall be installed with a minimum inside diameter of,

(i) 0.3 centimetres, if the inside diameter of the casing is less than 12.7 centimetres, or

(ii) 1.2 centimetres, if the inside diameter of the casing is 12.7 centimetres or more;

(b) the air vent,

(i) shall be of sufficient length to extend above the covering of the well pit, if a well pit exists, or

- (ii) shall extend above the ground surface a distance sufficient to prevent the entry of flood water from any anticipated flooding in the area but not less than 40 centimetres, if no well pit exists;
  - (c) the air vent shall extend above the well cap;
  - (d) the open end of the air vent shall be shielded and screened in a manner sufficient to prevent the entry of any materials into the well; and
  - (e) if natural gas is present, the air vent shall be extended to the outside atmosphere in a manner that will safely disperse all gases. O. Reg. 128/03, s. 20.
- (2) Subsection (1) does not apply to an uncased test hole or an uncased dewatering well. O. Reg. 128/03, s. 20.

#### TESTING OF WELL YIELD

- 19.** (1) If the yield of water from a well is tested,
- (a) the water level in the well shall be measured and recorded on the well record for the well,
    - (i) immediately before commencement of pumping,
    - (ii) at one minute intervals or more frequently during the first five minutes of pumping,
    - (iii) at five minute intervals or more frequently during the next 25 minutes of pumping,
    - (iv) at 10 minute intervals or more frequently during the next 30 minutes of pumping,
    - (v) at one minute intervals or more frequently during the first five minutes after pumping stops,
    - (vi) at five minute intervals or more frequently during the next 25 minutes after pumping stops, and
    - (vii) at 10 minute intervals or more frequently during the next 30 minutes after pumping stops;
  - (b) the water level in the well shall be measured by means of a plastic or metal tape that is clean or an air line or electrical device that is clean;
  - (c) water shall be pumped from the well at a steady rate, continuously for at least one hour; and
  - (d) the rate of pumping during the test shall be recorded on the well record. O. Reg. 128/03, s. 21.
- (2) If water cannot be pumped from the well continuously for one hour in accordance with clause (1) (c), no further measurements are required under clause (1) (a) and there shall be recorded on the well record,
- (a) the reason pumping was discontinued;
  - (b) the rate of pumping and the length of the pumping period; and
  - (c) the water level measurements made. O. Reg. 128/03, s. 21.
- (3) Revoked: O. Reg. 128/03, s. 21.

(4) Revoked: O. Reg. 128/03, s. 21.

(5) Every person testing water yield from a well shall ensure that the test is carried out, completed and recorded in accordance with this section. R.R.O. 1990, **Reg. 903**, s. 19 (5).

#### WELL MAINTENANCE

**20.** (1) Where a well is constructed and mineralized water is encountered, the person constructing the well shall immediately notify the well owner that the condition exists. R.R.O. 1990, **Reg. 903**, s. 20 (1).

(1.1) Subsection (1) does not apply to a test hole or dewatering well. O. Reg. 128/03, s. 22.

(2) Where a well is constructed and natural gas is encountered, the person constructing the well shall immediately notify the well owner and the Director that the condition exists. R.R.O. 1990, **Reg. 903**, s. 20 (2).

(3) The well owner shall 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. R.R.O. 1990, **Reg. 903**, s. 20 (3).

#### ABANDONMENT

**21.** (1) If a well is abandoned, the person abandoning the well shall ensure that the following steps are taken and, unless otherwise specified, they shall be taken in the sequence in which they are set out in this subsection:

1. If the well already has a well tag, the well tag shall be safeguarded and, when the steps required by paragraph 10 are taken, the well tag shall be reused for the purpose of complying with that paragraph.
2. All equipment and debris in the well shall be removed, but well casing shall not be removed unless it has collapsed.
3. The volume of water in the well shall be estimated and at least that volume of water shall be pumped from the well.
4. At least 25 litres of a solution of 50 milligrams of chlorine per litre of water shall be put into the well and the water remaining in the well shall be chlorinated to at least that concentration.
5. The well, including the annular space, shall be plugged by,
  - i. in the case of any well, placing a continuous column of an abandonment barrier from the bottom of the well upward to approximately one metre below the ground surface so that it prevents any movement of water, natural gas, contaminants or other material between subsurface formations or between a subsurface formation and the top of the abandonment barrier, or
  - ii. in the case of a well that is greater than 65.0 centimetres in diameter, taking the steps described in subsection (1.2).
6. If it was not removed under paragraph 2, the well casing shall be removed to a minimum depth of two metres below the ground surface, and the removal shall be done during the taking of the steps required by paragraph 5 but after the material placed in the well under that paragraph has reached a level approximately two metres below the ground surface.

7. If an abandonment barrier placed under paragraph 5 contains cement, it shall be allowed to set until firm and, if necessary, it shall then be topped up to approximately one metre below the ground surface.
  8. Unless they are used or maintained for future use, the above ground structures associated with the well shall be dismantled at any time before the steps required by paragraph 10 are taken.
  9. Below ground concrete structures, foundations and slabs shall be removed, at any time before the steps required by paragraph 10 are taken, at least to a depth adequate to accommodate the sealing measures described in paragraph 10.
  10. The well shall be sealed at the ground surface by,
    - i. placing at least 50 centimetres in vertical thickness of bentonite chips or pellets in the well opening, with the existing well tag, if any, pushed two centimetres into the top of the bentonite chips or pellets, and
    - ii. covering the entire well opening to the ground surface by at least 30 centimetres in vertical thickness of soil cover to prevent inadvertent or unauthorized access.
  11. The disturbed area shall, to the extent practical, be revegetated. O. Reg. 128/03, s. 23 (1).
- (1.1) The following rules apply for the purpose of paragraph 5 of subsection (1):
1. The abandonment barrier for a well that is less than or equal to 6.5 centimetres in diameter must be compatible with the quality of the water found in the well and must be a slurry consisting of clean water, Portland cement and not more than 5 per cent bentonite.
  2. The abandonment barrier for a well that is more than 6.5 centimetres in diameter must be compatible with the quality of the water found in the well and must be,
    - i. a slurry consisting of clean water and at least 20 per cent bentonite solids,
    - ii. a slurry consisting of clean water, Portland cement and not more than 5 per cent bentonite,
    - iii. a slurry consisting of clean water and Portland cement,
    - iv. a slurry consisting of clean water, Portland cement and clean, disinfected sand,
    - v. a slurry consisting of equal weights of Portland cement and clean, disinfected gravel, mixed with clean water,
    - vi. a slurry (sometimes called concrete slurry) consisting of clean water, Portland cement, clean, disinfected sand, and clean, disinfected gravel, or
    - vii. other material approved in writing by the Director, if the Director is of the opinion that the performance of the other material is equivalent to the performance of a slurry referred to in subparagraphs i to vi.
  3. If the well is in contact with contaminants, the abandonment barrier must be stable in the presence of the contaminants.

4. Subject to paragraph 5, an abandonment barrier that is wet shall be placed using a tremie pipe, with the bottom of the tremie pipe immersed in the rising accumulation of the abandonment barrier until the required level has been reached.
5. In the case of a well that is less than or equal to 6.5 centimetres in diameter, the abandonment barrier may be placed without the use of a tremie pipe, by pouring it down the casing before the casing is removed. O. Reg. 128/03, s. 23 (1).

(1.2) The steps referred to in subparagraph 5 ii of subsection (1) with respect to a well that is greater than 65.0 centimetres in diameter, which shall be taken in the sequence in which they are set out in this subsection, are the following:

1. Clean, disinfected sand or pea gravel shall be placed from the bottom of the well to the top of the deepest formation supplying water to the well or to the top of the water intake zone of the well, whichever is deeper.
2. At least 0.1 metre of bentonite chips or pellets shall be placed over the sand or pea gravel.
3. If the water level can be drawn down to the top of the bentonite chips or pellets,
  - i. the water level shall be drawn down to the top of the bentonite chips or pellets,
  - ii. at least 0.3 metres of a bentonite slurry that consists of clean water and at least 20 per cent bentonite solids and that is compatible with the quality of the water found in the well shall be placed over the bentonite chips or pellets, and
  - iii. clean gravel, sand, silt or clay shall be dropped over the bentonite slurry to fill the remainder of the well, while maintaining at least 0.3 metres of the bentonite slurry above the rising accumulation of gravel, sand, silt or clay.
4. If the water level cannot be drawn down to the top of the bentonite chips or pellets, the remainder of the well shall be filled with an abandonment barrier, which may be interspersed with clean, disinfected sand or pea gravel placed in each water intake zone of the well. O. Reg. 128/03, s. 23 (1).

(1.3) If the well is a flowing well, commercially manufactured drilling mud that does not impair the quality of the water with which it comes in contact may be used, in taking the steps required by subsection (1), to assist with drilling or placement of an abandonment barrier, but the drilling mud may not be used as an abandonment barrier. O. Reg. 128/03, s. 23 (1).

- (1.4) On completion of the abandonment of a well, the person abandoning the well shall,
- (a) complete the well record for the well, including the record of Global Positioning System coordinates for the well location;
  - (b) deliver a copy of the well record to the well owner,
    - (i) within 14 days after the date on which the well construction equipment is removed from the site, or
    - (ii) within 60 days after the date on which the well construction equipment is removed from the site, if the well is part of a well cluster for which one well record was prepared in accordance with section 11.1; and
  - (c) forward a copy of the well record to the Director,
    - (i) within 30 days after the date on which the well construction equipment is removed from the site, or

- (ii) within 75 days after the date on which the well construction equipment is removed from the site, if the well is part of a well cluster for which one well record was prepared in accordance with section 11.1. O. Reg. 128/03, s. 23 (1).

(1.5) A person constructing a well that is discontinued before completion shall forthwith abandon the well. O. Reg. 128/03, s. 23 (1).

(2) The well owner of a new well that is dry shall forthwith abandon the well. R.R.O. 1990, **Reg. 903**, s. 21 (2).

(3) The well owner of a well that is not being used or maintained for future use as a well shall forthwith abandon the well. R.R.O. 1990, **Reg. 903**, s. 21 (3).

(4) A well owner shall forthwith abandon a well that,

(a) produces salty, sulphurous or mineralized water;

(b) produces water that is not potable;

(c) contains natural gas or other gas;

(d) permits any movement of natural gas, contaminants or other materials between subsurface formations or between a subsurface formation and the ground surface;  
or

(e) is constructed in contravention of any provision of this Regulation dealing with the location or spacing of wells, the methods and materials used in the construction of wells or the standards of well construction. O. Reg. 128/03, s. 23 (2).

(5) Subsection (4) does not apply if the well owner has the written consent of the Director. O. Reg. 128/03, s. 23 (2).

(5.1) Subsection (2) and clauses (4) (a), (b) and (c) do not apply to a test hole or dewatering well. O. Reg. 128/03, s. 23 (2).

(5.2) Clauses (4) (a) and (b) do not apply to a well that,

(a) is used or intended for use as a source of water for agriculture; and

(b) is not used as a source of water for human consumption. O. Reg. 128/03, s. 23 (2).

(6) Every owner of an abandoned well shall ensure that the well is plugged in accordance with subsection (1). R.R.O. 1990, **Reg. 903**, s. 21 (6).

#### PROTECTION OF WELL TAG

**22.** (1) No person shall use a well tag obtained from the Ministry, except in accordance with this Regulation. O. Reg. 128/03, s. 24.

(2) No person shall remove a well tag affixed in accordance with this Regulation, except,

(a) in accordance with subsection 11 (3.2) or (3.3) or paragraph 1 of subsection 21 (1);  
or

(b) with the written consent of the Director. O. Reg. 128/03, s. 24.

(3) No person shall deface, alter, conceal or obstruct a well tag affixed in accordance with this Regulation. O. Reg. 128/03, s. 24.

FormS 1-9 Revoked: O. Reg. 128/03, s. 25.