UNIVERSITY OF ALBERTA

Abandoned Water Wells in Canada: Background Report

A Report Prepared for Agriculture and Agri-Food Canada

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Executive Summary

Introduction

Groundwater provides about 8.5 million Canadians with their household source of water[1]. Abandoned water wells pose a risk to groundwater by providing pathways that bypass the natural processes of attenuation that take place as water infiltrates through the earth. The risk of abandoned water wells can be mitigated through proper well decommissioning.

This report provides a background on the issue of abandoned wells in Canada and the efforts being made by agencies to ensure that abandoned wells are properly decommissioned. The goals of the report are to:

- Identify and summarize regulations for the approval/licencing/permitting for water well construction in each Province and Territory in Canada
- Identify and summarize regulations governing water well construction in each province and Territory in Canada
- Identify and summarize regulations governing abandoned wells and water well decommissioning in each province and Territory in Canada
- Review and summarize the available provincial level data regarding inventories of working or constructed water wells, abandoned water wells, and decommissioned water wells.
- Develop best estimates for the number of working or constructed water wells, the number of abandoned wells, and the number of decommissioned wells (with a focus on identifying the proportions of which are agricultural in nature).
- Identify, summarize, and analyse the technical methods of water well decommissioning as regulated and practiced across Canada (including methods in each province/territory) and four States in the United States.
- Identify and summarize the methods of outreach and promotion of well decommissioning to the public and agricultural producers specifically.

Risks Posed by Abandoned Wells

Aquifers are protected from surface contamination by overlying layers of strata. As water passes through these layers of material, contaminants are attenuated resulting in water from most freshwater aquifers to be able to be consumed or used for other purposes with minimal or no treatment. Water wells puncture the natural protective system that overlays aquifers and thus provide potential pathways for contaminants to bypass the natural systems of attenuation. Abandoned wells pose a particular risk as many were constructed improperly leaving an open annular space on the outside of the casing which can act as a direct contaminant pathway into the aquifer and also because they are prone to casing and

[1] Dewar, H. and Francois, S. (2010)

well head corrosion which expose the well to surface contamination. This can cause aquifer contamination from the surface and cross contamination from other aquifers (see Figures 1 and 2 below).

Figure 1: Contamination of Aquifer[2]

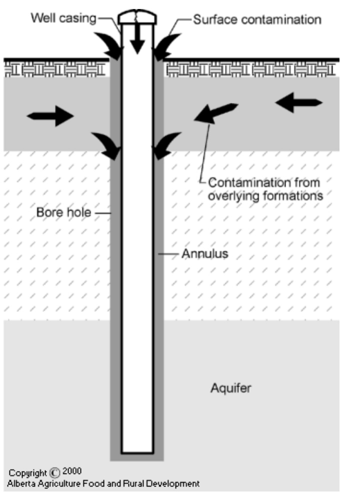
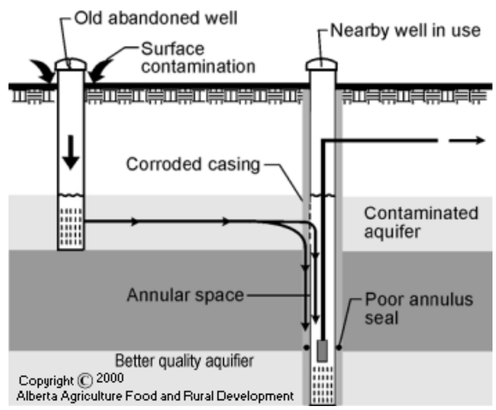


Figure 2: Potential Cross Contamination of Aquifers



Agricultural operations inherently carry some risks of groundwater pollution. The use of petrochemicals, pesticides and other chemicals poses the risk of contamination through use, storage, and spills. Livestock farms produce manure which can pose the risk of biological and nitrate contamination. The production and storage of silage can result in high concentrations of nutrients and acids. Onsite septic systems from households and buildings introduce a risk of biological contamination from human waste.

As farms have evolved from their initial homesteads to their modern state, multiple wells have likely been constructed and abandoned as they have failed or have become redundant. Many of these exist on abandoned homesteads as Canada's farming population has declined significantly over the last century.

Proper decommissioning of wells has been promoted over the last three decades, but in a limited manner. As has been indicated in other research on water well care and maintenance, water well issues tend to be 'out of sight' and therefore also tend to be 'out of mind'.[3]

Defining the risk that abandoned wells pose is difficult as contamination often goes unnoticed, and when it does, the sources of that contamination may be difficult to identify. Cause and effect may be determined when situations of acute illness occur and investigations are undertaken such as the Walkerton Inquiry[4] or in severe cases such as nitrate contamination causing *blue baby syndrome*[5]. However, for many acute conditions, such as gastrointestinal illnesses, the cause is attributed to food poisoning or person to person transmission when water from contaminated wells may be the source.

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[2] Alberta (2001) Water Wells that Last Generations (Figure 1 and Figure 2)
[3] Kreutzwiser,R. et al (2008), Summers, R.J. (2010).
[4] O'Donnel (2002)
[5] Knobeloch, LO. Et al (2000)

For many chronic illnesses with complex causality, the role of water well contamination is uncertain, however, many of the common chemical contaminants detected in water are known to be contributing factors to such illnesses.[6,7,8] Most cases of contamination of private wells are not investigated.

Research projects on private water well quality across Canada suggest that about 20 - 40 percent of private wells fall outside of safe drinking water guidelines.[9] Despite research demonstrating otherwise, the vast majority of private well owners are confident in the safety of their well water.[10,11] This sense of confidence is rooted in existing beliefs that groundwater is a safe source of water and the lack of attribution of illness events to private wells.

Estimates of Water Wells

The methods for identifying the number of wells constructed; abandoned, inactive, or decommissioned; and currently in use can be estimated through three methods. The first focuses on the supply of wells through looking at records of the number of wells constructed. The second is through considering the current and historical demand for wells which involves identifying what the demand for wells would be based upon population/household numbers in situations where water wells would almost certainly be the method of obtaining water. The third would be through surveys and inventories. It was found through a trial of possible methods that with current data limitations, demand side estimates were likely to be more effective. As such, this forms the basis for Table 1 which provides estimates for the number of wells in each province and territory.

Table 1: Estimated Number of Wells in Each Province and Territory

Province	Estimated Number of Active Domestic Wells [A]	Estimated Total Number of Active Wells [B]	Estimated Number of Abandoned Wells[C]	Estimated Number of Active Wells on Agricultural Properties [D]	Estimated Number of Abandoned Wells of Agricultural Origin[E]
British Columbia	115,000	135,000	220,000	40,000	41,000
Alberta	113,000	162,000	292,000	99,000	111,000
Saskatchewan	27,000	71,000	309,000	89,000	119,000
Manitoba	72,000	91,000	187,000	38,000	66,000
Ontario	455,000	513,000	730,000	114,000	202,000
Quebec	319,000	350,000	617,000	61,000	177,000
New Brunswick	145,000	148,000	136,000	5,500	31,000
Nova Scotia	162,000	166,000	140,000	7,600	26,000
PEI	27,000	28,700	37,000	3,400	11,200
Newfoundland	20,000	20,300	72,000	1,100	3,800
Yukon	Unknown	1,000	Unknown	Unknown	Unknown
NWT	Unknown	Unknown	Unknown	Unknown	Unknown
Nunavut	Very Few	Very Few	Very Few	Very Few	Very Few
Canada	1,455,000	1,686,000	2,740,000	458,600	788,000

A – Domestic wells refers to private household wells on agricultural and non-agricultural properties. Estimate was developed using 2010 Statistics Canada Survey on Human Activity and the Environment (CANSIM Table 153-0062), and 2006 Statistics Canada National Census of Canada.
B – Estimate includes private domestic and agricultural wells. It does not include industrial or municipal wells. Developed using 2010 Statistics Canada Survey on Human Activity and the Environment (CANSIM Table 153-0062), the 2006 Statistics Canada National Census of Canada, the 2006 Municipal Usage Database and the 2006 Agricultural Census of Canada. This estimate was arrived at by adding the estimated number of active domestic wells in the province with the number of non-domestic farm wells estimated (1 non domestic well per farm was used).
C and E – Developed using the 1951 and 1976 Censuses of Canada and information from Key Informant interviews
D – Includes wells for household and agricultural uses on agricultural properties. Developed using the 2006 Statistics Canada National Census of Canada and information from Key Informant interviews
Note: Numbers rounded to nearest 100 or 1000 depending upon magnitude and confidence in data.

[6] N.M Gatto et al, (2009)
[7] J.D. Ayotte, (2006)
[8] J. Colli et al., "(2009)
[9] G. van der Kamp and G. Grove, (*2001)*
[10] Summers, R. (2010)
[11] Kreutzwiser, R. (2008)

The details of how the estimates were arrived at and their limitations are presented in Appendix One. The estimates are provided here with limited confidence as there are simply too many gaps in the data to be able to develop accurate estimates.

The following summarizes some of the key conclusions of the methodology trial (outlined in Appendix One) that was undertaken.

1. Provincial water well databases cannot be effectively used to determine the number of wells constructed, in use, abandoned or inactive. They do provide insights into relative well densities, geologic and hydrogeological conditions, and minimum well inventories. The key problems with using the databases for inventories is that large numbers of wells were constructed prior to mandatory reporting and since mandatory reporting has been in place, compliance has been partial. As a result, a large proportion of wells are not represented in the databases.
2. Well owner surveys can be very valuable resources to develop estimates. Large surveys on water well use have been carried out in Alberta and Ontario in recent years and both provide some valuable insights into the use of private wells. However, both also have limitations in their ability to inform upon well numbers, in part because this was not the focus of the surveys, and also because the sensitive nature of abandoned wells leads to them being under reported. Future surveys should strive to collect accurate information from survey respondents regarding the numbers of wells in use, abandoned, inactive, and decommissioned.
3. Statistics Canada's recent effort to survey Canadians on their source of household water was extremely valuable for identifying the numbers of household dependent upon private wells. This data was used to develop an estimate of the number of wells in use for domestic purposes. It is considered to be a relatively accurate estimate.
4. On the ground well inventories are extremely valuable for collecting information on wells. However, very few of these have been documented in Canada.
5. Due to a lack of empirical data, the most effective method for estimating the total number of wells constructed and the number of abandoned or inactive wells is to consider rural settlement patterns along with assumptions based upon typical histories of wells on rural properties. These estimates return much larger results than estimates based upon the water well databases, but the logic behind their use is substantially stronger than those based upon the databases which are known to be incomplete.
6. The Territories present a unique challenge as many of the standard assumptions that can be used in the provinces do not hold. Additional research needs to be undertaken to determine the current extent of water wells in the Territories and the history of such wells.

Governance of Water Well Licencing and Construction

Water well licencing and construction regulations were examined for each of the Provinces and substantial variance in the scope and comprehensiveness of regulations was found between provinces.

British Columbia, Alberta, Ontario, Nova Scotia, New Brunswick, Newfoundland and PEI all limit who can construct and work on water wells through the granting of certificates based upon apprenticeship, coursework, experience and competency testing. Manitoba and Quebec require water well contractors to have licences, but obtaining a licence only requires completing a form and paying a fee; there are no competency requirements. There is currently no requirement for licensing well contractors in Saskatchewan. Both Manitoba and Saskatchewan require that the drilling rigs themselves be licenced for water well construction.

Ontario, Alberta, British Columbia, Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland provide very detailed construction standards. Ontario's standards are particularly meticulous. Other provinces have tended to rely upon older and less comprehensive regulations, many of which would be considered to be lacking relative to the standards promoted by industry.

All provinces regulate the sealing of the annulus to some degree and make clear mention of the sealing of the annular space, except Manitoba where the regulations only stipulate that surface water must not be able to enter the well. BC, AB, ON, QC, NB, NS and NL regulations require the annular sealing of all wells regardless of construction type (bored, drilled, dug, etc.).

With the exception of Newfoundland, all provinces require that a report outlining key construction methods, lithology, well type, and other information be submitted to the Ministry and sometimes the well owner. These requirements are usually identified on the official forms, not in the regulations.

Well Decommissioning

The goal of decommissioning a well is to restore the hydrogeological properties of the site.[12] This is primarily accomplished by filling the space inside the casing and any open space outside of the casing (the annulus of the well) with an impermeable material. These materials have included natural clay materials and cuttings from new wells, bentonite high solids grouts, bentonite chips and pellets, neat cement, concrete, and mixtures of sand and cement or bentonite grouts. Each of these approaches has advantages and disadvantages[13].

Decommissioning is made much more difficult by the presence of open annular space. In a properly constructed well, the annular space will be filled with impermeable material and the well will only tap a single aquifer. In practice, the annular space of older wells (and too often newer wells) is left as an open void for most of the casing string. To address this void, the casing of a well can sometimes be pulled, either in its entirety or in part. Other methods include puncturing the well casing to allow the cement or bentonite grout to seep into the annular space due to hydraulic column pressure, or puncturing the

[12] Houben, G and Treskatis, C (2007)

[13] For a detailed review see ASTM D5299-99 (2005) and Olafsen-Lackey, S. et al.(2009)

casing and pressurizing the grout to push it out into the annular space (using packers to maintain pressure in the well for a period of time).

Large diameter wells create a different challenge for decommissioning. Large diameter wells take a much larger volume of material to fill and thus, the use of grout or cement can be very expensive. As a result, it is common to use mixtures of low permeability sands with bentonite grouts to plug these wells. The risks of such wells are lower as they are often unconfined aquifers and the opportunity to see cross contamination between aquifers is reduced.

One of the key challenges has been encouraging well owners to undertake decommissioning. Survey research and Key informant interviews indicates that significant levels of apathy exist amongst well owners and as such, full subsidies for the costs of decommissioning were often required as an incentive. Research done in Ontario[14] with well owners indicated that there is a fear amongst well owners of hidden costs or responsibilities if they come forward and identify the presence of abandoned wells on their property. Key programs promoting proper decommissioning include the Ontario Drinking Water Stewardship Program (ODWSP), Manitoba Conservation District Programs, and the Federal/Provincial/Territorial Growing Forward initiative.

Well Decommissioning Regulations and Recommended Practices

The following summarizes the regulations and recommendations regarding well decommissioning in each of the provinces of Canada and in four American States that were seen to have substantial guidelines for decommissioning.

With the exception of the Ontario regulations, most regulations across Canada appear to be the result of incremental evolution from earlier sets of regulations that had spread across the country. As a result, the national landscape regarding regulations and recommendations addressing abandoned wells ranges from being very lax to being very stringent. Some provinces have very limited regulation and supplement this with more detailed recommended practices. There are often many contradictory recommendations when provincial regulations are compared and contrasted with one another. There are improvements that could be made in provinces with dated regulations that do not reflect contemporary industry guidelines.

Interviews in every province indicated severe shortcomings with regards to compliance in a number of areas. Reporting of new wells is seen as imperfect, but there is a sense that most new well reports are being submitted in most provinces and the Yukon Territory. Reporting of well abandonment across the country was considered rather dismal.

Key informants indicated mixed experiences with the professional water well industry, with some contractors being well informed with regards to well decommissioning and others not being so and as such, employing poor techniques that are not in line with industry standards or with regulations.

[14] Council of Canadian Academies. (2007)

The provinces all provide different levels of detail regarding sealing materials. One potential problem may be that bentonite grouts with 20% solids are broadly accepted as a fill material, however, in light of the weaknesses of this material in the vadose zone in the Nebraska Grout Study, perhaps this recommendation needs to be revisited. In the Nebraska Grout Study coated bentonite chips outperformed the high solids (20%) grout in their ability to prevent the movement of water in the vadose zone. These materials require less equipment and effort to install and thus are far less expensive.

There are a range of approaches to decommissioning abandoned large diameter wells in the provincial regulations. Some of the methods outlined by regulations are unlikely to successfully prevent the vertical movement of water. Approaches that integrate high quality sealants along with natural fill materials are likely to result in better outcomes than those that rely solely upon natural materials.

With more than two and a half million abandoned wells in Canada, the cost of decommissioning must be considered alongside of the efficacy of the methods used. The cost of decommissioning ranges greatly depending upon the methods employed. The approach advocated in Ontario involves the use of professional contractors and equipment. They recommend the use of down hole cameras, water quality testing, the preservation of the permeability of water producing layers and other practices that increase cost. Such decommissioning practices can be expected to costs thousands of dollars per well. Alternative methods using bentonite chips and buried bentonite 'caps' have costs that are significantly lower. Further investigation needs to be done on the relative effectiveness and cost of alternative approaches.

Summary

Issues/Trends of Concern

There are likely more than 2.5 million abandoned wells in Canada, each of which increases the risk of contamination degrading the quality of our groundwater. While efforts have been made to address this problem through decommissioning programs, an expanded and improved effort is needed from provincial agencies, federal agencies, municipal authorities, the agriculture industry, the water well industry, and others.

There are a number of concerning trends regarding abandoned wells. These are as follows:

1. Most importantly, more than 2.5 million abandoned wells pose some level of risk to our aquifers and the Canadian population. More wells are being constructed and in many cases the wells that they are replacing are not being properly decommissioned, meaning that there is an increase in the number of abandoned wells from year to year to year.
2. The limitations of the available data make estimating the number of wells constructed, wells in use, abandoned and inactive wells, and decommissioned wells very difficult. The accuracy of such estimates, including those produced in this document, are highly uncertain.

3. Reporting of well abandonment is not mandatory in many provinces, and in provinces where it is mandatory, compliance appears to range from incomplete to nearly non-existent.
4. The environmental and health risks of abandoned wells are not well defined. While it is understood that there are risks, there has been no comprehensive effort to qualify or quantify these risks.
5. Regulations in many provinces in Canada are not up to industry standards, particularly regarding the problem of open voids in annular space. In those cases, many wells that are decommissioned to provincial standards may carry a very similar risk to abandoned wells.
6. Current approaches to decommissioning wells in a comprehensive manner are very costly. With the large number of abandoned wells, the cost of addressing this could run into billions of dollars of public and private funds. The costs can be reduced substantially through the use of less expensive procedures (such as the application of bentonite chips), but the impacts of the different techniques in practice are poorly understood, thus leaving agencies and contractors to tend towards the more comprehensive and more expensive solutions.
7. Current systems of mapping aquifer vulnerability are based largely upon the attenuation effectiveness of the strata above aquifers, but abandoned wells create a bypass through these layers. As such, current mapping of aquifer vulnerability is of limited assistance in prioritizing regions and well sites for decommissioning.
8. Well owners have demonstrated a level of apathy and a level of fear of unknown costs towards the proper decommissioning of abandoned wells. Efforts to motivate well owners to decommission wells have been focused primarily upon subsidies and information provision. There has been very little research done on well owner decision making and behaviour regarding abandoned wells. As such, policy makers are essentially engaging in the use of trial and error approaches with a strong focus on comprehensive subsidies. Such an approach will be very costly given the large number of abandoned wells that may exist. More cost efficient methods may be available and could be identified through belief and behavioural research into the issue.
9. Water well contractors may face some capacity issues and knowledge issues regarding industry standards. At a base level, the industry has not fully adopted the promotion of well decommissioning, perhaps out of fear that it could increase the inherent costs in water wells as a commodity, or perhaps simply because of resistance to change.

Opportunities for AAFC and Others

This section will discuss possible opportunities for the Agri-Environment Services Branch of AAFC and others to complement existing practices and programs regarding the decommissioning of water wells on agricultural operations in addition to the work being done through Growing Forward and other programs and initiatives that promote water well decommissioning.

Improving the Information on Abandoned and Decommissioned Wells

There are three key approaches to understanding the number of wells (active, inactive, or abandoned) in regions of Canada. The first is supply based and can be explored through provincial databases. The second is demand based, and focuses on understanding the demand for wells and extrapolating out from that. The third is case based and involves extrapolating from case studies, surveys, and other forms of 'inventories' that can inform upon the actual 'on the ground' situation.

Local well inventories that include data on the quantity and location of wells in specific regions are extremely valuable in developing improved estimations of the extent of abandoned wells. Cross Canada survey research to collect information on water wells similar to the AWWS or the OHHWOS, but with an emphasis on abandoned wells included, could be very valuable in developing an understanding of the extent of working and abandoned wells.

Or, similar to research done on the Ontario Environmental Farm Plan in 2000, surveys could be undertaken with farm plan participants from various provinces to gather data.

Lastly, Provincial agencies who operate the water well databases and Water Well industry groups could improve the submission of data records to the provincial agencies.

Research on the Risk of Abandoned Wells

Research is required to develop a more comprehensive understanding of the risks that abandoned and partially abandoned wells pose. A review that integrates an understanding of surface and subsurface contaminant movement and attenuation, well construction, and health risks would be very valuable.

Improving Governance

The disparities between provincial governments regarding decommissioning are striking. While there is a need for further research into decommissioning approaches, there is room for improvement in the current techniques of decommissioning. As a national agency, AAFC could help facilitate interaction for the purposes of learning between regulating agencies.

Improving Decommissioning Approaches

The Nebraska grout study raised awareness that further research is needed on the sealing of water wells to better understand the merits and effectiveness of different approaches to decommissioning. Improving the decommissioning of wells and identifying the most effective, low cost methodologies will require research into techniques and sealing materials. Empirical research should be supported in this area.

Vulnerability Mapping for Abandoned Wells

When seeking to identify high risk areas relating to abandoned wells, vulnerability mapping should emphasize surface risks, well densities, multiple aquifer conditions, agricultural intensity, industrial intensity, and aquifer characteristics. The characteristics of the vadose zone are less important as a factor influencing vulnerability as abandoned wells create a potential infiltration bypass.

Given limited funding to subsidize decommissioning, there is value in knowing which areas should be prioritised. This type of mapping could assist in identifying those areas.

Researching Well Owner Decision Making

Over the past couple of decades, research into beliefs and decision making regarding environmentally significant behaviour has expanded significantly in behavioural economics and social psychology, at the same time similar behavioural research has taken place in public health regarding health behaviours. Much of this research addresses how people perceive risk, the impact of habits, procrastination, loss bias and other influences.

Research into what people believe about their water supply and about their ability to impact it could be very valuable. There could be substantial benefits to such research, particularly in motivating homeowners to take responsibility for their own abandoned wells. This could help to dramatically reduce the public costs of subsidizing decommissioning.

Success in broadly engaging water well owners and convincing or persuading them that well decommissioning is necessary would be very beneficial to the effort to reduce the risks posed by abandoned wells. First, a greater portion of the billions that it would cost to decommission wells could be borne by private well owners as opposed to being carried by taxpayer funded subsidies. Second, it would also be beneficial in ensuring that wells that become abandoned in the future are properly decommissioned. Third, it would help to address abandoned wells that would be missed through regulatory approaches because they are 'hidden' from the view of regulators and other agents (drillers, realtors, etc.) who could be empowered to require that a well be decommissioned. Fourth, successful persuasion efforts would create a culture of proper well decommissioning in the same manner that efforts such as other safety and health practices have become established in society.

Outreach and Partnerships with the Drilling Industry

Agricultural organizations do a tremendous amount of outreach work with the farming community. There could also be opportunities to work with the water well drilling industry to support seminars and demonstrations on well decommissioning. Some of this has taken place in Ontario when bill 903 was introduced and perhaps similar efforts have been made in other jurisdictions as well. Outreach to the industry through supporting information seminars and/or other forms of information sharing could be very influential in addressing the challenge of abandoned wells.

Water well contractors are on the proverbial front line of the problem of abandoned wells and having their informed and active involvement in addressing the issue could be critical. Well owners consider water well contractors as a primary source of good information regarding water wells and if contractors are actively promoting proper decommissioning, it will make a meaningful difference in reducing the number of abandoned water wells now and in the future.

Table of Contents

Contents

ABANDONED WATER WELLS IN CANADA: BACKGROUND REPORT

1.0 Introduction

Groundwater provides about 8.5 million Canadians with their household source of water[15]. Abandoned water wells pose a risk to groundwater by providing pathways that bypass the natural processes of attenuation that occur as water infiltrates through the earth. The risk posed by abandoned water wells can be mitigated through proper well decommissioning.

The University of Alberta was commissioned by the Agri-Environment Services Branch of Agriculture and Agri-Food Canada (AAFC) to develop a background report on the issue of abandoned water wells in Canada. This report provides a background on the issue of abandoned wells in Canada and the efforts being made by agencies to ensure that abandoned wells are properly decommissioned. The goals of the report are to:

- Identify and summarize regulations for the approval/licencing/permitting for water well construction in each Province and Territory in Canada
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- Identify and summarize the methods of outreach and promotion of well decommissioning to the public and agricultural producers specifically.

1.1 Terminology

Terminology shifts on this topic from source to source. For clarity purposes, this document will employ the following terms.

Inactive wells – wells that are currently unused but not fully abandoned, meaning that there are plans to perhaps use them again.

[15] Dewar, H. and Francois, S. (2010)

Abandoned wells – wells that have permanently ceased to serve any useful purpose or that are in a state of disrepair that they cannot be made operable again.

Partially decommissioned wells are wells that have been filled with inappropriate materials and capped or buried. These wells pose similar risks as abandoned wells and if they are located, they can be successfully decommissioned. Throughout this document, these wells will be included in the estimated counts of abandoned wells.

Decommissioning – the process of restoring an abandoned well to a state that prevents the possibility of the well acting as a pathway for contamination. Decommissioning is often referred to as abandoning or abandonment (which can be confusing) or reclaiming or reclamation.

1.2 Methodology

The report involved a literature review of relevant academic, technical, and statistical materials. The report also involved a review of outreach materials developed for the general public by agencies across Canada and in some areas of the United States. Forty two semi structured 'key informant' interviews of various lengths were undertaken with individuals involved in decommissioning programs, individuals involved in data management for water wells, and with contractors in the water well industry. Interviews were done via telephone or email. These key informant interviews were analysed using basic coding and evaluation techniques.

2.0 Risks Posed by Abandoned Wells

Groundwater exists in much greater quantities than surface water, and it is often much more easily accessed given its greater geographic distribution. Unlike surface water, which is prone to contamination due to its exposure, aquifers are protected from surface contamination by overlying layers of strata.   As water passes through these layers of material, contaminants are attenuated through biological, chemical and physical processes including filtration, sorption, oxidization, reduction, dilution, buffering, chemical precipitation, volatilization, evaporation, radioactive decay and biological decay. As a result water from most freshwater aquifers can be consumed or used for other purposes with minimal or no treatment.

Attenuation processes are most effective in unsaturated materials of limited permeability in the vadose zone (unsaturated zone) which lay between aquifers and the surface. In fractured bedrocks and highly permeable unconsolidated sediments, attenuation processes are far less effective. Attenuation processes are also far less effective in saturated zones.   As such, it is critically important that recharge water move through the soils and vadose zone prior to reaching the aquifers in order to reduce the possibility of contamination.

Water wells puncture the natural protective system that overlays aquifers and as such, they provide potential pathways for contaminants to bypass the natural systems of attenuation. Abandoned wells pose a particular threat in terms of acting as a contaminant pathway. Many were constructed improperly leaving an open annular space on the outside of the casing which can act as a direct contaminant pathway into the aquifer (see Figure 1 below). Also, due to their age, abandoned wells are prone to casing and well head corrosion which expose the well to surface contamination. As a result of this, contaminated surface water can enter the wells or move alongside of the wells very rapidly. As can be seen in Figure 2 below, these wells can result in the mixing of water between multiple aquifers potentially resulting in cross contamination due to water flowing from one aquifer to another.

Abandoned wells can also pose a physical hazard. Large diameter wells and well pits pose a risk for people or animals falling into them. Many such wells are poorly marked or covered, and in some cases the landowners are unaware that the wells even exist.

Figure 1: Contamination of Aquifer[16]

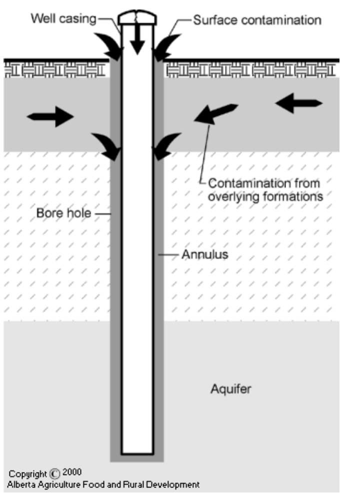
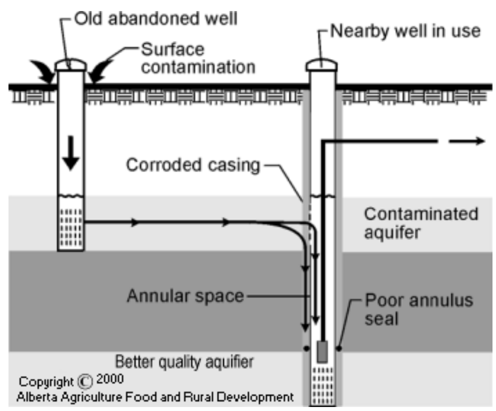


Figure 2: Potential Cross Contamination of Aquifers



2.1 Aquifer Vulnerability

In recent decades, efforts have been made across much of Canada to assess the vulnerability of aquifers to contamination. Processes of vulnerability analysis tend to focus primarily upon intrinsic factors of the geologic conditions of the saturated zones of the aquifer and the unsaturated zones through which recharge water flows[17]. Given that attenuation processes tend to be most effective in the unsaturated zones, they are given significant weight in the intrinsic vulnerability analysis. As abandoned wells provide vertical pathways that bypass the unsaturated layers allowing contaminants direct entry to groundwater and direct movement between groundwater layers, they negate the attenuation process, thus limiting the value of vulnerability mapping when considering the risks posed by abandoned wells.

Where abandoned wells are present, it may be necessary to reconsider aquifer vulnerability analysis to focus more heavily upon the intrinsic properties of specific aquifers themselves as horizontal movement becomes the primary process of attenuation. It would also be increasingly important to focus on sources of contamination as a key factor in aquifer vulnerability mapping. Information sources such as Alberta's Agricultural Intensity Index or any number of indexes relating to surface water contamination across Canada could be of value in this.

[16] Alberta (2001) Water Wells that Last Generations (Figure 1 and Figure 2)
[17] Gogu, R.C. and Dassargues, A. (2000)

2.2 Agricultural Context

2.2.1 Contamination Concerns in the Agricultural Context

While the presence of contamination of one sort or another is a common condition on the surface, agricultural operations pose a number of particular threats. Petrochemicals that are used to fuel and lubricate equipment are often both used and stored on site. Pesticides and fertilizers are sprayed broadly, but are also stored and handled on site in high concentrations. Numerous other chemicals are used for cleaning and maintenance of equipment and buildings. Livestock farms produce manure which can pose the risk of biological and nitrate contamination. The production and storage of silage can result in high concentrations of nutrients and acids. Onsite septic systems from households and buildings introduce a risk of biological contamination from human waste.

The safe handling and use of potential contaminants is the responsibility of the farmers themselves. As farming operations have industrialized over time and adopted the use of such products, a significant lag existed in the knowledge and experience required to minimize the risks of contamination. Programs such as *Farm*A*Syst* in the United States and the Environmental Farm Plan in Canada have gone a long way to improving farm practices with regards to risk management. However, even with adoption of improved management practices, contaminants at the surface will continue to threaten groundwater resources. Removing contaminant pathways such as abandoned wells is critical to ensure the protection of groundwater.

2.2.2 Logic Model for Prevalence of Abandoned Wells on Farms

As will be discussed later, estimating the number of abandoned wells can be a challenge. However, interviews with key informants indicate that a large number of abandoned wells exist. A 'farm logic model' is proposed here regarding water wells and farm evolution that can help to understand the presence of abandoned wells on Canadian farms.

The rational for multiple wells on farms, including many of which are inactive or abandoned relates to the evolution of farming in the 20th century. When farms were first settled, the new residents would have constructed a well for their own water supply. In many cases, this would have been some form of hand dug or machine dug well. Horse drawn water well rigs were a common sight across Canada through to the middle of the 20th century[18]. Given the reliance upon hand pumps or windmills for water, the high cost of piping systems, and the difficulty in burying pipe to protect it from freezing, many farms constructed multiple wells including wells for livestock (sometimes at multiple locations), for each household on the farm, and sometimes for garden areas. As farm operations began to grow and mechanized systems took over in farming and in well construction, new well designs presented themselves for exploiting groundwater. Farmers looking for a greater quantity of water or looking to replace failing dug wells could now hire mechanized drilling rigs (boring rigs, punching rigs, rotary, down hole hammers, etc) to construct wells and install full pressure systems. In many cases, these were constructed alongside of new barns or new houses. The advent of underground plastic piping provided opportunities for servicing more areas with a single well, however many farms continued to construct multiple wells to meet quantity demand or to service different areas of their property. Over time, these

[18] Summers, R.J. 2000

wells, often constructed of galvanized or steel casing would fail due to corrosion and new wells would be constructed to replace them.

In many cases, farmers might see value in the 'old' wells in that they provide options to provide water in locations without a new well, or they could be there as a back-up in case the 'new' well failed or if there was an extended power outage (for those with hand pumps or windmills). Research has indicated that humans are naturally loss averse and tend towards keeping items, even if they are of little use, because of the perceived nature of loss[19]. It was found in the 2010 Alberta Water Well Survey[20] that many well owners make the decision to leave the well as it is simply because there is no value perceived in expending the energy or costs to decommission it. There is also a fear with regards to how much decommissioning could cost. This attitude towards abandoned wells was also widely reported in the key informant interviews conducted for this report.

Proper decommissioning of wells has been promoted over the last three decades, but in a limited manner. As has been indicated in other research on water well care and maintenance, water well issues tend to be 'out of sight' and therefore also tend to be 'out of mind'.[21]

2.2.3 Understanding the Risk

Defining the risk that abandoned wells pose is difficult as contamination often goes unnoticed, and when it does, the sources of that contamination may be difficult to identify. Cause and effect can be determined when situations of acute illness occur and investigations are undertaken such as the Walkerton Inquiry[22] or in severe cases such as nitrate contamination causing *blue baby syndrome*[23]. However, for many acute conditions, such as gastrointestinal illnesses, the cause is attributed to food poisoning or person to person transmission when water from contaminated wells may be the source. For many chronic illnesses with complex causality, the role of water well contamination is uncertain, however, many of the common chemical contaminants detected in water are known to be contributing factors to such illnesses[24,25,26,27].

The risk of contamination through abandoned wells lies with the opening of pathways between the aquifers and the surface environment in which contamination is commonly present. Determining the extent of contamination that occurs through such pathways is also difficult. Most cases of contamination of private wells are not investigated and as such the pathways of contamination are not identified. Investigations only take place in notable events which are rare and sporadic in nature, and the results of such investigations have not been effectively consolidated to date. One such consolidation of case reports in Wisconsin identified nine cases of contamination in which investigations identified abandoned wells as a pathway for contamination[28].

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[19] Tversky, A. and D. Kahneman (1981)
[20] Summers, R. 2010
[21] Kreutzwiser,R. et al (2008), Summers, R.J. (2010).
[22] O'Donnel (2002)
[23] Knobeloch, LO. Et al (2000)
[24] N.M Gatto et al, (2009)
[25] J.D. Ayotte, (2006)
[26] J. Colli et al., "(2009)
[27] McKenna, D. et al (1989)
[28] WCU (1998)

Research projects on private water well quality across Canada suggest that about 20 - 40 percent of private wells fall outside of safe drinking water guidelines.[29] In a 1997 study of water wells on rural farmsteads in Alberta, more than 32 percent of wells tested exceeded at least one health related contaminant, with 14 percent having total coliform bacteria exceeding limits and six percent showing presence of fecal coliforms.[30] In a study of private wells in Ontario, approximately 40% of wells exceeded at least one health related contaminant[31]. A Nova Scotia study found pesticides in low concentrations in 41% of all wells tested[32]. Assessing the overall health impact across a population becomes somewhat of a guessing game. However, with a large proportion of wells falling outside of safe drinking water guidelines, it is reasonable to assume that there is a meaningful influence on the number of cases of short and long term illnesses in Canada.

Despite research demonstrating otherwise, the vast majority of private well owners are confident in the safety of their well water[33,34]. This sense of confidence is rooted in existing beliefs that groundwater is a safe source of water and the lack of attribution of illness events to private wells.

3.0 Estimates of Water Wells

One of the goals of the research was to develop estimates of the following for each of the provinces and territories:

- The total number of wells that are currently in use
- The number of wells that are currently in use on agricultural properties
- The total number of wells that are currently inactive or abandoned
- The number of wells that are currently inactive or abandoned on agricultural properties
- The total number of wells that have been decommissioned
- The number of wells that have been decommissioned on agricultural properties

The methods for identifying the number of wells constructed; abandoned, inactive, or decommissioned; and currently in use can be estimated through three methods. The first focuses on the supply of wells through looking at records of the number of wells constructed. The second is through considering the current and historical demand for wells which involves identifying what the demand for wells would be based upon population/household numbers in situations where water wells would almost certainly be the method of obtaining water. The third would be through surveys and inventories. It was found through a trial of possible methods that with current data limitations, demand side estimates were likely to be more effective. As such, this forms the basis for estimates of abandoned wells in Table 1.

[29] G. van der Kamp and G. Grove, (*2001)*
[30] D.A. Fitzgerald et al. (1997)
[31] Goss, et al (1998)
[32] Moerman, D, Briggans, D. (1994)
[33] Summers, R. (2010)
[34] Kreutzwiser, R. (2008)

Table 1 Estimated Number of Wells in Each Province and Territory

Province	Estimated Number of Active Domestic Wells [A]	Estimated Total Number of Active Wells [B]	Estimated Number of Abandoned Wells[C]	Estimated Number of Active Wells on Agricultural Properties [D]	Estimated Number of Abandoned Wells of Agricultural Origin[E]
British Columbia	115,000	135,000	220,000	40,000	41,000
Alberta	113,000	162,000	292,000	99,000	111,000
Saskatchewan	27,000	71,000	309,000	89,000	119,000
Manitoba	72,000	91,000	187,000	38,000	66,000
Ontario	455,000	513,000	730,000	114,000	202,000
Quebec	319,000	350,000	617,000	61,000	177,000
New Brunswick	145,000	148,000	136,000	5,500	31,000
Nova Scotia	162,000	166,000	140,000	7,600	26,000
PEI	27,000	29,000	37,000	3,400	11,200
Newfoundland	20,000	20,000	72,000	1,100	3,800
Yukon	Unknown	1,000	Unknown	Unknown	Unknown
NWT	Unknown	Unknown	Unknown	Unknown	Unknown
Nunavut	Very Few	Very Few	Very Few	Very Few	Very Few
Canada	1,455,000	1,686,000	2,740,000	458,600	788,000

A – Domestic wells refers to private household wells on agricultural and non-agricultural properties. Estimate was developed using 2010 Statistics Canada Survey on Human Activity and the Environment (CANSIM Table 153-0062), and 2006 Statistics Canada National Census of Canada.
B – Estimate includes private domestic and agricultural wells. It does not include industrial or municipal wells. Developed using 2010 Statistics Canada Survey on Human Activity and the Environment (CANSIM Table 153-0062), the 2006 Statistics Canada National Census of Canada, the 2006 Municipal Usage Database and the 2006 Agricultural Census of Canada. This estimate was arrived at by adding the estimated number of active domestic wells in the province with the number of non-domestic farm wells estimated (1 non domestic well per farm was used).
C and E – Developed using the 1951 and 1976 Censuses of Canada and information from Key Informant interviews
D – Includes wells for household and agricultural uses on agricultural properties. Developed using the 2006 Statistics Canada National Census of Canada and information from Key Informant interviews
Note: Numbers rounded to nearest 100 or 1000 depending upon magnitude and confidence in data.

The details of how the estimates were arrived at and their limitations are presented in Appendix One. The estimates are provided here with limited confidence as there are simply too many gaps in the data to be able to develop accurate estimates. The following sources were used in building estimates.

- Provincial data bases of well records
- The Alberta Water Well Survey[35]
- the Ontario Household Water Well Owner Survey (OHWWOS)[36]
- Human Activity and the Environment 2010 [37] survey by Statistics Canada
- The 1951, 1976, and 2006 Canada Censuses
- The 2006 Agricultural Census of Canada
- Milk River Aquifer Water Well Decommissioning Project[38]
- The Mount Hope Water Well Inventory[39]
- Forty-Two Key Informant Interviews[40]

The following summarizes some of the key conclusions of the methodology trial (outlined in Appendix One) that was undertaken.

[35] Summers (2010)
[36] Kreutzwiser, R. et al (2008)
[37] Dewar, H. and Francois, S. (2010)
[38] Printz, J, 2004
[39] Jaques, D. and Rohde, H. (2000)
[40] Key informant interviews were undertaken with professionals involved in agricultural outreach, water well decommissioning, water well construction, water well database management and related areas.

1. Provincial water well databases cannot be effectively used to determine the number of wells constructed, in use, abandoned or inactive. They do provide insights into relative well densities, geologic and hydrogeological conditions, and minimum well inventories. The key problems with using the databases for inventories is that large numbers of wells were constructed prior to mandatory reporting and since mandatory reporting has been in place, compliance has been partial[41]. As a result, a large proportion of wells are not represented in the databases.
2. Well owner surveys can be very valuable resources to develop estimates. Large surveys on water well use have been carried out in Alberta and Ontario in recent years and both provide some valuable insights into the use of private wells. However, both also have limitations in their ability to inform upon well numbers, in part because this was not the focus of the surveys, and also because the sensitive nature of abandoned wells leads to them being under reported. Future surveys should strive to collect accurate information from survey respondents regarding the numbers of wells in use, abandoned, inactive, and decommissioned.
3. Statistics Canada's recent effort to survey Canadians on their source of household water was extremely valuable for identifying the numbers of household dependent upon private wells. This data was used to develop an estimate of the number of wells in use for domestic purposes in Table 1. It is considered to be a relatively accurate estimate.
4. On the ground well inventories are extremely valuable for collecting information on wells. However, very few of these have been documented in Canada.
5. Due to a lack of empirical data, the most effective method for estimating the total number of wells constructed and the number of abandoned or inactive wells is to consider rural settlement patterns along with assumptions based upon typical histories of wells on rural properties. These estimates return much larger results than estimates based upon the water well databases, but the logic behind their use is substantially stronger than those based upon the databases which are known to be incomplete.
6. The Territories present a unique challenge as many of the standard assumptions that can be used in the provinces do not hold. Additional research needs to be undertaken to determine the current extent of water wells in the Territories and the history of such wells.

4.0 Governance of Water Well Licencing and Construction

The following is a brief summary of the regulations for water well construction across Canada. More detailed information can be seen in Appendix Two.

4.1 Licencing

British Columbia, Alberta, Ontario, Nova Scotia, New Brunswick, Newfoundland and PEI all limit who can construct and work on water wells through the granting of certificates based upon apprenticeship, coursework, experience and competency testing. These provinces also all have a tiered licencing system where individuals with different classes of licences can perform different levels of activities.

[41] Sustainable Water Well Infrastructure Expert Panel (2006)

Manitoba and Quebec require water well contractors to have licences, but obtaining a licence only requires completing a form and paying a fee, there is no competency requirements. There is currently no requirement for licensing well contractors in Saskatchewan. Both Manitoba and Saskatchewan require that the drilling rigs themselves be licenced for water well construction.

4.2 Well Construction

Provincial well construction regulations feature a good deal of overlap in their individual requirements, but there is a distinct difference in the level of regulatory detail provided by the provinces. The level of detail in water well regulations has increased over time and as such, provinces that have more recently updated their regulations tend to have the greatest level of specificity and detail in their regulations.

Ontario, Alberta, British Columbia, Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland provide very detailed construction standards. Ontario's standards are particularly meticulous, a result of the provincial process to improve water regulations that came out of the Walkerton Inquiry. Manitoba and Saskatchewan provide very limited detail in their regulations leaving most of the decision making with regards to construction up to the contractors. It is worth noting that Saskatchewan's groundwater regulations have not been seriously revisited since 1966. Quebec's regulations fall between the specificity of the more detailed regulations of provinces like Ontario and those of Saskatchewan and Manitoba.

Details are summarized below and outlined more clearly in the Appendixes.

4.2.1 Well Yield Testing:

Alberta, Nova Scotia and Ontario all provide detailed descriptions of the well yield methods within the regulations. Most require a yield test by a pump or bailer test and measurements of the static, pumping and post-pumping water levels as well as the water level recovery rate. The other provinces require yield tests on completed wells but provide less detail on the required methods for testing yield and the yield test time-frames.

4.2.2 New Well Disinfection:

Alberta and Ontario both state clear disinfection procedures in their regulations that included specified rates and durations of chlorine use. PEI's regulations also specify chlorine disinfection albeit with less detail than the previous two provinces. British Columbia regulates who may disinfect a well, but provide no details regarding disinfection methodologies. The rest of the provinces state that disinfection of the well is required, but provide no details or specifications.

4.2.3 Artesian Flow:

All the provincial regulations state that flowing wells must be controlled or stopped by fitting a cap or flow control device.

4.2.4 Aquifer Protection Measures:

All provinces except Quebec and Saskatchewan have regulated prohibitions on allowing contaminants to enter through the well head or annulus. In some cases this includes specific descriptions of contaminants such as chemicals, sewage, carcasses, refuse or fertilizers (in BC, MB, ON, NB and NL). The requirement to ensure that the casing is sealed through its length is regulated in Nova Scotia and New Brunswick and regulated action to address the occurrence of saline water is stated in the regulations of Alberta, Newfoundland and British Columbia.

All provinces regulate the sealing of the annulus to some degree and make clear mention of the sealing of the annular space, except Manitoba where the regulations only stipulate that surface water must not be able to enter the well. BC, AB, ON, QC, NB, NS and NL regulations require the annular sealing of all wells regardless of construction type (bored, drilled, dug, etc.). In these provinces, the regulations specify the use of specific sealant materials, most commonly a bentonite or cement grout and in the case of larger diameter wells the use of other materials such as sand, gravel or clay in conjunction with impermeable grouts (AB, ON, NB and NS).

All provinces except Newfoundland, Manitoba and Saskatchewan regulate different length and depth requirements for annular seals depending on the well depth, casing length and/or casing type.

4.2.5 Well Location

All provinces provide regulations on the site locations of water wells. Regulations for the distance from common categories of contamination sources, and from buildings, are listed for all provinces except Manitoba which provides only a regulation that wells need to be located at a 'safe distance' for sources of contamination. Distances of wells from contamination sources are commonly regulated by categories such as sewerage storage or conduits in various forms, petroleum storage facilities, animal waste sources or storage facilities and dwellings. Alberta and Ontario provide the most category listings and most detailed regulations. The eastern provinces of New Brunswick, Nova Scotia, PEI and Newfoundland all regulate similar distances and share similar location regulations. Saskatchewan regulates distance from only four types of potential groundwater contamination and British Columbia from only three types.

4.2.6 Well Construction Requirements

Well construction regulations typically refer to casing specifications and related equipment such as vents. Casing standards laid down by the American Society for Testing Materials and Canadian Standards Association are required for new well casings in Alberta, Ontario, Quebec, Nova Scotia, PEI, Newfoundland and New Brunswick (only for plastic casings in NB). Other provinces have no guidelines regarding casing materials or standards. Minimum casing lengths and diameters are regulated in Ontario, Quebec, New Brunswick, Nova Scotia an PEI. Casing wall thickness relative to casing diameter is regulated in Alberta, Ontario, New Brunswick, Nova Scotia and to a limited extent on PEI.

Connections made to well casings underground must be sealed in order to be water tight using an impermeable material like cement in Alberta, Ontario, Quebec, New Brunswick, Nova Scotia and Newfoundland.

Minimum casing extension above ground surface is stipulated in the regulations in British Columbia, Quebec, PEI (all with minimum height of 30cm), Alberta (minimum height 20cm), Ontario (minimum height 40cm), Nova Scotia and dug wells in New Brunswick (both 15cm minimum).

4.2.7 Well Reporting

With the exception of Newfoundland, all provinces require that a report outlining key construction methods, lithology, well type, and other information be submitted to the Ministry and sometimes the well owner. These requirements are usually identified on the official forms, not in the regulations. Many set deadlines for submission from 'upon completion' for BC to 60 days for Alberta and Prince Edward Island. Newfoundland, New Brunswick and Nova Scotia do not have deadlines. In Ontario, British Columbia, and New Brunswick permanent well identification tags (plates) must be affixed to new wells.

5.0 Well Decommissioning

Well decommissioning is a process which seeks to restore the hydrogeological characteristics of the area to its original state prior to well construction and to prevent the possibility of the abandoned well from acting as a conduit for contaminants from the surface or for the cross contamination of aquifers.

There are a number of techniques for the decommissioning of wells. These have evolved over the past half century, but in recent years, research has raised some questions regarding the effectiveness of previously accepted approaches. Regulations regarding well decommissioning differ from jurisdiction to jurisdiction. In addition to regulations, provinces and other organizations have undertaken outreach efforts which present recommended practices that may differ from those that are outlined in the regulations.

One of the key challenges in well decommissioning has been motivating well owners to decommission wells as opposed to leaving them abandoned or inactive. Depending upon the approaches used, decommissioning can be expensive, and as mentioned earlier, many well owners perceive such wells as having little risk. As a result, there is a tendency for many homeowners to not undertake proper decommissioning. In many jurisdictions in Canada, programs have been developed to encourage residents to decommission wells through the use of information provision, outreach, and direct subsidies.

5.1 Technical Aspects of Decommissioning

The traditional approach to decommissioning wells was to cover it with something to prevent anyone from falling in, or to fill it up with refuse or available dirt. Key informant interviews and some published materials suggest that these practices remain common today. A number of approaches have been developed for the proper decommissioning of wells. All involve the 'filling in' of the well with some form of material, usually a bentonite or cement grout product, to prevent the vertical movement of water. There are a number of other components to this process though. These are discussed below.

5.1.1 Removing Pumping Equipment

The removal of pumping equipment is important for two reasons. The first is that the equipment (piping, wiring, pump rods) can frequently act as a conduit for the movement of water if it remains in the well. Thus, without removing the pumping equipment, it would be possible to fill the well with appropriate grouting material only to have a pathway for contamination remaining. Second, the equipment could act as a barrier for the successful filling of the well space with materials.

5.1.2 Restoring the Hydrogeological Properties of the Site

The goal of decommissioning a well is to restore the hydrogeological properties of the site.[42] There are three goals to this. The first is to prevent vertical movement of water in the vadose zone. This prevents surface water from rapidly moving downwards and bypassing attenuation processes. The second is the restoration of aquitards. This is similar to the first goal in that it seeks to prevent the vertical flow of water. The third goal is to maintain the flow of water through the aquifer. This is frequently less of a concern as the well itself is a point of impact for the aquifer which usually extends some distance in both cardinal directions and as such the single point impact should be minimal on the overall conditions of the aquifer. In some materials, such as highly fractured bedrock, fluid based grouts may flow deep into the aquifer and have impacts on the aquifer performance.

In theory, decommissioning wells in such a manner that reflects the original hydrogeological state involves mimicking the layers of strata that existed previously. In most cases, the key focus is on preventing the unwanted movement of water in a vertical direction. As mentioned above, the localized impediment of aquifers is of less concern. This can be done by focusing on filling the inside of the casing up with an impermeable material. These materials have included natural clay materials and cuttings from new wells, bentonite high solids grouts, bentonite chips and pellets, neat cement, concrete, and mixtures of sand and cement or bentonite grouts. Each of these approaches has advantages and disadvantages[43].

Natural clays are problematic as a fill material and as such are not recommended (sometimes with exceptions for large diameter wells). The problem with natural clays is that if they are left in solid form, they have a tendency to bridge in the well, leaving voids, they also have a tendency to leave voids between clay pieces. When natural clays are mixed in a slurry, they will most often shrink as they lose moisture, thus leaving voids that could allow for the movement of water in the non saturated portions of the well.

Cement grouts and bentonite high solids grouts are products that can be mixed into a slurry and pumped into a well using a tremie pipe which fills the well from the bottom up (lifting the pipe during the process) ensuring that the entire space is filled and that any water in the well is pushed upwards and out of the well as the grout fills it. Both require specialized equipment for mixing and pumping. The concerns with using cement based grout are that there are concerns of contraction when drying and there have historically been concerns with it not bonding to casing walls[44]. More recent research done as part of the Nebraska Grout Study[45] have indicated that cement based grouts were more effective than bentonite based products in sealing the annular space in wells, particularly when the cement was mixed with a small percentage of sand. Contraction and cracking concerns were less of a concern than

[42] Houben, G and Treskatis, C (2007)
[43] For a detailed review see ASTM D5299-99 (2005) and Olafsen-Lackey, S. et al.(2009)
[44] Sterrett, R. (2007)
[45] This study examined the use of different products to fill the annulus of newly drilled wells. It employed the use of clear pvc casing so that the behaviour of the grouting materials could be observed.

previously suggested[46]. These tests also found that adding bentonite grout to the cement mix (a common practice in the industry) resulted in the sealant being less effective. Bentonite grout slurries, which had previously been lauded as more effective as it remained more malleable and was suspected of bonding to casing better, was proved to be far less effective than cement based grouts as moisture was wicked away by the vadose zone materials. The bentonite grouts (of various solid contents) contracted more than the cement due to this wicking action and thus, created voids, and also failed to bond to the casing. Penetration tests using dye demonstrated that the bentonite grouts were less effective in sealing the annulus (the tests were on sealing annular space) than other methods.[47] It should be noted that all of these difficulties were in the vadose zone where the products were exposed to drying processes, in the saturated zones all products performed very well.

Bentonite grout may fair significantly better in decommissioning operations inside of the casing because it will stay hydrated much longer as opposed to the materials that are in direct contact with the vadose zone. However, in many decommissioning approaches, there are efforts to ensure the annulus is filled through removing or puncturing the casing. This would open up the problem of moisture being wicked away by the vadose zone materials. Further research will need to be undertaken to determine if this is the case. The studies suggested that bentonite products with very high levels of solids, such as a mixture of sand to bentonite of 4 to 1, may be effective. Again, further research is needed.

Coated bentonite chips and pellets both performed very well in the Nebraska Grout Study. If properly installed, these products have many advantages for decommissioning wells. Given their compressed nature, they expand when wet and do not contract when drying in the same manner as fluid grouts do. They do have the tendency to 'bridge' when being poured into the annulus of new wells or into the casing of a well that is being decommissioned (when water is present). This can be avoided if proper techniques are followed, particularly in terms of the rate of application. This can be a problem in practice as the rate is much slower than that which is 'natural' for pouring. Techniques such as the use of a small container (300 ml or less) with the grout source sitting a full arm's length away from the well can help to counter natural tendencies to go quicker. Chips and pellets are inexpensive for grouting wells as no equipment is needed for their installation. They are a viable and low cost option when the goal is to fill the space inside the casing or when filling a hole that the casing has been removed from.

Decommissioning is made much more difficult when the annular space is considered. In a properly constructed well, the annular space will be filled with impermeable material and the well will only tap a single aquifer. In practice, the annular space of older wells (and too often newer wells) is left as an open void for most of the casing string. The space may be filled from above with cuttings or other materials that bridge near the top few meters of the well, leaving a large void alongside of the casing in the well. This means that on the outside of the casing, a vertical void exists which allows for the rapid vertical movement of water. Such voids can remain open indefinitely in most strata. This can frequently result in aquifer cross contamination as such voids may cross multiple aquifers and aquitards.

To address this void, the casing of a well can sometimes be pulled, either in its entirety or in part. There are challenges to this, including the possibility of a collapse of the sidewalls which might fail to seal the

[46] Olafsen-Lackey, S. et al.(2009)
[47] Olafsen-Lackey, S. et al (2009)

well effectively. To avoid this problem, the well can be filled with cement or bentonite grout in a fluid form prior to pulling the casing. Other methods that involve leaving the well casing in place, include puncturing the well casing to allow the cement or bentonite grout to seep into the annular space due to hydraulic column pressure, or puncturing the casing and pressurizing the grout to push it out into the annular space (using packers to maintain pressure in the well for a period of time). All of these approaches may be effective, but they also add expense onto the decommissioning projects.

An alternative would be to excavate the first few meters of a well (2-3 meters) to identify if an open annulus exists around the surface casing. Key informant interviews with water well contractors indicated frequent observations of open annular space beginning within the first few meters of the surface (these observations are made when excavating wells to repair pitless adapters). When open annular spaces are identified through excavation, they could be filled with bentonite chips.

Large diameter wells create a different challenge for decommissioning. Large diameter wells take a much larger volume of material to fill and thus grout or cement is very expensive. As a result, it is common to use mixtures of low permeability sands with bentonite grouts to plug these wells. The risks of such wells are lower as they are often unconfined aquifers and the opportunity for cross contamination between aquifers is reduced.

5.1.3 Surface Completion

After decommissioning, wells are often cut off below the surface (if the casing remains) and buried. On top of the abandoned well, a cement or grout cap is formed. This cap should be large enough so that it directs water away from the well and the annular space (even though they are filled). The greater the depth that the well is buried to, the greater the overlay of material that functions as an attenuating agent prior to surface water reaching the decommissioned well. It is important that the overlaying material be tamped well to prevent voids that could accelerate vertical movement of water.

5.2 Promoting Decommissioning

One of the key challenges in water well decommissioning has been encouraging well owners to undertake decommissioning. The OHWWOS found that well owners had positive attitudes towards the decommissioning of wells with 88% of those surveyed in agreement that unused wells should be properly decommissioned. However, both the AWWS and the OHWWOS found that home owners were largely apathetic to the decommissioning of their own wells. Key informant interviews also indicated significant levels of apathy existed amongst well owners and as such, full subsidies for the costs of decommissioning were often required as an incentive. They also indicated that other key motivating factors for decommissioning were concerns over liability for the contamination of aquifers, and concerns over someone being harmed by falling into the well (mostly for large diameter wells).

Research done in Ontario[48] with well owners indicated that there is a fear amongst well owners of hidden costs or responsibilities if they come forward and identify the presence of abandoned wells on their property.

[48] Council of Canadian Academies. (2007)

In most provinces, there are efforts to promote and inform well owners with regards to the benefits and practices of proper well abandonment. There are also programs that provide financial assistance/incentives towards decommissioning wells. The following is a brief summary of the major subsidy programs in Canada. These programs typically work through local level initiatives in each of the provinces. In addition to these, there are a number of smaller scale programs funded by local municipalities that provide incentives.

5.2.1 ODWSP – Ontario Drinking Water Stewardship Program

The creation of the Clean Water Act in 2006 along with Conservation Ontario's (Ministry of the Environment) mandate to provide clean drinking water to its citizens led to the creation of the Ontario Drinking Water Stewardship Program (ODWSP). The ODWSP is a technical and financial assistance program aimed at aiding landowners in the reduction of threats to drinking water sources. Funding for this program is provided by the Ontario Ministry of the Environment through partnerships with Conservation Authorities and municipalities across Ontario. The first phase of early actions consisted of septic system decommissioning and upgrading, runoff and erosion control measures, pollution prevention reviews for small businesses, best management practices, public education and well decommissioning. $21 million was available from 2008 through to 2011. 80% of the cost of the project up to $4000 was covered within these parameters: required permits and approvals for the project(s), purchased material and supplies, contract labour (e.g., electrical and plumbing), professional fees/technical support, fees for related design, inspection and construction.

The well decommissioning funding is offered to properly seal abandoned wells and secure improperly sealed business, institutional, house and farm wells. Eligible funding requires that: "the applicant's property be within or extend into the 100-metre radius of a municipal wellhead, the 200-metre radius of a municipal surface water intake, the 2-year time of travel around a municipal well, or the IPZ-1 (intake protection zone one) around a municipal surface water intake as accepted through a municipal council resolution (Conservation Ontario, 2009)."

The ODWSP is offered through partnerships with regional Conservation Authorities (CA's) and municipalities. This program's existence and subsequent eligibility stems from the Walkerton Inquiry and the resulting Clean Water Act. Many private wells do not fall under the requirements above and therefore CA's and municipalities have initiated their own programs to deal with abandoned wells.

Many of these CA's and municipal districts in partnership with local cities and towns offer decommissioning outreach programs of their own. Some examples include the Ottawa Rural Clean Water Grants Program, South Nation Conservation Clean Water Program Grants, Upper Grand River Rural Water Quality Program, Niagara Peninsula Conservation Authority Waterwell Decommissioning Grant Program, Region of Peel's Private Well Abandonment Program and the Lake Simcoe Water Quality Improvement Program.

5.2.2 Manitoba – Conservation District Programs

The Conservation Districts in Manitoba administer and fund their own regionally based well decommissioning outreach programs. These programs provide all resources needed to seal the abandoned well and require landowners to pay a percentage of the total cost in the form of a deposit or flat fee ranging from $25-$150 dependent on the program. The Conservation Districts framework provides information and funding access to interested landowners.

5.2.3 Growing Forward

The Growing Forward innovative Federal/Provincial/Territorial agriculture program provides funding for decommissioning and sealing of abandoned water wells. The decommissioning programs are typically under the water management sections of the Beneficial Management Practices component of each Provincial Growing Forward program. The levels of funding vary inter-provincially for example, 50% to a maximum of $2000 in Alberta and 75% up to a $6000 maximum in Saskatchewan. Each province also has its own eligibility requirements that normally entail participation in the Provincial Environmental Farm Plan (or equivalent). The Growing Forward initiative is rooted in earlier iterations of the Environmental Farm Plan and it is, by far, the largest effort to address abandoned wells in the country to this point.

6.0 Well Decommissioning Regulations and Recommended Practices

The following summarizes the regulations and recommendations regarding well decommissioning in each of the provinces in Canada and in four American States that were seen to have substantial guidelines for decommissioning. Recommended Practices were taken from outreach materials put out by the provinces and their partner agencies in promoting proper well decommissioning.

6.1 British Columbia

6.1.1 Regulations

6.1.1.1 Decommissioning Mandated

In British Columbia, if a well is not kept working on a regular basis for at least 5 years the owner must deactivate (temporarily close) or close (permanently seal and decommission) the well, or if the well has been deactivated for 10 years the owner must close the well unless:

- the well is intended as a backup water supply.
- the owner intends to put the well into service
- the well has yet to be used.

Otherwise the well must be deactivated (secure and protect the well while out of service) or closed (permanent decommissioning).

An engineer may also order the closure of a well within 90 days, or at least the alteration of a well in lieu of closure, where it is deemed necessary to mitigate a ground water or public safety threat.

Decommissioning is the responsibility of the well owner of the land owner where the well is situated if the land owner does not know who owns the well.

6.1.1.2 Who Can Decommission Wells

Most well decommissioning procedures must be performed by a licenced contractor. Any well less than 5 meters or any dug well less than 15 meters can be decommissioned by the well owner.

6.1.1.3 Decommissioning Standards

The well casing may be left in place. The well must be filled throughout its depth with a combination of appropriate sealants and backfill materials and with a closure plug in the upper portion of the well. Sealant plugs must be minimum 3 feet (0.91m) thick; the top plug in wells deeper than 15ft (4.57m) must be at least 15 feet (4.57m). Space between sealant plugs cannot exceed 20ft (6m) and should be backfilled with an appropriate material. Attempts must be made to re-establish impermeable layers through which the well extends by placing a sealant layer adjacent to the impermeable layer. Appropriate sealant materials include:

(a) a non-toxic, commercially available material or mixture of materials, including

(i) bentonite clay,

(ii) bentonite clay and water mixture,

(iii) bentonite clay and sand and water mixture,

(iv) neat cement grout,

(v) sand cement grout, and

(vi) concrete grout, or

(b) a non-toxic material or mixture of materials that has a lower permeability than the surrounding geologic formation to be sealed;

6.1.2 Recommended Practices[49]

BC's recommendations are very limited and do not really inform well owners how to undertake the process. No instruction or technique is provided.

6.2 Alberta

6.2.1 Regulations

Alberta has one of the more comprehensive sets of regulations in the country.

6.2.1.1 Decommissioning Mandated

If a well is abandoned after completion, is in disrepair or produces non-potable water the owner is required to decommission the well. If a well is not completed due to construction problems or lack of required yield the driller must reclaim the well and the driller or approval holder must submit the details in the drilling report.

[49] http://www.bcgwa.org/files/handbook/TAB_1.pdf

6.2.1.2 Who Can Decommission Wells

Wells can be decommissioned by water well contractors or homeowners.

6.2.1.3 Decommissioning Standards

The water in the well must be flushed and cleaned of foreign materials, then disinfected with 200mg of chlorine per litre of water in the well.

All material must be removed and where the removal of the casing or other equipment is not possible it should be cut off at least 0.5m below ground surface.

The length of the well must be filled to prevent vertical water movement within the well bore.

The filler material must not have an adverse effect on safety, health or the environment. Suitable substances include bentonite, cement, concrete, clay or other clean impermeable slurries such as well cuttings or overburden materials. These materials must be introduced in a way that prevents their dilution or segregation. This includes using a tremie or grout line for slurries for example.

The uppermost 0.5 metre of the borehole up to the ground surface of the water well where the casing removal or cutting excavation took place must be backfilled with material appropriate for the intended use of the land.

6.2.1.4 Recommended Practices[50]

Alberta provides recommendations, but they lack clarity and it would be difficult for a homeowner to follow without additional information. It would also be difficult for most homeowners to undertake many of the practices such as the removal of casing.

It is recommended that the casing be removed first if possible. If the casing cannot be removed, it suggests that a slurry method of filling the well will be required and that pellets cannot be used. Interestingly, it gives instructions on how to use pellets in filling a well and preventing bridging in the casing (with a diagram). If pellets are to be used, they recommend that care be taken in pouring to prevent bridging (however, the normal recommendation of pouring pellets very slowly is not mentioned, rather the focus is on breaking up bridges if they occur, which may not be possible).

If a slurry approach is used, grout, neat cement, sand-cement, concrete, clean clay or high yield bentonite (no percentage indicated) is recommended, with bentonite being considered the superior option as it is suggested that it will not shrink. If a slurry method is used, they recommend hiring a contractor.

Upon completion, the recommendation is to cut the casing (if it remains) 0.5m below the ground surface and backfill with a material such as clay. No bentonite or cement cap is mentioned as a recommendation.

Limited information is provided regarding large diameter wells. It indicated that clay should be used in a manner that seals off the well and that it should be cut below the ground surface.

[50] http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/wwg414

6.3 Saskatchewan

6.3.1 Regulations

6.3.1.1 Decommissioning Mandated

If the well is abandoned or no longer in use it must be decommissioned in a manner that prevents the vertical movement of water.

6.3.1.2 Who Can Decommission Wells

There are no restrictions specified.

6.3.1.3 Decommissioning Standards

For wells with a diameter of 18 inches (0.45m) or less the casing, screen and similar material must be removed and the well filled with cement or approved heavy drilling mud. Alternatively the casing must be cut off at least 2 feet (0.61m) below the surface of the ground and a steel plate or other approved cap must be securely fitted to the top of the casing. The excavation above must be backfilled with compacted earth.

6.3.1.4 Recommended Practices

Saskatchewan provides detailed explanations with regards to well decommissioning that target well owners with the goal of assisting them to undertake the process themselves for bored wells. They indicate that a qualified contractor with special equipment will be needed to decommission a drilled well.

The recommendations indicate that sand and gravel that is free from silt can be used to fill a bored well (large diameter well), but that bentonite clay seals (using chips) should be put in place to ensure that water cannot move in the well. Details are provided with regards to how and to set the grout chips. The top ten feet of a bored well should be removed and build a large bentonite cap over the well extending over the edges of the well.

They indicate that neat cement with 3-5% bentonite powder or high solids bentonite grout (20%) are suitable for filling drilled wells and that either product should be pumped into the well using a tremie line. Pellets and chips are not recommended as they could bridge partway down the well preventing the proper sealing of the well. The top ten feet of casing should be removed and a bentonite cap developed on top. The excavation should then be backfilled with a clean non permeable material like clay which is compacted at one foot intervals. They do not indicate that the casing should be removed or punctured.

6.4 Manitoba

6.4.1 Regulations

6.4.1.1 Decommissioning Mandated

If a well is dry or abandoned it must be sealed to prevent the vertical movement of water within it. If an official feels that a well has become contaminated, is improperly capped or has been abandoned the official may order the owner to cap, rehabilitate or seal the well.

6.4.1.2 Who Can Decommission Wells

There are no restrictions specified.

6.4.1.3 Decommissioning Standards

Where a well is dry or abandoned, the owner shall fill and seal it in a manner sufficient to prevent the vertical movement of water in it

The provincial government may choose to regulate the decommissioning of wells and prescribe methods to be used and precautions to be taken in decommissioning if deemed necessary.

6.4.1.4 Recommended Practices[51]

Manitoba provides a short, but helpful technical information sheet (6 pages) on decommissioning wells.

Landowners can decommission their own wells but it is recommended that they get professional help in certain situations such as with flowing wells.

For smaller diameter wells up to 100ft (30.5m) deep they recommend adding bentonite chips from ground level and filling the well space up to 4ft (1.2m) from the top of the casing. They recommend then removing the top 4 ft (1.2m) of casing. This 4 foot (1.2m) deep excavation should then be filled with clay and earth mounded on top of that.

For wells deeper than 100ft (30.5m) or greater than 6" (0.15m) in diameter, sand can be used to fill up the well with a 3ft (0.91m) layer of bentonite chips for every 10-15ft (3m-4.57m) of sand to create impermeable layers. The first 10ft (3m) of the bottom of the casing should be filled with bentonite chips then the sand layers can be added until within 4 ft (1.2m) of the top of the casing. The top 4 feet (1.2m) of casing should then be removed the excavation filled with clay and a topsoil mound.

Small diameter wells with well pits should be filled the same way and the pit should be filled with clay after the pit cribbing has been removed. If clay is difficult to find locally then the bottom of the pit can be filled with a layer of bentonite chips (after the well has been filled) and then the rest of the pit can be filled with sand, with an earth mound over it.

For large diameter wells the use of sand is recommended. Fill the well to within 12ft (3.6m) of the top of the casing and then the last 12ft (3.6m) should be removed, which normally involves excavation with a backhoe. If this is not possible then at least the top 4 ft (1.2m) of casing should be removed. The top 12ft (3.6m) should then be filled with local clay, topped with an earth mound. If clay is not locally available then a layer of bentonite chips or compacted clay should be added at the 12ft (3.6m) level, then filled with sand up to the 4ft (1.2m) level and then another layer of clay and bentonite chips added on top of that. The top 4 ft (1.2m) can be filled with sand, or preferably compacted clay, followed by an earth mound.

There is no indication of removing the entire string of casing, or puncturing casing. The details on creating a bentonite cap are very limited.

[51] http://www.gov.mb.ca/waterstewardship/water_info/misc/abandoned_wells.pdf

6.5 Ontario

6.5.1 Regulations

Ontario has, by far, the most detailed regulations in Canada. This is, in part, due to the regulatory movement around water supplies following the Walkerton tragedy.

6.5.1.1 Decommissioning Mandated

With some exceptions, existing wells must be properly decommissioned if any of the following conditions occur.

- a newly purchased well is dry
- there is no intention for future use of a well
- the well produces mineralized water, gas or otherwise un-potable water
- the well permits the movement of contaminants' between subsurface formations or between these formations and the ground surface that may impair water quality
- a well is constructed in contravention of the well construction regulations and cannot be rectified

6.5.1.2 Who Can Decommission Wells

The well owner, anyone working without remuneration, or a licenced water well contractor can decommission wells.

6.5.1.3 Decommissioning Standards

If the casing or screens have collapsed, all reasonable efforts should be made to remove them. If they cannot be entirely removed then they should be removed, if possible, to at least 2m below round surface. Below ground structures, slabs or foundations also need to be removed where possible or safe.

For wells less than or equal to 6.5cm in which the casing has been removed, a neat cement (with 5% bentonite) slurry or a minimum 20% bentonite slurry can be used with a tremie pipe, if the casing has been removed. If the casing is in place then the neat cement (with 5% bentonite) slurry or bentonite chips can be used.

For wells greater than 6.5cm in diameter the well or borehole must be filled with one of:

- a slurry of at least 20 per cent bentonite solids
- a slurry of Portland cement and maximum 5 per cent bentonite
- a slurry consisting of Portland cement
- a slurry of Portland cement and clean sand
- a slurry of equal weights of Portland cement and clean gravel
- a slurry of Portland cement, clean sand, and clean gravel (concrete)
- bentonite chips or pellets
- washed sand or gravel only in water producing or fracture zones
- other material approved in writing by the director

Slurries must be placed with a tremie pipe.

For wells greater than 65cm in diameter (and for well pits), clean sand or gravel must be placed at the bottom of the well to the top of the water producing zone or top of the screen, whichever is deeper. This must be covered with at least 0.1m of bentonite chips. If the water can be drawn down to the top of these chips then another layer, at least 0.3m thick, of bentonite slurry (min 20% bentonite content) should placed over the chips. The remainder of the well must be filled with sand, silt, clay or gravel and a minimum 0.3m layer of bentonite slurry must be maintained over the rising accumulation of this fill.

If the water level cannot be drawn down to the top of the bentonite chips, the remainder of the well must be filled to approximately 2m below the ground surface with an abandonment barrier, which may be interspersed with sand or gravel placed in each water producing zone of the well.

For all wells, the top of the well must be sealed with a layer of 50-150cm vertical thickness bentonite placed in the excavation. The remaining vertical height of the excavation can be filled with soil cover. The excavated area must be stabilized to prevent erosion.

6.5.1.4 Recommended Practices[52]

Ontario provides a 70 page document on decommissioning wells. It is too detailed to outline completely here, but it provides instructions on various types of wells. The key elements will be discussed here.

The document recommends that a down-hole camera be used to assess the well for biofouling. It also recommends that testing be done to determine if materials in the water would react with the plugging materials (high TDS or high chlorides). To assess the analysis of the water it suggests that the services of a professional engineer or geoscientist may be required.

The document indicates that while the Ontario regulations allow for well owners to decommission their own wells, it suggests that this is virtually impossible to accomplish given the equipment and technology required. The document is clearly written to discourage well owners from decommissioning their own wells. "Although the Ontario Water Resources Act and the Wells Regulation allow residential well owners to abandon their own wells without a licence, the equipment, materials and expertise needed to comply with the requirements under the Wells Regulation far exceed the average well owner's abilities and resources". Additionally it warns that "land owners who improperly plug wells may face enforcement actions and additional legal liabilities (e.g. property and environmental damage, personal injury). Re-drilling, re-excavating, and having to plug and seal the well a second time creates a significant increase in costs that could have been avoided if the original plugging and sealing was properly completed."

The document recommends that on all wells, the barrier must be placed from the bottom of the well upwards until approximately within 2 m of the ground surface. In addition to the decommissioning materials listed above in the regulations, the document indicates that clean washed sand or gravel be used in water producing zones to prevent interfering with the aquifer flow. If possible during or after the placement of the barrier, the casing must be removed. Any collapsed casing or screen should be removed as effectively as possible. If not feasible then at least the first 2m below the ground surface

[52] http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_076344.pdf

must be removed. In essence, the recommended practices are a more accessible version of the regulation with a bit of added detail.

In addition to guiding homeowners (and contractors) through the very detailed requirements of Ontario's water well decommissioning regulations, the document makes an effort to teach individuals about the specifics of well abandonment, for example, there is a detailed table that outlines the advantages and disadvantages of different barrier (grouting) materials.

6.6 Quebec

6.6.1 Regulations

6.6.1.1 Decommissioning Mandated

The owner must decommission the well if:

- pumping equipment has not been installed 3 years after completion.
- pumping has been interrupted for at least 3 years;
- a new work intended to replace it is installed
- where the catchment work is non-productive or does not meet the owner's needs.

If the owner does intend to fit a pump, the first requirement can be suspended if the owner expresses this in a notice filed to their municipality. This notice must be renewed every 3 years.

6.6.1.2 Who Can Decommission Wells

There are no limitations on this

6.6.1.3 Decommissioning Standards

Quebec has no regulations regarding the techniques of well decommissioning

6.6.1.4 Recommended Practices

Quebec has no recommendations for the decommissioning of wells.

6.7 New Brunswick

6.7.1 Regulations

6.7.1.1 Decommissioning Mandated

New Brunswick does not require that any wells be decommissioned.

6.7.1.2 Who Can Decommission Wells

There are no limitations on this

6.7.1.3 Decommissioning Standards

New Brunswick has no regulations regarding the techniques of well decommissioning

6.7.1.4 Recommended Practices[53]

New Brunswick has very limited detail in their document which consists of about one page of material.

Approved methods for decommissioning drilled wells include filling the well with bentonite clay or bentonite grout. There are no indications with regards to material specifications. Alternatively uncontaminated materials such as sand or drill cuttings may be placed opposite the water bearing aquifers or fracture zones with bentonite layers in between or opposite the impermeable layers. If the whole borehole cannot be filled with grout then layers of bentonite at lest 1.5m (5') thick can be placed at every 5m (15') interval of filler material, between aquifers or water bearing zones.

If the casing is left in place the top 3ft/1m shall be cut off and removed. The top 10ft/3m up to the cut off point must be filled with bentonite grout. It may be advisable to cap the well with a cement cap. Where the casing is left a bentonite plug of at least 3m/10ft needs to straddle the drive shoe valve or bottom of the casing where it seats in the rock so that at least 0.5-1.5m of bentonite is in the casing. If the casing is less than 10m/30ft then the whole length needs to be filled with bentonite. If the casing is more than 10m/30ft then the above layering approach can be used.

For large diameter wells, it is recommended to backfill the well with a clean material like sand, drill cuttings or clean fill to within 0.5m of the static water level. A bentonite plug is then added that should extend to 0.5m above the water table. The remaining cavity should then be filled with uncontaminated material to within 1m of ground surface and then a second 0.5m bentonite or grout seal should be added on top of this. The remaining space is then filled with impervious natural material like clay or hardpan and mounded to prevent erosion or accumulation. (if the water table is close to the surface then this first bentonite seal should extend to 1m below the ground surface).

6.8 Nova Scotia

6.8.1 Regulations

6.8.1.1 Decommissioning Mandated

The Minister may require a well to be decommissioned in accordance with the Water Well Decommissioning Guidelines issued by the Department if it is causing, or has the potential to cause, an adverse effect.

A well that is not being maintained for present or future use must be immediately decommissioned by sealing it in a manner that prevents the vertical movement of water into the well in accordance with the Water Well Decommissioning Guidelines issued by the Department.

6.8.1.2 Who Can Decommission Wells

Drilled well decommissioning must be conducted only by well drillers holding a valid certificate of qualification (certified well driller), dug well decommissioning only by well diggers holding a valid certificate of qualification (certified well digger), or either type of well may be decommissioned by an individual conducting work on lands that they own or lease.

[53] http://www.gnb.ca/0009/0002-e.pdf

6.8.1.3 Decommissioning Standards

For drilled wells all equipment and the casing should be removed if possible. If it is not possible, it will need to be cut 0.6 meters below surface. The well can then be filled with neat cement, sand cement concrete mix, high solids bentonite grout, or other non-shrinking liquid grout from the bottom of the well using a tremie pipe or hose. Screened bentonite chips (must be coarse grade for wells deeper than 61m) can also be used provided that they are applied no faster than the manufactures recommended rate. If possible, at least 0.3 m of grout must be placed above the top of the casing, followed by a minimum of 0.3m compacted natural fill to be level to grade surface. The top of the site should be mounded or paved or graded to eliminate the collection of surface water.

For dug wells, all pumping equipment should be removed and cement crocks or other well casing should be removed from surface to at least 1.5m below grade surface (unless their removal will cause collapse). A bentonite layer must be installed from the base of the well to at least 0.3m above the bedrock/overburden interface if the base of the well is in contact with the bedrock. Following this, the well can be filled with a backfill of clean natural soils in compacted layers no greater than 3 m thick interspersed with bentonite layers to 1 m below grade surface. The upper 1 m of backfill material must include either 1 m of uniform, clean, compacted clay free of boulders or a layer of at least 0.3 m of dry granular bentonite. The top of the site should be mounded or paved or graded to eliminate the collection of surface water.

Site specific methods may have to be approved by Nova Scotia Environment and Labour in cases such as:

- flowing artesian wells
- salt water impacts
- high yield production wells
- extremely deep wells
- wells contaminated by natural or man-made conditions
- wells constructed by neither drilling nor digging

Nova Scotia requires that the person responsible for the decommissioning submit a report to the well owner and to Nova Scotia Environment and Labour either upon request or by January 31 of the following calendar year. The record should be kept for 2 years.

6.8.1.4 Recommended Practices

Nova Scotia[54]

The Nova Scotia recommended practices are essentially the regulations reworded into an easy to understand document. The only additional bit of information is that the guidelines indicate that grouts should be a minimum of 20% solids by weight. They also provide some specific techniques for successfully using grout or bentonite chips. The document provides some basic educational material as well.

[54] http://www.gov.ns.ca/nse/groundwater/docs/WellDecommissioningGuidelines.pdf

6.9 Prince Edward Island

6.9.1 Regulations

6.9.1.1 Decommissioning Mandated

An owner that has an unused well on his or her property must have the well filled within 30 days of surrendering the use of the well or of discovering the unused well. The Minister may declare a well to be an unused well and give notice to the owner to have it filled.

6.9.1.2 Who Can Decommission Wells

There are no restrictions on who can decommission a well.

6.9.1.3 Decommissioning Standards

For drilled wells, all obstructions in the well must be removed prior to filling the well. The well should then be filled with alternating layers of bentonite or cement and clean fill (clay till or sand). The bottom 3 m (10 feet) of the bore hole must be filled with the bentonite or cement. The thickness of the individual layers of bentonite shall be not less than 0.3 m (1 foot) thick. The thickness of clean fill layers shall not exceed 1.5 m (5 feet). This plugging procedure is intended to prevent the vertical movement of contamination down the well bore hole. In addition, if the portion of the casing which is above ground becomes an eyesore or a safety concern, it can be cut off below the ground surface.

For dug wells, any obstructions in the well (piping, pump, wooden material, etc.) must be removed prior to the plugging of the well. The well shall be filled to within 1 m (3 feet) of the ground surface with a mixture of sandstone and clean fill material. A minimum 0.15 m (6 inches) thick layer of a low permeability material such as bentonite or compacted clay must be installed within 1 m (3 feet) of the ground surface to prevent the entry of surface water to the water table. The surface area of the top of the well must be covered with topsoil and graded in a manner that will allow drainage away from the well.

6.9.2 Recommended Practices[55]

As part of the Growing Forward Environmental Farm Plan initiative in Prince Edward Island, a beneficial management practice document has been produced. However, the document uses the same wording as the regulations and provides very little additional information about well abandonment.

6.10 Newfoundland

6.10.1 Regulations

6.10.1.1 Decommissioning Mandated

Decommissioning of wells is required when a well is dry, when it is not being used or maintained for future use, when a well is producing salty, sulphurous or mineralized water, or water that is otherwise

[55] http://www.gov.pe.ca/photos/original/af_cpeiaspwell.pdf

not potable, when a well encounters natural gas; or when a well is constructed in contravention of any provisions of the Water Resources Act or the Well Drilling Regulations

6.10.1.2 Who Can Decommission Wells

Homeowners, individuals not receiving remuneration, and licenced contractors are permitted to decommission wells.

6.10.1.3 Decommissioning Standards

Wells must be decommissioned using a method approved by the Minister sufficient to prevent the vertical movement of water in the well.

6.10.1.4 Recommended Practices[56]

The Newfoundland guidelines for decommissioning provide a basic description of the 'requirements' of decommissioning of water wells. It does not discuss techniques nor does it seek to educate. It is, in essence, the de facto regulations in the province.

For drilled wells, the entire well may be filled with bentonite clay or bentonite grout, or alternatively, suitable uncontaminated material (e.g. sand, drill cuttings, etc.) should be placed opposite the aquifers or water bearing fracture zones with bentonite grout placed opposite impermeable zones between the aquifers.

If the distance between the aquifers is such that it is impractical to fill the borehole with grout for the entire length, suitable uncontaminated material may be used to fill the borehole provided that bentonite grout plugs of no less than 1.5 m (5ft) in thickness are placed within every 5 m (15ft) interval of fill between the aquifers or water bearing fracture zones.

If the casing is left in the borehole and the well is less than 10 m deep, then the entire casing should be filled with grout. If the casing is deeper, then the casing shall be cut off (1m or 3ft) below ground surface and the well filled in as discussed above. In all water well abandonment the top three metres (10 ft) (below where the casing is cut off) shall be filled with bentonite grout. In certain cases it may be advisable to cap the top of the well with concrete. A bentonite plug (3m or 10 ft in thickness) shall be placed straddling the position of the casing drive shoe seal or the bottom of the casing where it seats in the rock, such that approximately 0.5 to 1m (1.5 to 3 ft) of bentonite is inside the casing.

For dug wells, the well should be backfilled with suitable uncontaminated material (e.g. sand, drill cuttings, clean fill, etc.) to 0.5 m (1.5 ft) below the static water level. A bentonite or grout seal should extend from this level to 0.5 m (1.5 ft) above the water table. The remaining cavity should be filled with suitable uncontaminated material that should extend to within 1 m (3 ft) below the final ground surface, and 0.5 m (1.5 ft) bentonite or grout seal should be placed on top. The remaining space is then filled with impervious natural material (e.g. clay, or hardpan) or native soil and slightly mounded in order to prevent surface water runoff from entering the well; seed or sod to establish ground cover. If water table is close to the land surface, the lower bentonite plug should simply extend to 1 m (3 ft) below ground surface.

[56]http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/well/guidelines_for_sealing_groundwater_wells.pdf

6.11 The Territories

There are no regulations or recommendations regarding decommissioning in any of the territories. The decommissioning of wells could be required for health or environmental reasons, but there are no regulations directly pertaining to decommissioning.

6.12 Other Jurisdictions

6.12.1 Nebraska

Nebraska has replaced the term 'abandoned' wells with the term 'illegal wells'. The Department of Health and Human Services notes that "Illegal wells" represent one of the greatest threats to groundwater in Nebraska."

6.12.1.1 Decommissioning Mandated

Illegal water wells are required to be decommissioned. An illegal water well includes a well with any of the following conditions:

- The water well is in such a condition that it cannot be placed in active or inactive status.
- Any necessary operating equipment has been removed and the well has not been placed in inactive status.
- The water well is in such a state of disrepair that continued use for the purpose for which it was constructed is impractical.
- The water well was constructed after Oct. 1, 1986, but not constructed by a licensed water well contractor or by an individual on land owned by him or her and used by him or her for farming, ranching, or agricultural purposes or at his or her place of abode.
- The water well poses a health or safety hazard.
- The water well was constructed after Oct. 1, 1986, and such well is not in compliance with the standards developed under the Water Well Standards and Contractors Licensing Act.

6.12.1.2 Who Can Decommission Wells

Water well decommissioning must be carried out or supervised by an individual with a valid Nebraska Water Well Standards and Contractors' license.

6.12.1.3 Decommissioning Standards

In all wells, any pumping materials should first be removed.

The volume of material to be used in the hole must be calculated prior to starting so that bridging can be identified. If a bridging event is experienced, the filling of the well must stop and the bridge be broken up, by redrilling if needed. Measure the static water level and the total depth of the well.

If the well is a single aquifer well (draws water from only one aquifer), it well can be filled with clean disinfected sand, gravel, or grout up to 1 foot (0.3m) below the static water level. If the static water level is less than 6 feet (1.8m) from surface, then a surface plug can be installed to complete the decommissioning (see below). If the water level is greater than 6 feet (1.8m), then a grout plug of at least three feet (0.9m) thick must be placed on top of the sand/gravel fill. This can be done using any of the following materials: neat cement grout slurry (not more than 6 gallons of water per bag), sand cement grout slurry with no more than 2 parts sand to 1 part cement, concrete grout slurry, bentonite chips/pellets, cement/bentonite grout slurry (3-5% bentonite), or a high solids bentonite grout slurry (20% solids or more). The fluid grouts need to be installed with a tremie line.

Above this, the well can be filled within ten feet of surface with sand/gravel fill if the well is known to have a good annular seal (and must then be finished with surface plug option 2), or six feet (1.8m) from the surface if that is not known to be the case (surface plug option 1).

Surface plug option 1 - If the well is suspected of not having an appropriate annular seal or if it is an unknown, then the well should be excavated to a depth of three feet and the casing should be cut. The well can be filled with clean, disinfected sand and gravel with the exception of the top three feet of remaining casing which must be filled with a plug of an acceptable material. This includes neat cement grout slurry (not more than 6 gallons of water per bag), sand cement grout slurry with no more than 2 parts sand to 1 part cement, concrete grout slurry, bentonite chips/pellets, cement/bentonite grout slurry (3-5% bentonite),or a high solids bentonite grout slurry (20% solids or more). Above this a 1 foot (0.3m) grout plug should cover the well and extend over the annular space and onto the natural ground. The well should then be buried with natural materials and mounded so that water flows away from that location.

Surface plug option 2 - If the well is known to have an appropriate annular seal, the casing may be left in place. The well can be filled with clean disinfected sand & gravel throughout its length with the exception of the top 10 feet (3m) which must be filled with a sealant (as described above). The well can then be capped with a watertight secure cover.

Water wells that obtained water from more than one aquifer must have a seal between each zone if each water bearing zone is separated by a confining layer. A grout seal not less than 5 feet in length must be placed adjacent to each confining layer and 3 feet (0.91m) of grout at the static water level.

The procedure for flowing wells is as follows:

Decommissioning flowing wells requires the placement of neat cement through a tremie line fast enough to stop the flow; otherwise, expandable plugs may be installed in the casing (or bedrock if not cased) to stop the water flow. If it is known that a confining layer exists, the following procedure to install an intermediate seal is required. If, during construction, the casing was not grouted at the confining unit, a plug is set at the bottom of the confining layer and the casing perforated a minimum of 3 feet (0.91m), to allow pressure grouting of the annular space with neat cement. Pressure grouting with neat cement is required. Bentonite grout can be used above the confining layer if the flow is stopped using neat cement with or without a packer. The casing is filled to within 3 feet (0.91m) of the land surface. The casing is then cut off and the hole backfilled with compacted native soil.

The procedure for dug water wells is as follows:

The well cavity must be filled up to within 1 foot (0.3m) of the measured static water level with clean disinfected sand and/or gravel and then a 3-foot (0.91m) bentonite seal must be installed on top of the disinfected fill material. The remainder of the well cavity must be filled with sand, gravel, or native earth material that extends up to within 6 feet (1.8m) of the ground or final graded surface. Then 3 feet (0.91m) of grout or bentonite seal material must be placed in the casing. The top 3 feet (0.91m) of the casing must be removed and a grout seal with a minimum thickness of 6 inches (0.15m) must be installed over the well and that extends 1 foot (0.3m) beyond the well casing. The area must be filled with natural soils and mounded to keep water from settling there.

6.12.2 New York State

6.12.2.1 Decommissioning Mandated

There are no mandatory standards indicating that abandoned wells must be decommissioned, although some local regulatory agencies do have such regulations at the municipal level.

6.12.2.2 Who Can Decommission Wells

Decommissioning can be done by the homeowner or a registered water well driller.

6.12.2.3 Decommissioning Standards

New York has state-wide decommissioning standards of practice, but these can be overlain by local standards. This section explores the state-wide standards and recommendations.

New York requires that casing with an open annular space be either grouted in place or removed. For casing removed from a collapsing formation, grout should be pumped through a tremie pipe.

Where casing is grouted in place, the casing should be cut off at least 24 inches (0.61m) below grade, where practicable. For wells located in a building, upon completion of grouting the casing should be filled to floor level with no less than 12 inches (0.3m) of cement. Casing should be cut off not more than 3 inches (76mm) from floor level. For wells terminating in a well pit, casing should be cut off not less than twelve inches below the grade established when the pit is filled.

After the grout has consolidated, the top of the casing should be closed and sealed. Steel casings should be sealed with a welded steel plate; PVC casings with a permanently affixed PVC cap.

Any portions of a well occupied by the well screen should be filled with clean sand or gravel. The rest of the casing should be sealed with bentonite slurry, concrete slurry, neat sand slurry or coarse grade chips or pellets. The regulations lay out specific recommendations for pouring the bentonite chips into the well at a measured pace (a rate of not faster than 50lbs (22.7kg) per minute) and the depth to the settled chips should be measured after each bag to ensure that bridging has not occurred.

Sealing materials should have bearing strength sufficient to prevent subsidence and support traffic or building loads. Standards are not given with regards to sealing material other than a note that the use of too much bentonite in the grout mix can lead to excessive shrinkage and cracking.

Coarse grade or pelletized bentonite can also be used. It is recommended that the pelleted be poured slowly into the top of the well to avoid bridging of material in the casing or borehole. Pellets or coarse bentonite should be placed into the well by pouring at an even rate not to exceed fifty pounds (22.7kg) per five minute interval. Fine bentonite particles which accumulate in the bottom of the shipping container should not be used. A work pipe or weighted drop string should be placed in the well and the height of accumulated plugging material measured after each 50 pounds (22.7kg) of bentonite is placed in the well. If measurement indicates that bridging of plugging material has occurred, a work pipe, drill rods, or other weighted device should be run into the casing to break the bridge. The plugging operation should continue until the bentonite appears at the surface. Water should then be placed into the casing to promote expansion of the bentonite above the static water level.

Large diameter wells can be sealed by pouring at a rate sufficient to completely fill the well without bridging using:

- uniformly mixed dry bentonite powder or granular bentonite and sand in a ratio of one part bentonite to five parts sand;
- clean unconsolidated materials with a permeability of 10^{-6} centimeters per second or less; or
- concrete grout.

For flowing wells the integrity of the exterior casing seal should be tested prior to decommissioning the well. To test the seal, the well should be capped for a period of one week and checked for any leakage around the outside of the casing. If any leakage occurs, the casing exterior must be resealed prior to well decommissioning. Once leakage has been eliminated, the interior of the well casing should be pressure grouted.

Well pits should be filled with clean soil to the established grade level. Upon completion of well decommissioning, the site should be restored to a condition that reasonably approaches the original condition of the property prior to the start of work.

6.12.3 California

6.12.3.1 Decommissioning Mandated

In California any well that is 'no longer useful' must be destroyed, the term they use for decommissioning. Any well that has been abandoned and unused for more than a year must be destroyed unless the owner shows clear intention or plans to use the well in the future. Unused wells that are intended for future use must be covered with either a purpose made well cap or equipment fitted to the well that prevents unauthorised access to the well or the entry of unwanted substances.

6.12.3.2 Who Can Decommission Wells

Persons permitted to deconstruct a water well must possess C-57 Contractors license (water well drillers license).

6.12.3.3 Decommissioning Standards

All debris, obstructions and pollutants (e.g. oil or pump chemicals that could interfere with the sealants) must be removed. California requires that the well and annular spaces are filled. Casing may be left in place but should be perforated to ensure than the annulus or adjacent spaces are sealed. Where possible, sections of casing must be removed but the removal must not compromise the ability to seal the borehole. Dug wells should have as much of the casing removed as possible prior to filling.

Wells situated in unconsolidated material in unconfined groundwater zones: In all cases the upper 20 feet (6m) of the well shall be sealed with suitable sealing material and the remainder of the well shall be filled with suitable fill, or sealing material.

Wells penetrating several aquifers or formations. In all cases the upper 20 feet (6m) of the well shall be sealed with impervious material. If it is the case that there may be harmful interchanges of water between different aquifers, the well must be filled and sealed in order to prevent vertical movement of contaminating water. To prevent the vertical movement of water from the unsuitable formation, impervious sealant material must be placed opposite confining formations above and below the better quality producing formation(s) for at least 10 feet (3m). The formation producing the deleterious water must be sealed by placing impervious material opposite the formation, and opposite the confining formations for a sufficient vertical distance (also no less than 10 feet/3m) in both directions. Sand or other suitable inorganic material may be placed opposite the producing aquifers and other formations where impervious sealing material is not required. If interchange between aquifers will not be detrimental, suitable inorganic material may be placed opposite the formations penetrated. When the boundaries of the various formations are unknown, alternate layers of impervious and pervious material must be placed in the well.

Wells penetrating creviced or fractured rock. Creviced or fractured rock formations just below the surface must be sealed with neat cement, sand-cement grout, or concrete. If these fractured formations extend to considerable depth, alternate layers of coarse stone and cement grout or concrete may be used to fill the well. Fine grained material must not be used to fill fractured layers.

Wells in noncreviced, consolidated formation. The upper 20 feet (6m) of a well must be filled with impervious material. The remainder of the well may be filled with clay or other suitable inorganic material.

Placement of material. Where liquid sealants such as cement grout, sand-cement grout, or concrete are used, they must be applied in one continuous operation. The well casing must be perforated when pressure is applied to the grout. These include cases where 1. The gravel pack around the casing needs to be sealed 2. Where the pressure producing flow conditions is high. Where pressure is used to force grout into the annular space, the pressure must be maintained for the duration required to set the grout. The volume of sealing material placed in the well must be checked against the well volume to ensure so bridging or jamming has occurred.

Suitable materials for destroying wells. Suitable impervious materials include neat cement, sand-cement grout, concrete, and bentonite clay; and well-proportioned mixes of silts, sands, and clays (or cement), and native soils that have a coefficient of permeability of less than 10 feet (3m) per year. Used drilling muds are not acceptable.

Additional Requirements for Wells in Urban Areas. A hole must be excavated around the well casing to a depth of 5 feet (1.5m) below the ground surface and the well casing removed to the bottom of the excavation. The sealant used at the top of the well must be allowed to overflow into the excavation. Once the sealant has set the excavation must be filled with native soil.

6.12.4 Texas

6.12.4.1 Decommissioning Mandated

The plugging of abandoned wells is regulated in Texas. An abandoned well is any well that has not been in use for 6 months or more.

6.12.4.2 Who Can Decommission Wells

A landowner (where the well is situated) may plug the water well. In all other cases a licensed water well contractor or pump installer must conduct the well plugging.

6.12.4.3 Decommissioning Standards

Texas regulations require that where possible the casing must be removed before plugging and any surface completion be removed (e.g. above ground casing must at least be cut off at ground level). The basic plugging requirement is that the entire well be pressured with cement using a tremie pipe from the bottom to the land surface.

Alternative methods include filling the well with bentonite grout that is at least 9.1 pounds (4.1kg) bentonite per gallon weight. This bentonite should be topped with a cement plug that extends from land surface to at least 2 feet (0.65m) deep. If the well to be plugged has one hundred 100 feet (30.5m) or less of standing water the entire well may be filled with a solid column of 3/8 (9.5mm) inch or larger granular sodium bentonite used in adherence to the manufacturers' recommendations. The minimum 2 foot (0.6m) long cement cap must also be used in this situation as an atmospheric barrier. Bentonite must not be used where chloride concentrations exceed 1500 ppm or hydrocarbons are present.

Where contaminated water or pollutants are present, they must be isolated from the fresh water zone(s) with cement plugs and the remainder of the wellbore filled with neat cement or clean bentonite grout of a minimum 9.1 pound (4.1kg) weight as above, followed by the cement plug that extends for a minimum of 2 feet (0.6m) from land surface.

Dug and bored wells 36-inches or greater in diameter that extend to one hundred (100) feet in depth may be plugged by back filling with compacted clay or caliche to surface once all removable debris has been removed from the well. If the well contains standing water, it must first be chlorinated by adding chlorine bleach at a rate of 1 gallon for every 500 gallons of standing water. The backfill material needs to be mounded above the surrounding surface to compensate for settling.

Dry wells (where there is no groundwater present) may be plugged by back filling with drill cuttings from the bottom to the surface. The fill should be mounded at surface to compensate for settling.

Well plugging reports must be filled and submitted within 30 days of plugging a well.

6.13 Analysis of Provincial Approaches

6.13.1 Introduction

With the exception of the Ontario regulations, most regulations across Canada appear to be the result of incremental evolution from earlier sets of regulations that had spread across the country. As a result, the national landscape regarding regulations and recommendations addressing abandoned wells ranges from being very lax to being very stringent. Some provinces have very limited regulation and supplement this with more detailed recommended practices. There are often many contradictory recommendations when provincial regulations are compared and contrasted with one another.

Clearly, there are improvements that could be made in provinces with dated regulations that do not reflect contemporary industry guidelines.

6.13.2 Regulations in Practice

Interviews in every province indicated severe shortcomings with regards to compliance in a number of areas. Reporting of new wells is seen as imperfect, but there is a sense that most new well reports are being submitted in most provinces and the Yukon Territory. Reporting of well abandonment across the country was considered rather dismal.

In terms of well owner and contractor compliance with well decommissioning in practice, key informants suggested that most homeowners do not see the need for proper decommissioning. Similar results were found in the Alberta Water Well Survey[57].

Key informants indicated mixed experiences with the professional water well industry, with some contractors being well informed with regards to well decommissioning and others not being so and as such, employing poor techniques that are not in line with industry standards or with regulations. The lack of proper grouting equipment, the mixing of slurries too thinly, and the tendency to deviate from accepted procedures were all indicated as problems experienced. Where there has been a significant number of water well decommissioning subsidy programs, interview respondents indicated that capabilities were expanding. Thus, such programs provide benefits in terms of capacity building as well as the impact of well decommissioning.

6.13.3 Methodology Considerations

6.13.3.1 Materials Used

The provinces all provide different levels of detail regarding materials, but generally they centre on the materials recommended by the research. Bentonite grouts with 20% solids are broadly accepted as a fill material, however, in light of the weaknesses of this material in the vadose zone in the Nebraska Grout Study, perhaps this recommendation needs to be revisited.

The use of sand and other fill materials is allowed in some provinces and not allowed in others. There is little research done on the impact of layering plugs and permeable fill materials. Such approaches lower costs significantly and as such should be investigated as alternative approaches.

[57] Summers, 2010

In the Nebraska Grout Study, coated bentonite chips outperformed the high solids (20%) grout in their ability to prevent the movement of water in the vadose zone. These materials require less equipment and effort to install and thus are far less expensive. There are two key shortcomings of this. The first is the possibility of bridging in the well due to the difficulty in controlling the speed of application and the presence of fine powders. Some of the regulations and recommended practices have suggested protocols to reduce the likelihood of this happening. The second issue with this method is that it fails to address the annular space unless the casing has been pulled (which is less likely if homeowners are decommissioning their own wells). As discussed later, this can be a problem for other approaches and materials as well.

There are a range of approaches to decommissioning abandoned large diameter wells in the provincial regulations. Some of the methods outlined by regulations are unlikely to successfully prevent the vertical movement of water. Approaches that integrate high quality sealants along with natural fill materials are likely to result in better outcomes than those that rely solely upon natural materials.

6.13.3.2 Cost Versus Quality of Completion

With possibly more than two and a half million abandoned wells in Canada, the cost of decommissioning must be considered alongside of the efficacy of the methods used. The cost of decommissioning ranges greatly depending upon the methods employed. Data from the Healthy Futures program in Ontario which saw 835 wells decommissioned had an average cost of $1,667 per small diameter well. The cost per well for the Milk River Aquifer Project which required the removal or puncturing of casing was $5,500 per well (2004). The approach currently advocated in Ontario involves the use of professional contractors and equipment. They recommend the use of down hole cameras, water quality testing, the preservation of the permeability of water producing layers and other practices that increase cost. Decommissioning practices like this will have costs significantly over $2500 per well. This would lead to billions in costs to decommission the abandoned wells in Canada.

Other provinces, such as Manitoba allow for the well to be filled with natural materials such as well cuttings from a new well or bentonite grout pellets or chips, greatly reducing the costs of decommissioning for owners. At a cost less than $400 for most wells, abandonment of the wells across Canada would be much more affordable.

Furthermore, questions remain regarding the need to preserve flow paths in and around the well within aquifers. Ontario regulations call for this, as do some of the American regulations. Doing so raises the cost of decommissioning and may lower the quality of the effective sealing of the well, particularly the flow between aquifers. The Milk River Aquifer Project indicated that there was no impact upon surrounding wells when the entire well was sealed (with no provisions made for preserving flow in aquifers).

Lastly, new methods regarding the use of very high solids (sand) with bentonite are being explored in the Nebraska Grout Study. Exploring high sand volume grouts (up to 80% sand) could be extremely valuable in identifying methods to improve effectiveness and lower costs of well decommissioning.

6.13.3.3 Annulus

Perhaps the most vexing issue for well decommissioning is the problem of filling the annulus. If a well is filled successfully with either a slurry or a pellet or chip product, but the annulus remains an open void for much of the length of the surface casing, then risk of contamination remains.

Experienced drillers interviewed indicated that the presence of open voids in the well annulus is a common occurrence. This situation is often observed when contractors replace or repair a pitless adaptor. Many of the methods presented in the existing regulations do not address this issue other than recommending that the casing should be removed from the hole **if possible**. Ontario does encourage the cutting of the casing if the entire string cannot be removed.

Approaches to addressing this problem in affordable ways need to be considered. The American regulations address the annulus more frequently than Canadian recommendations, but they consider the problem addressed by the bentonite 'cap' on the top of the well area (underground). Recommendations regarding puncturing the casing should perhaps be considered to address this shortcoming, but this will result in a high cost of decommissioning and research should be undertaken first to identify the effectiveness of this approach. Excavating wells to a depth of 2 to 3 meters may also be a way to identify open annular space to ensure that it gets properly filled. At the very least, such excavations (and refilling) help to ensure that water must flow through two meters of vertical material.

Again, findings from the Nebraska Grout Study complicate this as this study has demonstrated that bentonite grouts perform poorly when exposed to the vadose zone. By perforating the casing or pulling the casing, any grout products used to fill the well could see wicking of water by the vadose zone, possibly significantly reducing the effectiveness of the well sealing.

7.0 Summary

7.1 Issues/Trends of Concern

There are likely more than 2.5 million abandoned wells in Canada, each of which increases the risk of contamination degrading the quality of our groundwater. While efforts have been made to address this problem through decommissioning programs, an expanded and improved effort is needed from provincial agencies, federal agencies, municipal authorities, the agriculture industry, the water well industry, and others.

There are a number of concerning trends regarding abandoned wells. These are as follows:

1. Most importantly, more than 2.5 million abandoned wells pose some level of risk to our aquifers and the Canadian population. More wells are being constructed and in many cases the wells that they are replacing are not being properly decommissioned, meaning that there is an increase in the number of abandoned wells from year to year to year.
2. The limitations of the available data make estimating the number of wells constructed, wells in use, abandoned and inactive wells, and decommissioned wells very difficult. The accuracy of such estimates, including those produced in this document, are highly uncertain.

3. Reporting of well abandonment is not mandatory in many provinces, and in provinces where it is mandatory, compliance appears to range from incomplete to nearly non-existent.
4. The environmental and health risks of abandoned wells are not well defined. While it is understood that there are risks, there has been no comprehensive effort to qualify or quantify these risks.
5. Regulations in many provinces in Canada are not up to industry standards, particularly regarding the problem of open voids in annular space. In those cases, many wells that are decommissioned to provincial standards may carry a very similar risk to abandoned wells.
6. Current approaches to decommissioning wells in a comprehensive manner are very costly. With the large number of abandoned wells, the cost of addressing this could run into billions of dollars of public and private funds. The costs can be reduced substantially through the use of less expensive procedures (such as the application of bentonite chips), but the impacts of the different techniques in practice are poorly understood, thus leaving agencies and contractors to tend towards the more comprehensive and more expensive solutions.
7. Current systems of mapping aquifer vulnerability are based largely upon the attenuation effectiveness of the strata above aquifers, but abandoned wells create a bypass through these layers. As such, current mapping of aquifer vulnerability is of limited assistance in prioritizing regions and well sites for decommissioning.
8. Well owners have demonstrated a level of apathy and a level of fear of unknown costs towards the proper decommissioning of abandoned wells. Efforts to motivate well owners to decommission wells have been focused primarily upon subsidies and information provision. There has been very little research done on well owner decision making and behaviour regarding abandoned wells. As such, policy makers are essentially engaging in the use of trial and error approaches with a strong focus on comprehensive subsidies. Such an approach will be very costly given the large number of abandoned wells that may exist. More cost efficient methods may be available and could be identified through belief and behavioural research into the issue.
9. Water well contractors may face some capacity issues and knowledge issues regarding industry standards. At a base level, the industry has not fully adopted the promotion of well decommissioning, perhaps out of fear that it could increase the inherent costs in water wells as a commodity, or perhaps simply because of resistance to change.

7.2 Opportunities for AAFC and Others

This section will discuss possible opportunities for the Agri-Environment Services Branch of AAFC and others to complement existing practices and programs regarding the decommissioning of water wells on agricultural operations in addition to the work being done through Growing Forward and other programs and initiatives that promote water well decommissioning.

7.2.1 Improving the Information on Abandoned and Decommissioned Wells

There are three key approaches to understanding the number of wells (active, inactive, or abandoned) in regions of Canada. The first is supply based and can be explored through provincial databases. The second is demand based, and focuses on understanding the demand for wells and extrapolating out from that. The third is case based and involves extrapolating from case studies, surveys, and other forms of 'inventories' that can inform upon the actual 'on the ground' situation.

Local well inventories that include data on the quantity of wells in specific regions, as in the case of the Milk River Aquifer Project in Alberta, and in some municipalities in Ontario and Conservation Districts in Manitoba, are extremely valuable in developing improved estimations of the extent of abandoned wells.

Cross Canada survey research to collect information on water wells similar to the AWWS or the OHHWOS, but with an emphasis on abandoned wells included, could be very valuable in developing an understanding of the extent of working and abandoned wells.

Or, similar to research done on the Ontario Environmental Farm Plan in 2000, surveys could be undertaken with farm plan participants from various provinces to gather such data.

Lastly, Provincial agencies who operate the water well databases and Water Well industry groups could improve the submission of data records to the provincial agencies.

7.2.2 Research on the Risk of Abandoned Wells

Research is required to develop a more comprehensive understanding of the risks that abandoned and partially abandoned wells pose. A review that integrates an understanding of surface and subsurface contaminant movement and attenuation, well construction, and health risks would be very valuable. Documentation on known contamination incidents are generally held at the state or provincial level with no centrally accessible records. There is a significant amount of research available on contaminants in groundwater and there is research available on the role of contaminants as health and environmental risks. Thus, it would be possible for a group to develop a comprehensive report on the risks of abandoned wells through a review of existing literature and case studies.

7.2.3 Improving Governance

The disparities between provincial government regulations regarding decommissioning are striking. While there is a need for further research into decommissioning approaches, there is room for improvement in the current techniques of decommissioning based upon existing knowledge. As a national agency, AAFC could help facilitate interaction for the purposes of learning between regulating agencies. Bringing together the individuals and groups responsible for regulation and recommendation development could be a powerful way to share lessons learned from their current situation. For example, it may be that Ontario's detailed regulations are having the desired effect, or it could be that the greater detail has created a barrier to compliance. These types of lessons will be key to other agencies that are reviewing their own regulations.

7.2.4 Improving Decommissioning Approaches

The Nebraska grout study raised awareness that further research is needed on the sealing of water wells to better understand what happens in the ground. Improving the decommissioning of wells will require research into techniques and sealing materials. Empirical research should be supported in this area. It is important to note that the Nebraska study focused on sealing the annular space of wells under construction and that it does not address the behaviour of sealing materials in decommissioning operations. There is a gap in research in this area.

A second subject that needs to be researched is the identification of most effective low cost methodologies. The cost of having a professional driller puncture or remove casing and to run grout plants, tremie lines and other related practices is very costly and increases decommissioning costs to thousands of dollars per well. In the case of a well that is free of pumping equipment or obstructions, an individual home owner could pour bentonite pellets down the well according to recommended procedures. The result may be a reasonably effective decommissioning outcome assuming the annular seal is intact, but it would be done at a significantly lower cost than the more comprehensive method identified above. The disparity in approaches is significant in terms of cost, but the real world impacts on the quality of the decommissioning are not well understood. Research into reducing the cost of decommissioning through alternative methodologies and evaluating the effective outcomes of reduced cost methods could be very important given the large number of abandoned wells estimated in this study.

7.2.5 Vulnerability Mapping for Abandoned Wells

When seeking to identify high risk areas relating to abandoned wells, vulnerability mapping should emphasize surface risks, well densities, multiple aquifer conditions, agricultural intensity, industrial intensity, and aquifer characteristics. The characteristics of the vadose zone are less important as a factor influencing vulnerability as abandoned wells create a potential infiltration bypass.

Given limited funding to subsidize decommissioning, there is value in knowing which areas should be prioritised. This type of mapping could assist in identifying those areas.

7.2.6 Researching Well Owner Decision Making

Achieving widespread decommissioning of abandoned wells through regulation and enforcement would be logistically and politically challenging. Achieving it through comprehensive subsidy programs would be very expensive and likely still only a partial solution. As with many situations involving health, safety, or environmental concerns on private property, addressing the problem of abandoned wells will require the active ‘buy in’ of the well owners themselves.

Success in broadly engaging water well owners and convincing or persuading them that well decommissioning is necessary would be very beneficial to the effort to reduce the risks posed by abandoned wells. First, a greater portion of the billions that it would cost to decommission wells could be borne by private well owners as opposed to being carried by taxpayer funded subsidies. Second, it would also be beneficial in ensuring that wells that become abandoned in the future are properly decommissioned. Third, it would help to address abandoned wells that would be missed through regulatory approaches because they are 'hidden' from the view of regulators and other agents (drillers, realtors, etc.) who could be empowered to require that a well be decommissioned. Fourth, successful persuasion efforts would create a culture of proper well decommissioning in the same manner that efforts such as other safety and health practices have become established in society.

Over the past couple of decades, research into beliefs and decision making regarding environmentally significant behaviour has expanded significantly in behavioural economics and social psychology, at the same time similar behavioural research has taken place in public health regarding health behaviours. Much of this research addresses how people perceive risk, the impact of habits, procrastination, loss bias and other influences.

Research into what people believe about their water supply and about their ability to impact it could be instrumental in the effort to address abandoned wells.

7.2.7 Outreach and Partnerships with the Drilling Industry

Agricultural organizations do a tremendous amount of outreach work with the farming community. There could also be opportunities to work with the water well drilling industry to support seminars and demonstrations on well decommissioning. Some of this has taken place in Ontario when bill 903 was introduced and perhaps similar efforts have been made in other jurisdictions as well. Outreach to the industry through supporting information seminars and/or other forms of information sharing could be very influential in addressing the challenge of abandoned wells.

Water well contractors are on the proverbial front line of the problem of abandoned wells and having their informed and active involvement in addressing the issue could be critical. Well owners consider water well contractors as a primary source of good information regarding water wells and if contractors are actively promoting proper decommissioning, it will make a meaningful difference in reducing the number of abandoned water wells now and in the future.

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Appendixes

Appendix One: Methodologies Employed in Developing Estimates

The following documents the various methodologies that were undertaken in the research. Some of these were used to determine the above estimates.

Provincial Databases

Purpose and Rationale: All provinces in Canada maintain provincial level inventories of water wells. These are based upon the submission of reports on activities such as water well construction, water well testing, and water well decommissioning. Estimates regarding wells constructed (total and agricultural) and wells decommissioned can be made directly drawing data from the provincial databases. Figures from the provincial databases are often used by government and organizations.

Methods: Available data can be drawn directly from the databases.

Validity and Limitations: There is a wide consensus from key informants that provincial water well databases are not comprehensive. Database managers indicated that compliance with the submission of reports is strongest for new wells (with the exception of dug wells), but lacking for other interactions with wells (maintenance, decommissioning, and other practices). There was also an indication that the comprehensiveness of the well databases degraded the further back in time that records refer to.

While published evidence with regards to the quality of provincial databases is limited, two documented cases identify shortcomings in their provincial databases. In a study[58] done in the Surrey-Langley area on contamination issues, 98 participants offered to have their wells tested for potential contaminants. When the research team sought information on the water wells in the BC Water Well Application database they found that only 44 (45%) of them had been registered in the database. A study in Mud Lake Labrador experienced a similar outcome with only 4 of 10 private wells were identified in the provincial database[59].

In terms of agricultural data, the provincial databases are problematic. Some provinces provide information on the number of wells that are agricultural in nature, but this almost always excludes domestic wells on farms (unless the wells are dual purpose). Additionally, some agricultural wells may be classified as industrial wells. As a result, data from the provincial databases must be considered very limited.

The databases are considered to be too incomplete to develop effective estimates. As a result, the databases were not used for developing most of the estimate values. One exception is with regards to the estimate total number of wells in use. As is discussed later, the proportion of domestic to non-domestic wells is used as part of that calculation.

Estimates based upon the 2010 Statistics Canada Human Activity and the Environment Survey

Purpose and Rationale: It is possible to estimate the number of households served by private wells using data from the 2010 Human Activity and the Environment Survey on Freshwater Supply and

[58] Wilson et al, (2008)
[59] AMEC (2010)

Demand in Canada[60] and the general population using data from the Canadian Census [61]. This method allows for an estimate of domestic wells currently in use.

Methodology: The Human Activity and the Environment Survey on Freshwater Supply and Demand in Canada survey was a sample survey of 20,000 households from across Canada. It included questions regarding the primary source of water to the household including the proportion of respondents dependent upon a private well. The Canada Census provides population and dwelling counts.

%DPW x ND = DPW

(%DPW)= Percentage of Dwellings reliant upon Private Wells

ND=Total Number of Dwellings

DPW = Dwellings served by Private Wells

An example is given here for British Columbia.

7% x 1 642 715 = 114,990 Households Serviced by Private Wells

Validity and Limitations: This estimate would exclude wells not used for household supplies such as wells for irrigation, livestock, industrial uses, and other uses. It would count wells shared by multiple households more than once. It would count multiple wells supplying one household as a single well. Given that the vast majority of private wells service a single household, it is probably the most effective estimate of the total number of private household wells in use and as such, it is the statistic used for Estimated Number of Active Domestic Wells in Table 1 of this report.

Statistics Canada noted that data for Saskatchewan and Newfoundland should be "Used with Caution" and it does appear to result in a significant underestimate for those two provinces. In Saskatchewan, it results in a number that is smaller than the current number of farms. Also, as can be seen in the following section, the numbers between this estimate and the deductive 'non serviced' method are very different for Ontario and Newfoundland while they are quite similar for the other provinces. The data for Saskatchewan is more complex due to the large number of very small water supply systems that exist there.

Deduction from Municipal Use Database and the 2006 Census of Canada

Purpose and Rationale: It is also possible to estimate the number of households served by private wells using data from the 2006 Municipal Water Use Database[62] and the general population using data from the Canadian Census. This method also allows for an estimate of domestic wells currently in use.

[60] CANSIM table 153-0062
[61] Statistics Canada. (2007)
[62] Canada Municipal Use Database (2006)

Methodology: This estimate is developed through identifying the number of residents that are not identified as being served by municipal water supplies in the Municipal Use Database and then assuming that approximately 80% of those households are services by private wells.

$$\frac{(P - PMW) \times 80\%}{AHH} = DPW$$

P = Population of the Province/Territory

PMW = Population served by municipal water supply (as identified in Municipal Water Use Database)

AHH = Average Household Size

DPW = Dwellings served by Private Wells

An example is given here for the province of British Columbia.

$$\frac{(4{,}113{,}487 - 3{,}338{,}993) \times 80\%}{2.5} = 247{,}838$$

Validity and Limitations: Like the previous estimate, this estimate would exclude wells not used for household supplies such as wells for irrigation, livestock, industrial uses, and other uses. It would count wells shared by multiple households more than once. It would count multiple wells supplying one household as a single well.

This estimate will tend towards overestimating well numbers due to small scale water municipal supply systems that fail to be included in the Muncipal Use Database. Saskatchewan, B.C. and Newfoundland tend to have many such small systems. This measure was largely used as a comparative to set an 'upper limit' for domestic well numbers for the provinces.

Estimates based upon the Agricultural Census of Canada, Interview Data, and Case Studies

Purpose and Rationale: This estimate draws upon the agricultural census of Canada to provide an estimate for the total number of wells in use on farm properties.

Methodology: The agricultural census of Canada provides information on the number of farm households in each province and territory. An estimate can be made regarding the number of agricultural wells in each province by considering the number of farms and making assumptions about the average number of wells per farm. The range identified by key informants was 1.5 to 2.5 average wells per farm, and thus a number of 2 wells per farm will be used for this estimate (this includes any domestic wells).

$$(\text{Number of Farms}) \times 2 = \text{Number of Farm Wells}$$

Validity and Limitations: The average number of wells was based upon a small number of estimates by professionals who have experience in dealing with water supplies on farms. Despite this limitation, this approach was considered to be the most reliable approach to estimating the total number of agricultural wells in use and is the basis of the estimate given in Table 1 of this report. This decision was made due to the weaknesses of other methods and the consistency of this approach with the logic model outlined earlier in this document.

Estimates based upon Relevant Survey Data, Well Inventories, and Expert Opinion

Purpose and Rationale: This approach produces estimates of the number of inactive and abandoned wells for all properties (including farm properties) and for farm properties (separately). It draws upon the Alberta Water Well Survey, the Milk River Aquifer Water Well Decommissioning Project, and the Mount Hope Water Well Inventory for insights. Each of these are discussed in more detail in the following sections.

Methods: Surveys of well owners and case studies can provide insights into well numbers in particular regions. Two such surveys and three case studies were identified and reviewed for this report. The specifics of these are outlined in detail below the discussion validity and limitations. The surveys and well inventories provide indications of the number of abandoned and inactive wells for all property types and for agricultural property types. The data is all geographically limited, but in the absence of data for each geographic region of Canada, it was determined that adopting a single measure of the 'average' number of abandoned and inactive wells could be employed to develop rough estimates of total abandoned well numbers. Drawing from the surveys and cases, an estimate of the average number of abandoned or inactive wells per property for agricultural properties and on all property types was made and the following calculation was derived.

(Total Number of Households) x 30% = Number of abandoned or inactive wells

(Number of Agricultural Households) x 45% = Number of abandoned or inactive wells on farms

Validity and Limitations: None of the studies used here had a primary focus on identifying abandoned or inactive wells and as such they provide incomplete data. It was necessary to make assumptions regarding what the values indicated. A survey designed to collect information on such wells could be much more effective in providing accurate information. The authors of the Ontario study indicated respondents appeared to underreport abandoned and inactive wells. A fear of liability concerns or the imposition of mandated decommissioning at owner expense could be a factor behind this under-reporting.

The Alberta Water Well Survey

The Alberta water study collected random data throughout the province on household water supply wells. The survey collected data from 1014 water well owners throughout Alberta. The survey provides information on two key areas, abandoned and inactive wells and the age of wells currently in use.

Table 2 presents information on inactive, abandoned, and decommissioned wells. Wells labeled as *decommissioned* in the survey include all wells abandoned by a contractor (with the assumption that it was done properly), and those filled with some form of bentonite product or natural clay with the casing either removed or capped in some fashion. Those labelled as partially decommissioned were filled with porous material or simply capped or buried (without fill). Those labelled as abandoned are not expected to be used again. Those labelled as inactive are those that the owner may make use of again, but that they are not currently using.

Table 2 Inactive, Abandoned, and Decommissioned Wells Identified on All Property Types

All Respondents Well Type Present	Number of Wells	Percentage of Total Respondents
Decommissioned Well Present	99	9.8%
Partially Decommissioned Well Present	31	3.1%
Abandoned Well Present	143	14.1%
Inactive Well Present	215	21.2%

As can be seen in Table 2, 35.3% of respondent households currently have an inactive or abandoned well on their property

Table 3: Inactive, Abandoned, and Decommissioned Wells Identified on Agricultural Properties

Agricultural Respondents (595) Well Type Present	Number of Wells	Percentage of Total Respondents
Decommissioned Well Present	65	11.6%
Partially Decommissioned Well Present	16	2.7%
Abandoned Well Present	108	18.2%
Inactive Well Present	164	27.5%

As can be seen in Table 3, 45.7% of agricultural respondents reported having a well that was abandoned or inactive on their property.

The limitations of this data are first, that it will miss any properties where private wells have been replaced by municipal water systems. Second, respondents were not asked to indicate if they had more than one abandoned well or more than one inactive well, so additional wells will not be counted. Lastly, as mentioned earlier, the survey may be impacted by underreporting by respondents.

Ontario Household Water Well Owner Survey (OHWWOS)

The 2008 Ontario Household Water Well Owner Survey[63]. (OHWWOS) was conducted in Southern Ontario and had 1567 respondents. While this survey focused primarily upon wells in use, it does provide some insights into well abandonment numbers in Southern Ontario. In that survey, 198 respondents indicated that they had a non-functioning well (12.6%), however, when this data was cross-referenced with questions regarding the reasons for constructing a new well, specifically with regards to replacing an old well that was functioning poorly or no longer functioning, there was a strong indication that respondents significantly under-reported the presence of non-functioning wells on their property and that the number of abandoned and inactive wells might be substantially higher than reported. The

[63] Kreutzwiser, R. et al (2008)

report also indicated that residents indicated an unwillingness to share information about abandoned or inactive wells.

Interviews with field workers in agricultural programs and Conservation Authorities in Ontario indicated that the number of abandoned wells is much greater. Key informants suggested that that there is likely an average of around one abandoned or inactive well on each farm property and abandoned wells on at least 20-35% of non-farm properties in the region.

Milk River Aquifer Water Well Decommissioning Project

The Milk River Aquifer Water Well Decommissioning Project[64] focused on the identification and reclamation of abandoned wells in the Milk River Aquifer in Southern Alberta. The project involved a survey of all wells in the area through the use of field research.

A total of 1,027 water wells were identified in the region. Of these 585 were determined to be active wells and 442 or 43% were determined to be inactive or abandoned. This figure is very similar to that found through the AWWS for the province.

Mount Hope Water Well Inventory

As part of the 2000 Rural Municipality Of Mount Hope # 279 Water Well Inventory[65] and Microbiological Activity Assessment, an on the ground inventory of water wells was collected. Residents were contacted for further information regarding their wells. From this it was found that of 183 wells, 52 wells (28.4%) were either inactive or abandoned. The median age of active wells was 17 years and the average age of wells prior to abandonment was 18 years (based upon limited data from 10 wells).

Seine River Watershed

The 2007 Seine River Watershed Report[66] provides information on two groundwater rehabilitation programs undertaken in the watershed in 1998 and 2000 – 2003. This program identified 385 wells in the area and decommissioned 74 of them. No indication was given as to whether any of the remaining 311 wells were inactive or abandoned, but this situation in the watershed suggests that at least 74 of 385 wells (19.2%) had been abandoned and then decommissioned through the program.

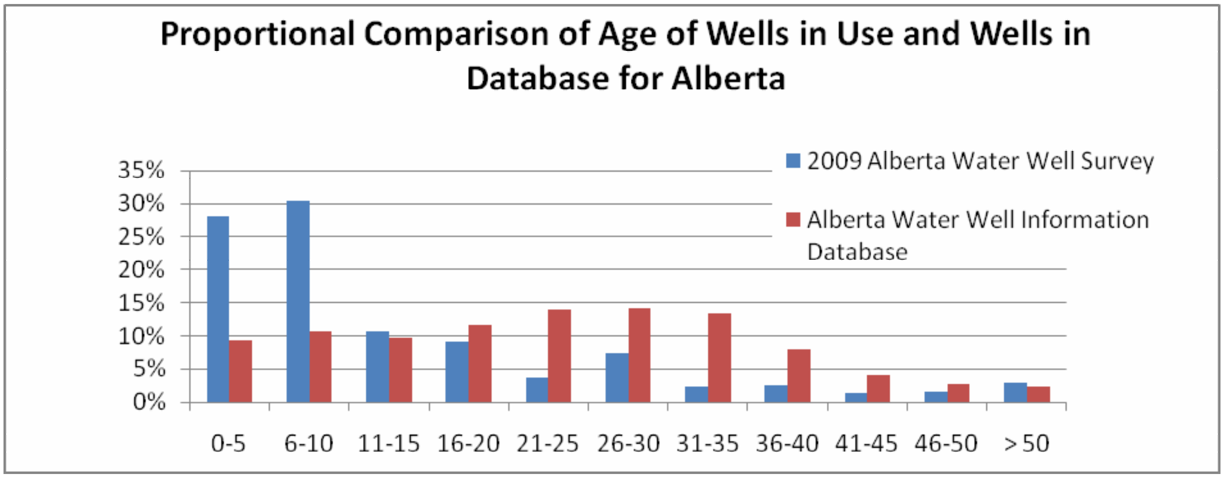
Estimate of Abandoned and Inactive Wells based upon Provincial Databases and Age of Well -

Purpose and Rationale: This method produces an estimate for the number of wells that are likely to have been abandoned or are inactive over time in Canada. This number is based upon the notion of well life cycles and the provincial databases. It also draws upon the AWWS and the Mount Hope case study to develop a rough estimate for the lifespan of wells.

Methodology: The data from the AWWS provides some information on the deterioration and possible abandonment of wells through time which offers an approach that can be used to estimate the number of abandoned an inactive wells. The survey collected age of well data for 971 wells through the survey. This identified the age of the well currently in use by the household. When this data is compared with

[64] Printz, J, 2004
[65] Jaques, D. and Rohde, H. (2000)
[66] Frost, L. (2007)

data from the Alberta Water Well Information Database, it can be seen that the majority of wells in use are much newer than the wells that have been constructed in Alberta. Given that the sample frame for the research was the database itself, it is reasonable to assume that the different distribution observed in the sample is due to many of the older wells being replaced by newer wells on the properties that were surveyed. From the data, it can be seen that after approximately 20 years, the likelihood that a well remains in use drops dramatically. Given that many wells constructed prior to 1990 were constructed with galvanized steel or steel as casing and that these have largely been replaced by PVC style casings, this trend may not continue into the future at the same rate seen in this graph.



In the Mount Hope Water Well Inventory study (discussed below), it was found that the average age of wells prior to abandonment was 18 years (based upon limited data from 10 wells).

Key informants across all regions suggested that they have observed a somewhat similar distribution of the ages of wells in use with the majority of wells in use being less than two decades old.

For the purposes of this method a value of 60% was used to calculate the number of wells older than 20 years that are no longer in active use. This is slightly lower than observed in the AWWS, and the adjustment was made due to the input from key informants.

Number of wells older than 20 years in provincial database x 60% = Estimate for number of wells abandoned, inactive or decommissioned.

Limitations Validity and Limitations: This approach has the severe limitation of being dependent upon the accuracy of the water well databases, and in this case with a focus on wells 20 years or older. It is also based upon extrapolating results from Alberta to other provinces which may not be accurate. Generally, this result was used as consideration as a minimum for the number of wells that are abandoned or inactive.

Water Well Life Cycle Estimate and Historical Rural Dwelling Figures

Purpose and Rationale: The purpose of this approach is to estimate the number of abandoned and inactive wells. It employs census and agricultural census data from 1951, 1976, and 2006. It is a demand based approach which is based on the concept that a portion of rural households will have required a well in the past and that these wells will have had a limited lifespan and thus have become inactive or abandoned.

Methodology: Census Canada has collected and maintained detailed statistics on the settlement patterns of Canadians for more than a century. As a result, it becomes possible to identify the number of farm and non-farm rural households that were very likely to be dependent upon a private well.

With a few assumptions, it becomes possible to estimate the number of wells that have been constructed and to estimate the number of these that are no longer in service. These following assumptions are based upon information from key informants. First, it is assumed that 90% of unserviced rural households in 1951 were dependent upon water well (100 % for PEI). Second, it is assumed that by 1976, most (75%) of these households that were still in rural in nature and were occupied had replaced that well with a new well and that by present day, 90% of them had[67]. Third, it is assumed that the majority of the wells constructed around 1976 (80%) are no longer functioning. The use of steel and galvanized steel casing is a factor in considering the lifespan of the 1976 wells.

It should be noted here that these dates are being used to identify rural household counts and that the well failure/abandonment events do not need to line up with those dates. A house with a well constructed in 1920 and another well in 1968 would align adequately with the assumptions presented here, as it would if the second well were produced in 1980. The key assumption is that, on average, rural properties dependent upon wells would abandon two wells over the past 60 years.

90% x (Number of rural dwellings in 1951) + (75% x 80% x (Number of rural dwellings in 1976) = Total number of abandoned, inactive, or decommissioned wells at present

90% x (Number of farm dwellings in 1951) + (75% x 80% x (Number of farm dwellings in 1976) = Total number of abandoned, inactive, or decommissioned wells wells on farms at present

To determine the number of currently abandoned and inactive wells a ratio for the number of wells that have not been decommissioned must then be multiplied by the findings of the above.

For the purposes of this estimate the ratio of 70% has been adopted.

Validity and Limitations: There are many assumptions here and many of them could be inaccurate. Wells could be over or undercounted depending upon if households shared wells or if they had more than one well. Households serviced by small community systems or other surface water sources may be miscounted as being reliant on wells[68]. A larger or smaller proportion of wells may have been abandoned and or decommissioned than assumed. However, the strength of this estimate approach lies in the rationale that most of these households had water wells, that abandoned homesteads likely did not decommission the well, and that many operating homesteads have not decommissioned wells (as indicated in key informant interviews). Despite the limitations, this is considered the most reliable

[67] In a study of these early wells in Texas, Mace (1994) found that 90% of them were no longer operational and that the majority of them had been used for discarding refuse.

[68] Efforts were made to identify counts of small rural systems for which there are no Statistics Canada records, but this data was not attainable for this study. More detailed research into provincial archives could be undertaken and would improve the validity of the method.

estimate for the total number of wells that have been constructed and the total number abandoned, inactive, or decommissioned.

Estimates from Other Sources

Data for the Yukon was provided by the Yukon government. Representatives from Nunavut indicated that there are basically no wells in the Territory. No data was available for North West Territories.

Example Results from Methods - Alberta

The following Table explores the various results from diverse methods for the province of Alberta. The Alberta figures are provided here as the Alberta database allowed for all of the proposed approaches to be explored. As is discussed below, most of the estimates presented in Table 4 did not depend upon the water well database and instead were based upon settlement data and demand estimates.

Table 4: Estimates by Various Methods for Alberta

Estimated Variable	Estimate	Key Sources/Calculations
Estimates for Number of Wells in Province		
New Wells Constructed in Province	197,517	• Wells recorded as new construction in the Alberta Water Well Information Database (Feb, 2011)
Unique Wells Identified in Province	213, 145	• Includes unique wells identified through New Well Reports, Inventories, Deepening, Reconditioning, in the Alberta Water Well Information Database (Feb, 2011) • Chemistry reports were not included as duplication of records (creating unique Well IDs for each chemistry report) appeared to be the standard practice in the database.
Number of wells Identified as being for domestic purposes	155,412	• Includes unique wells identified as being for domestic use through New Well Reports, Inventories, Deepening, Reconditioning, in the Alberta Water Well Information Database (Feb, 2011)
Number of wells in use for Domestic Purposes	113,057	• 2006 Census of Canada (1,256,195 Alberta households) • 2007 Households and the Environment Survey Table 153-0062 (9% of Albertans dependent upon Private Wells)
Number of total wells in use in Province	162,458	• 2006 Census of Canada (1,256,195 Alberta households) • 2007 Households and the Environment Survey Table 153-0062 (9% of Albertans dependent upon Private Wells) • Assumption of one non-domestic agricultural well on each farm in province
Number of Agricultural Wells in Province		
Number of New Wells identified as Agricultural in Nature	60,837	• Alberta Water Well Information Database (Feb, 2011) • Also includes wells identified as dual purpose with agricultural and domestic use • Does not include domestic use only wells on agricultural properties
Number of unique Agricultural Wells Identified in Database	64,903	• Alberta Water Well Information Database (Feb, 2011) • Includes unique wells identified through New Well Reports, Inventories, Deepening, Reconditioning, or other. • Also includes wells identified as dual purpose with agricultural and domestic use • Does not include domestic use only wells on agricultural properties
Number of Agricultural Wells based upon 'two wells per farm'	98,862	• 49,431 farms in 2006 • Based upon rough estimate of two functioning wells per farm
Number of Abandoned Wells		
Number of Decommissioned Wells	4,226	• Provincial Database (Feb, 2011) • Database is suspected to be very incomplete
Abandoned/Inactive /decommissioned wells based upon well lifecycle and settlement patterns	292,500	• Canada Census 1951 • Canada Census 1976 • Assumed that 90% of rural homes relied upon private wells • Likely a very reasonable estimate of total number of wells abandoned since about 1950, but it is unknown how many have been decommissioned by simply filling them in. • Is the only estimate here of abandoned wells that is not dependent upon the provincial database
Abandoned/Inactive /decommissioned wells from database based upon age of well	109,554	• Alberta Water Well Information Database (Feb, 2011) • 156,506 wells in total • Assumed 70% of wells older than 20 years are no longer working • Database for wells prior to 1991 may be significantly underrepresented
Abandoned/Inactive /decommissioned domestic wells based upon Current 'in use' vs initial construction in database	42,354	• Alberta Water Well Information Database (Feb, 2011) 155,412 Domestic Wells in use • 2006 Census of Canada (1,256,195 Alberta households) • 2007 Households and the Environment Survey Table 153-0062 (9% or 113,057 Albertans dependent upon Private Wells) • Wells supplying more than one household count twice as 'in use' • Wells not entered into provincial database or not identified as domestic are not represented

Estimate of Inactive and Abandoned wells on All Properties based upon Survey Data Estimate	33,917	• 2006 Census of Canada (1,256,195 Alberta households) • 2007 Households and the Environment Survey Table 153-0062 (9% of Albertans dependent upon Private Wells) • 2010 AWWS. • Assumed that 30% of all households had abandoned or inactive well present. • Survey results may be affected by underreporting by respondents • Survey affected by inability of respondents to indicate more than one well in that condition
Number of Abandoned/ Inactive Agricultural Wells in Province		
Alberta Water Well Study Estimate of Unused and Abandoned Wells on Agricultural Properties.	20,761	• 2006 Agricultural Census of Canada (49,431 Alberta Farm Households) • 2010 AWWS • Assumed that 42% of all households had abandoned or inactive well present • Survey results may be affected by underreporting.
Abandoned/Inactive /decommissioned Agricultural wells based upon well lifecycle and settlement patterns	111,500	• Canada Census 1951 • Canada Census 1976 • Assumed that 90% of rural homes relied upon private wells and other assumptions as outlined in Appendix One • Likely an underestimate as it assumes only one working well on all properties from 1951 to 1956 • It is unknown how many have been decommissioned by simply filling them in. • Is the only estimate here of abandoned wells that is not dependent upon the provincial database
Abandoned/Inactive Agricultural wells based upon age of well	30,388	• Alberta Water Well Information Database (Feb, 2011) • 50,648 wells in total

Appendix Two: Regulations Summary

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
Well Authority	Ministry of the Environment	Alberta Environment	Saskatchewan Watershed Authority	
Well and Well Driller Licensing	Drillers need to be at least 19 years of age and have proof that they have: -5 years of full time well drilling experience in BC or another jurisdiction, or -A Certificate of Qualification as a Water Well Driller issued by the province and a record of minimum 3 years of full time well drilling experience, or - a Certificate as a Ground water Drilling Technician issued by the Canadian Ground Water Association and evidence of 3 years full time well drilling experience. Registration as a licensed pump installer requires one of the same three options above, but with qualification and experience relevant to pump installation or a particular class of pump installation. Only licensed drillers or someone under the direct supervision of a driller or professional geotechnical engineer or hydrologist may drill, close, disinfect or deactivate a well. -unless the well is excavated and less than 15m deep. - well owners may deactivate or disinfect their own wells. A person who installs a pump or conducts a pump test must be a licenced well driller, pump installer, professional geotechnical engineer or hydrologist or be under their supervision, unless: -the well is being disinfected by the	Well drillers in Alberta fall into 5 categories. Category A drillers may drill or dig well anywhere in the province. This qualification is given only to certified journeyman in the trade of water well drilling, or someone whose intent it is to employ someone with this qualification to conduct well construction. Only someone under direct supervision of a Journeyman Well Driller may operate a drilling machine.	Drilling rigs must be licensed and registered with the SWA. No drilling can be conducted with an unregistered drilling machine. The SWA has a regulatory requirement for non-domestic water wells that includes 1) A Ground Water Investigation Permit 2) Approval to Construct and Operate Works and Water Rights Licence to Use Ground Water.	Drillers are required to have a provincially issued well drilling license in order to drill water wells unless they drill on their own land with equipment they own. Drilling Licenses require application and $10 fee. There are no educational/training requirements. Commercial drilling machines must be registered and licensed.

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
	owner -the work is considered by regulation to be routine maintenance. Some areas require specific authorization to drill, alter, install pumps of conduct flow tests. Licensed drillers must apply for an authorization from the Comptroller.			
Well Reporting Requirements	Anyone who constructs a well, installs a pump, conducts a flow test or close a well must keep a daily log of these activities and submit a report to the comptroller, the well owners or on request of an authority, as required by the regulations.	The person responsible for drilling a well must complete a report within 60 days of drilling the well and submit it to the Director and the well owner. The responsible driller must keep a copy of the report for 5 years. The driller must maintain a record during the drilling of the well, including the water testing and lithology. This report must be available for inspection. The occurrence of Saline water during drilling must be reported to the owner and the saline water sealed off to prevent contact with other sources of non-saline water. If unsafe quantities of gas are encountered the driller must notify the owner and the Director within 24hrs. The gas must be sealed off to prevent adverse effects. The occurrence of saline water or gas and the associated remedial steps must be included in drilling report to the Director.	The driller is required to mail a Notice of Drilling on the required form to the SWA before commencing with the drilling of a well. Within 30 days of completing a well the driller needs to submit notice of completion on the correct form. The driller also needs to forward a copy of any logs kept during the drilling and all the pertinent information relevant to that log.	Well drillers must submit well reports within 5 days of drilling a well. Drillers must take sample during drilling at intervals of not more than 10 feet or with each change ins strata. The samples may be required for submission within 30 days of drilling.
Water quality and Yield testing	The person responsible for drilling a well of making prescribed alterations must sample the ground water and submit the sample for testing. If the water is for 'domestic purposes' analyses must comply with the Drinking Water Act. The person responsible must submit a report to the comptroller, the well owners or	Upon completion of the well the driller must test the well by pumping at the same rate as expected usage, continuously for at least 2 hours followed by a 2 hour recovery. To test yield the static water level just prior to pumping must be measured and measured at intervals specified in the pumping report during the 2	Domestic wells must be yield tested by the driller upon completion by means of a pump, bailer or other approved means. Wells intended for agriculture, industrial or municipal purposes, mineral water or mineral recovery must be yield tested by the permit holder by means of a step-drawdown or constant rate pump	A well driller must complete a yield test upon completion of the well by pump, bailer or other means or device approved by the director. Any applicant for a licence to divert and use ground water shall conduct aquifer pumping tests in accordance with instructions of the Water

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
	on request of an authority, as required by the regulations. Testing is not required for monitoring or geotechnical wells.	hour pumping. Water level in the well must then be measured at the end of the pumping and at intervals for at least 2 hrs or until 90% recovery of the static level, whichever is first. All measurement must be recorded in the drilling report. If the well cannot be pumped for 2 continuous hours the same measurement steps must be taken and the report must show the reason why the pumping was discontinued, the pumping rate, length of time, recovery methods and measurements taken. Well yield tested by means other than pumping (e.g. with a bailer) and are conducted with the same parameters and measurements with water removed for 2 hours.	test for a minimum of 24hrs. These test data must be submitted with 60 days on the correct SWA form. There are no testing requirements for private wells.	Branch of the Department of Conservation, as a condition precedent to the issue of the licence.
Well Disinfection	A person who disinfects a well must either be a qualified well driller, under a QWD supervision or be qualified in the field of hydrology or geotechnical engineering, unless: -the well is less than 15m deep -the person is the owner of the well. -the activity is prescribed as 'routine maintenance'.	The driller must disinfect the completed well, except a flowing well, with 200mg of chlorine per litre of water that is present throughout the length of the well and maintain that concentration for at least 12 hrs.	Upon completion and prior to use the driller must remove all foreign substances from the well and disinfect the well.	A Health Officer may order the disinfection of a well if it is deemed unsafe. Disinfection not required in the absence of erratic or high level coliform contamination or other contaminating factors.
Well Identification and Documentation	Water supply wells constructed before November 1 2005 were required to have well ID plates fitted by October 2006. Water supply wells, recharge or injection wells made by drilling and permanent vertical dewatering wells made by drilling constructed on or after 1November 2005 must be fitted with an ID plate. Those existing before Nov 1 2005 but altered after this date also require an ID plate. Well plate must be attached to the well by the person drilling or altering the well or by the owner for an existing well.			

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
	-The person who fits the plate must submit a report to the comptroller or if requested by an official. -The ID plate is not required for monitoring or geotechnical wells. -the person responsible for closing a well must submit the ID plate to the comptroller.			
Artesian Flow	Licensed well drillers or professionals must ensure that artesian flow is stopped or if the likelihood of artesian flow is identified that measures are taken to prevent this. Anyone who constructs a well and encounters artesian flow must inform and licensed well driller or professional who must prevent the flow. The owner of the well or where the owner is not known, the owner of the land must notify a licensed professional or driller of artesian flow in compliance with regulations.	Drillers ensure they drill potentially flowing wells in a manner that prevents out-of-control flow. The completed flowing well must be equipped with a variable flow device and the driller must stop the flow for not less than 48hrs upon completion of the well. The well must be sealed to prevent the escape of water from the annulus. Water flow may not exceed the lesser of either: the water requirement of the well owner or 100cubic meters/week, unless the well license permits great volumes of usage.	Where flowing well conditions exist the driller must set and cement sufficient surface sealing to enable the control of the water flow.	Where a well driller has been notified that artesian conditions may exist at the site of a proposed well, he shall take adequate precautions to ensure that the well casing is firmly sealed in the impermeable formation above the artesian aquifer. The minister in charge may direct the owner of a well to control flow from a well. In failure to do so the minister may authorize someone to take the necessary action to control a flowing well. The costs o this operation and the person responsible for these costs may be determined by the minister.
Well management and aquifer protection	A person must manage a well in such a manner that does not allow the intrusion of salt water in the aquifer or that has an adverse impact on the quality of the groundwater in that aquifer. This includes a prohibition on the introduction in to the well of carcases, human or animal waste, fertilizer or pesticides, refuse, any construction or demolition material, or any contaminant that will adversely affect the quality of the ground water or the existing uses of the well. These prohibitions do not include instances of disinfections, well closure, alteration, repair or other	The owner must ensure that the well does not allow the entry of any substance that could have an adverse effect on the water quality and maintain the area immediately around the well in a sanitary condition. The owner must protect the well at ground surface from physical damage and if non-metallic casing is used it must be protected at ground level by steel casing which is firmly anchored into the ground. If saline water enters the well after completion the owner must ensure that the saline water is sealed off to prevent adverse effects.		A well driller shall construct each well so as to effectively prevent the entrance of non-potable water or other deleterious matter into any aquifer and to prevent intermixing of water. If non-potable water enters a well after the date of completion of the well, the owner shall immediately seal off the non-potable water in a manner so as to prevent impairment of the quality of other water. No person shall drill a well without taking reasonable precautions to avoid polluting, or contaminating, or diminishing the purity of, ground water in the area.

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
	prescribed or authorised procedures. An engineer may order someone to remove, stop the introduction of contaminants and undertake the remediation or mitigation of the introduction of the contaminant or substance into the well. It is the responsibility of the well owner, or land owner where the well is situated, to comply with directives to remediate contamination of the well or be responsible for government debts to undertake these actions.			No owner shall deposit or place, or allow any other person to deposit, or place in or near a well on his property, any material, substance, or thing, that might pollute, or contaminate, or diminish the purity of, water in the well or ground water in the area of the well. No person shall deposit or inject any sewage discharge, filth, liquid waste or surface drainage into a water well. An existing well can only be recharged or replenished with water from a source approved by a health officer (unless another source is authorized).
Wells on Crown Land	A person who has right to use or occupy Crown Land that has a well may be subject to the provisions enforcing the closing or deactivating the well, capping or covering the well, control artesian flow and the prevention of introduction of foreign matter into the well. This despite subsequent terminations of the right to use the well.			
Surface Sealing / Filling the Annulus.	The person responsible for drilling the well must ensure that the surface of the well is sealed in order to prevent the entry of contaminants into the well or aquifer. The owner of the well must maintain the surface seal and seal any annular space that develops. An engineer may request that a well owner upgrade the surface seal should the existing seal be considered inadequate. Surface of all well deeper than 15m/50ft must be undertaken by a registered well driller or licensed professional or person under their direct supervision.	Wells drilled by methods other than boring or digging must: -fill the annulus from the bottom of the casing to the ground surface when the casing-liner completion method is used. -fill the annulus from the top of the perforated section to the ground surface when the single string casing completion method is used. Annular spaces must be filled with an appropriate grout, cement, concrete, bentonite slurry or similar impervious material slurry such as clay. A dug or bored well deeper than 4.5m must have the annulus	Well casings must be set and cemented or 'driven' in order to seal the annular space.	The driller must ensure that surface water cannot enter the well and take steps during the construction of a well to prevent surface water from entering the well.

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
	The surface seal must be at least 1"/2.54cm in thickness and must seal the annulus between the final production casing (after drive shoe is removed) and the geological formation. If surface casing cannot be removed then the area around the casing must be excavated to a depth of 3 feet from ground surface and that extends laterally to fill the entire excavated area. Surface sealing is required to a minimum of 3 feet for holes < 15ft and 15ft for holes > 15ft in depth (except those drilled by driving or excavating). Annular space between casings must be sealed. If bedrock is encountered within 15 ft of the surface when drilling a well >15ft deep the annular seal must extend at least 3ft/0.9m into that bedrock. In excavated wells the seal must extend laterally to fill any excavations, be at least 1"/2.54cm thick and extend at least 3 ft/0.9m in length. Sealant should not extend more than within 1ft/0.3m below ground surface (taking into account its minimum required length of 3 or 15ft).	adjacent to the perforated section filled with a clean fill material free of clay and silt to within no less than 4.5 m of the surface. The top 4.5m must be filled with an appropriate grout, cement, concrete, bentonite slurry or similar impervious material slurry such as clay. A bored or dug well less than 4.5m in depth must have the annulus filled from the bottom of the well to within not less than 1m from ground surface. The remaining 1m to the ground surface must be filled with an impervious grout type seal or other impervious material like drill cuttings, clay or impervious overburden. Any well that requires groundwater diversion licensing must have the entire annular space from the ground surface to the top of the aquifer sealed with an appropriate grout, cement, concrete, bentonite slurry or similar impervious material slurry such as clay.		
Flood Proofing the well	The owner of a new water supply well must protect the well in order to prevent contaminants entering the top of the well or through the			

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
	annular space. The well head must also be protected from damage by flood water, ice or associated corrosion. An engineer may also require a well owner to take steps to ensure the well head is flood protected or employ the services of a professional who can carry out the flood protection actions. The above steps may also be required of the owner of a well that is in close proximity to a water supply well. Any alterations in accordance with these requirements must be undertaken by a qualified well driller, a professional hydrogeologist or someone under their direct supervision.			
Protection of the well head	The person responsible for drilling or the owner of a new well must ensure that the casing extends at least 0.3m/12" above the adjacent ground level or 0.3m/12" above the floor of a well pit, pump house or sump. Wells finished or altered after 1 October 2005 must be completed so that water does not pond around the well head or area disturbed during drilling (those in sumps or pits must be able to drain water away from the well head). This does not apply to geotechnical well, dewatering wells, drainage wells or monitoring wells drilled under professional supervision. Thermoplastic casing at ground level must be protected from material breakdown and damage.	The casing must extend at least 20cm above the pump-house floor or established ground surface and at least 60cm above the highest recorded flood levels, unless the well will be fitted with a watertight cap.		
Change of purpose	If the use of the well changes or the well is altered from its original purpose for which it was drilled the owner must ensure it continues to meet regulations.			

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
Well Location / Siting	*discrepancy between old and new BC regs, the new regs have no siting info and supersede the old ones*	Wells must not be subject to water pooling in the vicinity around them, cannot be located in a pit and must be upslope of contaminants as much as possible and cannot be housed in a building other than a well ventilated, bona fide pump house. They must be accessible for maintenance, testing, inspection, repair and cleaning. They cannot be within 3.25m of at least: -10m from water tight septic or sewage tanks. -15m from a weeping tile effluent disposal field of evaporation mound -50m from sewage effluent discharge into the ground surface -100m from sewage lagoon -50m from above ground storage tanks for petroleum substances. -2m from overhead power lines if the conductors are insulated and weatherproofed and the lines conduct less than 750volts. -6m from overhead lines if the well does not have a pipe and sucker rod system, has PVC or non-conducting pipe pumping system and has a casing longer than 7m (23ft). -12m from overhead power lines in all other situations. -500m from a sanitary landfill.	The following refer to the distance between wastewater disposal and water sources: -Septic tanks, package sewage treatment plants, or holding tanks should be located no less than 9 m from a water source. -Absorption fields, chamber systems, and mounds should be located no less than 15 m from a water source. -Open discharge systems and jet-type disposals should be located no less than 45 m from a water source. -Private sewage lagoons should be located no less than 90 m from a water source.	The provincial government may determine the spacing and depths of wells if deemed necessary. Wells must be located in such a manner as to prevent contamination.
Well Deepening		If a bored or dug well is deepened by any means other than boring or digging the well must have a casing that extends upwards through the bored/dug well and that is in accordance with casing dimension regulations. The annulus between the existing case and new casing must be filled with a suitable impervious material like those used to normally seal annular spaces.		
Pump Installation		Pumps must be installed so that pumps and the surrounding can be access and kept in a sanitary, clean		

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
		condition. Pumps cannot be placed in an unsupported open hole and pumping rate cannot exceed the recommended pumping rate. Pump – casing connection below ground must use a pitless adapter with a water tight connection. This outside excavation should extend 0.5m from the casing and to within 0.5m of the ground surface and should be filled with an acceptable impermeable grout like cement, bentonite, concrete, clay or impervious overburden materials. If pumping equipment is installed in a water well drilled by a method other than boring or digging, the top of the casing must sealed with a commercially manufactured water well cap.		
General Well Construction specifications	All openings in production casing such as joints, holes, pitless adapter seems etc must be sealed.	Well drilling and construction materials, (e.g. casing thickness) must meet or exceed Canadian Standards Association or American Society for Testing Materials minimum standards and the following minimum wall thickness: -4.78mm for metal casing -3.96mm for metal liner casing -6.35cm for cement-like casing with well diameter < 60.96cm and an additional 2.54cm for every 30.48cm diameter increase. -16 gauge for galvanized or corrugated casing using in bored or dug wells. Plastic ABS or PVC must be approved for potable water and adhere to these standards If a submersible or independent jet pump are used the casing must have an inside diameter of at least 10.16 centimetres from the	Every well must be completed in a manner that prevents contamination of the well and the related aquifer.	Drillers must install unused casing in new wells. The provincial government may prescribe specifications and standards for casings, equipment and materials used in, or in drilling, wells. Wells must be constructed in such a manner as to prevent contamination.

Prov	British Columbia	Alberta	Saskatchewan	Manitoba
		top of the water well to below the optimum pump intake depth When non-metallic pipe is used as casing, the water well must be protected at the ground surface by steel casing that is firmly anchored in the ground. In the case of ground water diversions that must be licensed the well must not result in multiple aquifer completions and must be completed with an open hole and a slotted of screened section that does not exceed 7.62m in length. The driller must make sure all the casing joints are sealed to prevent entry into the well of any harmful substance. Wells must be vented where necessary (i.e. the casing does not transmit water and the well cap does not allow the well to vent). The air vent must extend at least 30cm above ground or to the highest recorded flood record. The venting hole must be a minimum of 0.3cm for well casing 10.16cm in diameter of less, or at least 1.2cm for larger diameter casings.		

Province	Ontario	Quebec	New Brunswick	Nova Scotia
Well Authority	Ministry of the Environment	Development durable, Environment et Parcs Quebec	Department of Environment	Nova Scotia Environment and Labour.
Well and Well Driller Licensing	Well Contractors must be licensed and be at least 18 years of age and hold the relevant qualifications. The contractor must supervise all well work or have the work undertaken by an employee who is a well technician. Well Driller Licenses fall into the	A person who applies to construct a well must hold a well drilling contractor's licence issued by the Régie du bâtiment du Québec.	A Well Contractors Permit is necessary to drill, dig, bore, re-drill or recondition a well on land on which a person is not the owner. A Well Contractors Permit is necessary to engage in the business of drilling wells. A Well Drillers Permit is required for	A well driller qualification is needed for anyone who offers their services as a well driller, constructs, repairs or modifies a well or operates a drilling machine with the purpose of drilling a well, unless on lands which they own or lease. A well driller qualification is not

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	following categories: -Well Drilling: may use/supervise cable, rotary or diamond drilling equipment. - Well Digging and Boring: use/supervise non-powered equipment, back hoe, power shovel or auger/boring equipment. -Other Well Construction: construct/supervise well construction by methods stated on the license -Pump Installation: install/supervise installation of well pumps. -Monitoring, Sampling, Testing and Non-Powered Construction: Install monitoring or test equipment other that the equipment for yield testing, install pumps in a test or dewatering hole and construct test or dewatering holes with non-powered equipment. Applicants for a well technician license need to be 18 years or older an satisfy the Director of their qualifications which may include: -a course of study of at least 30hrs that is approved by the director for the particular class of license. -4000 hours of work experience for relevant class of license. For Monitoring, Sampling, Testing and Non-Powered Construction licenses the applicant needs: - a course of study of at least 30hrs that is approved by the director for the particular class of license. -1000 hours of work experience for relevant class of license. Applicants who are either is a member of the Association of Professional Engineers of Ontario as an engineer-in-training; a member of the Association of Professional Geoscientists of Ontario		person who operates a machine for the purpose of drilling, altering or repairing a well. The holder of the permit must hold a valid certificate of qualification in the water well driller trade issued under the *Apprenticeship and Occupational Certification Act* or have held a valid well driller's permit issued under the *Water Well Regulation - Clean Environment Act*. All drilling machines must be clearly marked with the contractor's details.	necessary for some assisting a qualified driller. A certificate of qualification as a well driller can be issued to someone who is: -at least 18 years old. -has minimum 4000hrs of supervised experience with a drilling machine. -has successfully completed a provincial drilling exam and drilling filed test. In order to construct only dug wells (no drilling) the Act stipulates the same regulation as a drilling certificate with the following changes: - 2000hrs of supervised experience with an excavating machine. - proof of on-site work experience in constructing at least 3 dug wells under the supervision of a well digger. - successfully complete a provincial exam in well digging and a field test. If someone constructs a dug or drilled well on land they own, the construction must still adhere to the regulations in the Well Construction Regulations in the Environment Act. Well drillers and digger must identify themselves on their drilling/digging machinery. Pump installers are registered as class I or II installers which determines the size and type of pump they are permitted to work with or install. Both licenses require stipulated exams, minimum work experience and qualifications.

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	as a geoscientist-in-training; or are a member of the Ontario Association of Certified Engineering Technicians and Technologists as a technician or technologist in training require: - a course of study of at least 315hrs that is approved by the director for the particular class of license. -500 hours of work experience for relevant class of license. Applicants need to take an examination set by the Director. Drilling technicians are also subject to continuing education as condition to renew licenses.			
Well Reporting Requirements	A log of bedrock and overburden as well as field notes and a construction record must be kept by anyone constructing or abandoning a well (lithography log not necessary when the well is constructed by driven point, the well is altered without deepening or is being abandoning). On completion of the well the driller must complete the well report and within 14 days hand a copy to the well purchaser and land owner. And within 30 days send a copy of the report to the director. Drillers must retain a copy for 2 years. Reporting is not necessary for minor alterations to the well or pump instalment. Single reports for clusters of wells are permissible.	Every catchment work installation (incl. wells) is subject to the authorization of the local or regional municipality in the territory of which the work will be installed. The application must specify the location of the work and its capacity. A person who drills or deepens a well must, within 30 days after completion draw up a report, in accordance with the sample standard format. The report must certify that the work complies with the standards provided for in the Regulations. A copy of the report must be provided to the owner of a catchment work, the municipality and the Minister.	A person who bores, drills, digs or redrills a well Must complete a water well driller's report as required by the Minister, in triplicate for each well. They must deliver a copy of the report to the well owner and retain a copy for at least 2 years.	The Department or an inspector may ask a well driller, digger or pump installer to notify them of their intent to construct a well, which they must do later within 24hrs of construction. An individual who intends to construct a well on lands they own or lease must notify the Department no later than 24 hours before they begin the work. A well construction record must be completed for all well on a form supplied by the Department. The driller or digger must deliver a copy to the owner and the Department as well as keep a copy on record for at least 2 years. A pump installation record must be completed on a form supplied by the Department. The installer must deliver a copy to the owner and the Department as well as keep a copy on record for at least 2 years.
Water quality and Yield testing	The person constructing the well must test the yield before completion of the structural stage. Water level must be measured just	A person who drills a tube well must carry out a flow rate test for not less than 30 minutes, during which the flow rate and the water level before	Drillers may not complete the construction of a well without conducting a yield test. Public supply wells must include a stage	All new or modified wells must be yield tested by either a bail or air lift test for at least 1hr or a pump test for at least 2 hrs. Measurement must

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	prior to pumping and then: -every minute for the first 5 mins. -every 5 mins for next 25mins -every 10 mins for the next 30 mins The rate of pumping must be for at least one hour and the rate recorded on the well record. After pumping stops the water level is measured at the same intervals. If water cannot be pumped for one hour the well record must show why pumping was stopped, what measurements were taken, pumping rate and duration and what the water levels were.	pumping and at the end of pumping must be measured. The test must verify if the flow rate meets the daily peak requirements of the residence, where applicable. The owner of a well must have groundwater samples taken between the second and the thirtieth day following the beginning of use of the pumping equipment and have the samples analyzed by a laboratory accredited by the Minister.	drawdown test and a constant rate test, all including water level measurements in the well and in at least one observation well and for those drawing more than 50 cubic meters a day the test must be carried out for 24hours or more. Wells intended for household use must endure a yield test for at least 1 hour during which measurements must be made before, during and after the pumping test to establish the recovery curve. The results of tests or measurements must be reported to the Minister within 30days.	included: -static water level before pumping -yield rate during pumping -water level recovery measurements after pumping for the equivalent period of the yield test or until 95% of the static water level has recovered.
Well Disinfection	On the day the well is structurally completed the responsible person must disinfect the well with between 50 and 200mg/l of free chlorine and allow the well to rest for at least 12 hours. Submersible pump and/or pipe installation also requires the same chlorine disinfection unless it is an emergency replacement and no alternative sources of water exist. The chlorine concentration must be tested between 12 and 24 hours after application. The concentration must be reduced to no more than 1mg/l by the responsible person prior to use. The well owner must be given the test reports.	The person constructing or alters the well must clean and disinfect the well to prevent any contamination. This applies to a person who fits a pump more than 2 days after the completion of the well.	After completion of drilled or dug wells the well driller must remove debris from the well and disinfect the well with a method approved by the Minister.	All wells must be cleaned of debris and disinfected after completion by the driller, digger or individual conducting work on their own land.
Well Identification and Documentation	The person constructing the well must obtain a well tag and affix it to the casing or permanent part of the well in a visible place.			

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	Major alteration to existing cased wells require a well tag to be attached as with a new well. Illegible or lost tags must be returned a replaced, the well record amended within 30 to reflect the new well tag number.			
Artesian Flow	Flowing wells must be fitted with a device that can control or stop the flow of water from the well casing or back flow into the well, and withstand the freezing of water.	The owner of a well in artesian condition must have it installed and maintain it so as to prevent any gushing.	The owner of a flowing well shall ensure that the well is at all times fitted with an approved control device that prevents or minimizes the flow of water.	An owner of a flowing well must ensure that an appropriate certificate holder installs any well modifications, well grouting, pumping systems, well packers or vermin proof well caps fitted with gaskets or seals necessary to stop and control the flow of water and to ensure that water is not discharged immediately around the well head.
Well management and aquifer protection	The person who constructs the well must take reasonable steps to 'develop' the well by removing debris, drill fluids and cuttings. A well owner must maintain a well in such a way to prevent the entry of surface water and debris.		A well may not be constructed in a manner or location such that surface water may enter the well. Joins or connections in well casings must be made water tight. No well may be used for waste disposal without the written approval of the Minister.	All well casings must be sealed and prevent water or any other substance from leaking into the well from an annular space, the drive shoe or the well casing interface with subsurface geologic materials.
Wells on Crown Land				
Surface Sealing / Filling the Annulus.	The annular space between casings of different diameters must be sealed with suitable sealant to prevent the entry into the well of surface water and other foreign materials. Bored wells: the diameter of the well from ground surface down to 2.5m must be at least 15.2 cm greater than the outside diameter of the casing and at least 7.6cm wider than the casing from 2.5m below ground down to 6m or the bottom of the well (whichever is first). If a screen is used the annular space must be filled with clean washed gravel or	In well installed into bedrock and deeper than 5 m the well must be drilled with a diameter of at least 10 cm greater than the nominal diameter of the casing for sealing purposes. This annular space must be filled with an appropriate sealer like a bentonite and cement slurry. The annular space in shallow or large diameter wells must be filled with a material that ensures, over a space of at least 5 cm, a watertight and durable sealing such as a cement bentonite mix, to a depth of 1 m below the ground surface.	Where the fitting of a drive shoe does not prevent contamination and the casing in seated in the bedrock the contractor must surround the casing with a cement grout that is not less than sixty millimetres in thickness. In dug wells, from the top of the well to a distance at least 2m below land surface, the annular space between the casing or rocked-up portion of the well and the side walls of the excavation must be filled with clean gravel, sand, crushed rock or small boulders. Any portion of the annular space between the casing	A seal of high solids bentonite grout or other grout is required to seal the annular space for at least 1 m from the base of a drilled well casing. The remaining volume of the annulus must be filled with grout, drill cuttings or impermeable soil to the ground surface and must prevent surface water from entering the annular space. When a well liner is installed to repair or modify a drilled well to remediate well water contamination, a seal of high solids bentonite grout or other grout must seal the annular space from the base

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	sand from the bottom of the well to the top of the screen but not closer than 6m from the ground surface (or 2.5m in the case of a shallower well). The remaining annular space from the top of the screen (or is not screen is used) must be filled with a suitable grout material via a tremie pipe. The remaining 2.5m of annulus to the ground surface must be filled with bentonite chips with a diameter between 6mm-20mm. Dug wells: The annular space must be filled with clean, washed sand or gravel, or native materials from the excavation, replaced in order of their vertical horizons, from the bottom of the well to no closer than 2.5m from the ground surface. The remaining 2.5m must be filled with a suitable sealant that will support the weight of people or vehicles on top of it. Drilled wells: should constructed with a diameter of at least 7.6cm greater diameter than the outside diameter of the casing for the full depth of the well or at least 6 meters, whichever is less. If a screen is used the annulus from the bottom of the well to the top of the screen must be filled with clean gravel or sand that is deposited or developed from surging and must be no closer than 6m (2.5m in shallow wells <6m deep). The remaining annulus must be filled from the top of the sand pack, or bottom of the casing where no screen is used, with a suitable sealant material via a tremie pipe, up to the ground surface. If a well pit is used the diameter of the pit must be at least 7.6 cm greater than the outside diameter of		or rocked-up portion of a dug well and the side walls of the excavation not filled with these materials must be filled with cement grout, concrete, bentonite or equivalent commercial slurry, clay slurry or puddled clay to prevent surface waters from getting into the well.	of the well liner to as near surface as is practical. In dug wells the annular space from the bottom of the well up to the apron must be filled with filter pack materials suitable for potable water applications (sand, gravel or crushed rock). The annular space above the apron in a dug well must be filled to the ground surface with a concrete, bentonite, cement or commercial grout to prevent surface water from entering the well.

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	the pit and this space from the bottom of the pit to the ground surface must be filled with a suitable sealant material.			
Flood Proofing the well		Casings must rise above the ground sufficiently to prevent the entry of flood water. In areas that experience a regular flood every 0-20 years it is prohibited to build any catchment works unless it is to replace a catchment work existing on 15 June 2002. In this case only a tube well that meting construction regulations is approved and its casing must extend above ground level high enough to prevent possible immersion. The finished grade within a 1m radius of the well must allow the area to drain and not allow for stagnant water or allow entry of water into the well.	Dug wells must have a casing that extends a minimum of 15cm above ground and be must be surrounded by an impermeable apron that slopes away from the well. Where a well is located at a place where surface water will pass over or near the opening, the area surrounding the well opening must be filled with clay or clean earth for a distance of at least 5m in all directions and graded at the opening to an elevation at least 60cm above the ground.	If a well has surface water that passes over or near the opening the owner must ensure that: -the area surrounding the well is filled with clay or clean earth for at least 4.5 m in all directions. - the area immediately surrounding the well is graded to an elevation of at least 610 mm above the highest known surface water level. The area around a dug well must be sloped so that water drains away from the well.
Protection of the well head	No-one may reduce the height of the above ground casing to less than 40cm above ground surface.			
Change of purpose				
Well Location / Siting	Drilled wells with a casing of at least 6 m underground must be located at least 15m from a source of contaminants and: -15m from an earth pit privy -10m privy vault or pail privy -10m from a greywater system -30m from a cesspool. -15m from treatment units such as a septic tank -15m from a distribution pipe in a leaching or filter bed. -15m from a holding tank Wells with less than 6m of casing or those constructed by means other than drilling must be 30m from contaminants and: -30m from an earth pit privy	A tube well that complies with regulations can be constructed no closer than 15m from a wastewater system. It is prohibited to install a groundwater catchment work for human consumption purposes less than 30 m from a cultivated parcel. Facilities for raising animals or storing animal waste can be no closer than 30m from a supply well intended for human consumption. 75m for over wintering site for beef cattle. (this does not apply for canids, felids, zoos or aquaculture). Direct on the ground storage of	All wells must always be accessible for cleaning, treatment, repair, testing and inspection. Wells may not be housed under a building under provisions are made to allow for the cleaning, treatment, repair, testing and inspection. A well may not be located closer than 2m to any portion of a building. Wells may not be constructed closer than the prescribed distance from the following sources of contamination: -15m from a raw sewage cesspool. - 25m (drilled well) or 30m (dug well) from a seepage (leaching) pit, filter	A well must be located and maintained so that it can be accessed to clean, repair or inspect the well or test or treat the water. A well cannot be constructed in a place or manner that allows surface water to enter the aquifer. A well must be constructed so that it is located far enough away from a source of contamination including: -61m from a cesspool -15.2m (drilled well) or 30.5m (dug well) from an on-site sewage disposal system.

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	-15m privy vault or pail privy -15m from a greywater system -60m from a cesspool. -15m from treatment units such as a septic tank -30m from a distribution pipe in a leaching or filter bed. -15m from a holding tank The site of a new well shall be chosen so that the well is accessible for cleaning, treatment, repair, testing, inspection and visual examination and the well site should be higher than the immediate surrounding areas.	animal waste or fertilizing compounds is not permitted within 300m of a supply well intended for human consumption). The spreading of animal waste, farm compost, mineral fertilizer and fertilizing waste substances is prohibited less than 30 m from any groundwater catchment work intended to supply water for human consumption. This distance is 100m for sludge from municipal waste works. Owners of an installation that supplies more than 20 people with drinking water must establish an immediate protection zone with a radius not less than 30m from the well. Those wells that produce more than 75cubic meters/day must have a bacteriological protection radius of 100m and a virological protection radius of 200m.	bed, soil absorption field or earth pit privy. -15m (drilled well) or 30m (dug well) from a septic tank, concrete vault privy, sewer of tightly jointed tile or sewer connected foundation drain. -3m from a sewer of cast iron with leaded or approved mechanical joints, independent clean water drain or cistern. -60cm from pumphouse floor drain, cast iron with leaded or approved mechanical joints, draining to ground surface. Wells cannot be located less than 60m from cesspool or seepage pit that is more than 3.5m deep unless it is correctly cased or permanently sealed. A well may not be located near a sanitary land fill or garbage dump. No well shall be located within ten metres of the right-of-way of any highway or public road unless approved by the Minister.	- 15.2m (drilled well) or 30.5m (dug well) from a sewer of tightly jointed pipe, sewer-connected foundation or floor drain or water treatment discharge point. -3m from a sewer with secondary containment, roof drainage discharge point, non-sewer-connected foundation or floor drain, or cistern. -61cm from a pumphouse floor drain -5m (drilled well) or 15.2m (dug well) from an above-ground petroleum storage tank of 1200 L or less. -15.m from an above-ground petroleum tank storage system greater than 1200 L capacity. -15.2m from an underground petroleum storage tank system. - 6.1m from an outer boundary of any public road or public highway. -61m from a solid waste management facility, landfill, former dump site or other significant source of potential contamination. Wells may not be constructed in basements. The Minister may allow the contravention of these regulations

Province	Ontario	Quebec	New Brunswick	Nova Scotia
				where necessary or acceptable.
Well Depth/Deepening	Wells must be at least 6m deep. If not possible due to available aquifer depth then the well must be at least 3m deep. If the nature of the geologic strata change when deepening a well the regulations pertaining to casing and intrusion into bedrock apply. A well may not be deepened by drilling, jetting or driving through the bottom of an existing bored/dug well.			
Pump/Equipment Installation	Connections to the casing made below ground must use a watertight connection and in drilled wells must use a pitless adapter. Outside excavation from underground connections must be filled with a suitable sealant that extends from the casing at least 20cm outward and from the bottom of the excavation to within at least 20 of the ground surface.		If a pump is installed on a drilled well the top of the casing must be capped and sealed. Pumps must be disinfected after installation. An air vent must extend at least 30cm into open air at the well surface and have an inside diameter no less than 6mm with a screen to prevent the entry any contaminant.	The diameter of pumping equipment installed in a well must be at least 25 mm smaller than the diameter of the open borehole, well casing and well screen. A hand pump must be mounted to the well casing or pump mounting sleeve in a manner that seals the top of the well casing or sleeve. A water sampling port or a tap must be installed in a well at a point between the well pump and any water treatment device After installation or repair the installer must remove all debris from within and around the well and

Province	Ontario	Quebec	New Brunswick	Nova Scotia
				disinfect the well.
General Well Construction specifications	New wells are typically not allowed to be constructed in well pits, nor are pits allowed to be added to existing wells. The construction must prevent pooling of water at the well head and ensure drainage away from the well. Casing and screens must be new, uncontaminated and be continuous and made water tight where joins occur. Concrete casing sections must be joined by a mastic sealer approved for potable water. Wells that draw water from overburden must be cased from the water intake zone to not less than 40cm above the highest point within 3 m of the well casing. Those that draw from bedrock must be cased from the bedrock to at least 40cm above the highest point within 3 m of the well casing. Well casing must extend at least 6m deep or in the case of shallower wells due to aquifer availability, at least 2.5m deep. The casing of a drilled well that obtains water from bedrock, other than from the weathered bedrock zone, must be sealed into the bedrock. Casing standards adhere to American Society for Testing Materials specifications and include: -steel casing with an inside diameter of at least 50.8mm must have a	The casing of both drilled or large diameter wells must extended at least 30cm above ground at all times. Well casing must always be new when installed. Casing must be at least 5.3 m long and have an inside diameter wider than 8 cm. Allowable casing must bear the following marks: -ASTM Standard A 53/A 53M - 99b for steel casing - ASTM Standard A 409/A 409M - 95a for stainless steel casing - ASTM Standard F 480 – 00 for plastic casing If a tube well is installed into a rock formation a drive shoes must be connected to the bottom of the casing. If the rock formation is deeper than 5m the well must be drilled so that: -the casing must be sunk to a depth not less than 5m and the casing must be anchored at least 60cm into the rock formation or until penetration ceases. Connections between 2 casings in drilled bedrock wells must be water tight. Shallow wells must be constructed with new materials and: -must be at least 60cm in diameter. -may not be more than 9m deep. - the casing must be either porous concrete, plastic, stonework or	Drilled well casing material must be: -new -at least 6m long -sealed water tight at the joints -at least 12.7cm inside diameter. -be fitted a drive shoe on the end that provides a suitable seal with the surrounding formation and fitted by threading or welding. Drilled well casing pipe dimensions must be in accordance with Schedule A of the Clean Water Act and as follows- Inside diameter: wall thickness: 12.70 cm : 0.478 cm 15.24 cm : 0.478 cm 17.78 cm : 0.587 cm 20.32 cm : 0.478 cm 22.86 cm : 0.714 cm 25.40 cm : 0.478 cm Individual lengths of casing must between 4.5m and 7.2m Galvanized casing is acceptable. Plastic casing must meet Canadian Standards Association Standard B181.1-1973, Acrylonitrile- Butadiene-Styrene Drain, Waste and Vent (ABS-DWV) Pipe and Pipe Fittings. Where the fitting of a drive shoe does not prevent contamination the contractor must fit the casing in the bedrock at a depth specified by the Director. No connection below the land surface shall be made	A drilled well must have a casing. Casing, well liner or well screen installed in a drilled well must meet the following regulations: -casing must be at least 6.1m long. -the casing must extend at least 152 mm above the ground surface when the well is completed. - for a steel well casing, a drive shoe must be attached to the bottom of the well casing and be firmly sealed with the bedrock or consolidated geologic formations. -casing must be welded or otherwise connected to any well screen. -any natural or manufactured filter pack materials used with a well screen are developed after installation and are made of material suitable for potable water. Drilled well casing must meet the following requirements: -must be new steel or thermoplastic be and uncontaminated. -must have an inside diameter of at least 152mm and steel casing must have a wall diameter of at least 4.7mm and thermoplastic casing must have a wall diameter of at least 7.1mm. -carbon steel casings must meet ASTM standard ASTM A589. -steel pipes must meet ASTM standard ASTM A53/A53M. -thermoplastic casing must conform to ASTM standard ASTM F480. If the inside diameter of the thermoplastic casing is greater than 152mm it must have a wall thickness that meets or exceeds the specifications set out for standard dimension ratio (SDR) 17,

Province	Ontario	Quebec	New Brunswick	Nova Scotia
	minimum wall thickness of 2.41mm. -galvanised steel casing used in bored/dug well must be 18 gauge. -Concrete casing with an inside diameter of 60.96 cm or more must have nominal wall thickness of 5.08 cm. -Plastic casing with an inside diameter of at least 10.16 cm must have a minimum wall thickness of 0.635 cm 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. Casing must be vented unless it is used to transmit water or is a test hole. Vents on drilled wells with pumps must be at least 0.3cm for casing less than 12.7cm in diameter and at least 1.2cm for casing 12.7cm or larger. It must extend no less than 40cm from the top of the ground surface or higher if need be to prevent the entry of flood water. It must be screened to avoid the entry of debris. Lightning conductors may not be earthed to wells.	concrete pipes complying with Standard NQ 2622-126. -joints in casing must be water tight. A point well must: -be constructed with new materials -have a diameter no more than 8cm -have casing that complies with the standards laid out for drilled wells. All underground connections to wells must be water tight.	to the casing of a drilled well unless the connection is made watertight with a commercially manufactured sealant. Dug wells must have the first 2m below land surface cased with concrete rings, steel rings, poured reinforced concrete or brick. Any connection to the casing of a dug well is made below land surface, the connection must be watertight and the connection excavation must be filled with cement grout, concrete, bentonite or equivalent commercial slurry, clay slurry or puddled clay for a minimum radial distance of 30cm from the casing and from the bottom of the excavation to within 60cm of the land surface.	or Schedule 80 of ASTM standard ASTM F480. Well liners must meet the same regulations as well casing with the following exceptions: -have an inside diameter of at least 102 mm. -steel well liner with an inside diameter of 102 mm must have a wall thickness of at least 3.6 mm. -thermoplastic well liner with an inside diameter of 102 mm must have a wall thickness of at least 6.0 mm. Any greater diameter liner must conform to the same standards as for well casing. A Dug Well: -must have a casing that is minimum 1.8m long and extends minimum 152mm above ground surface. The casing can made of precast concrete rings with grooved joints or from steel or thermoplastic which meets the same specification as for drilled well casings. - a concrete or hydrated bentonite apron at least 152 mm thick around the well that is placed below the frost line but above the water table, and extends a minimum of 914 mm from the well with a minimum slope of 21 mm/m. Piping connections to the dug well casing below ground must be water-tight and sealed and the connection excavation must be cement,

Province	Ontario	Quebec	New Brunswick	Nova Scotia
				concrete, bentonite or commercial grout. Water used for constructing any well must be from: -an approved municipal supply. -a public drinking water supply that is registered with the Department. -a non-registered drinking water supply that is monitored and tested in the same manner as registered public drinking water supply and meets health requirements.

Prov	PEI	NFLD
Well Authority	Department of Environment, Energy and Forestry.	Department of Environment and Conservation Water Resources Management Division
Well and Well Driller Licensing	A Well Driller's Licence can be issued to someone who -is 18 or older. -has 4000hrs of experience, of which at least 1500 is in the province. -has successfully completed a written or oral test of competence in well drilling, approved by the Minister. -has successfully completed a field test. A Well Contractors License can be issued to someone who: - is a well driller -employs a well driller -is in possession of well construction equipment that is capable of constructing wells to the standards prescribed by the regulations. Property owners must obtain a well permit prior to well construction. A groundwater exploration permit is required to construct or draw water from any well that pumps at great than 4l/second or supplies a central water supply system.	A license to carry out a business drilling water wells can be issued:: - to an individual who has successfully completed specialized training in well drilling from an institution approved by the minister and has completed not less than one year apprentice training under the supervision of a licensed well driller. - where the applicant has participated in the drilling of not less than 50 wells during the 2 years immediately preceding application for the licence and successfully passes a written examination which the department responsible for the Act shall give and administer. -to a corporation who employs someone with this relevant training and experience. - An applicant for a licence shall use equipment for drilling groundwater wells that is designed for that purpose and which complies with well drilling industry standards. This equipment must be clearly marked with their name and licence number.
Well Reporting Requirements	On completion of a well the well contractor must: -complete a well construction report on a form approved by the Minister. - provide a copy of the well construction report to the owner as soon as possible. -forward a copy of the report to the Department within 60 days of the well's completion.	
Water quality and Yield testing	Upon completion of a well all earthen material and rill cuttings must be	Immediately upon completion of the well, the well driller must clean all

Prov	PEI	NFLD
	removed from the well. A well must be yield tested by first recording the static water level, conducting a pump test for a minimum of 30 minutes, and recording on the water well report at the conclusion of the test, the static water level, the pumping rate and the pumping water level; The yield test will be used to recommend a pump capacity and pump depth, based on the drawdown characteristics of the well.	foreign substances from the well. A well driller must conduct a yield test before completion of a well. Where the well is intended for domestic purposes to supply a single family dwelling a sufficient yield test may include a bail, pump or airlift test, each option not less than 1hr in duration. If the well is intended for purposes other than domestic use by a single family dwelling the yield test will be between 6 and 72 hrs duration by a method approved by the minister and must include water level recovery measurements. Results must be reported to the minister within 30 days.
Well Disinfection	The well must be disinfected with a solution of 1l of laundry bleach diluted in 45l of water that is poured into the well and left to stand for 8hrs.	Upon completion of the well the driller must disinfect the well using a method approved by the minister.
Well Identification and Documentation		
Artesian Flow	The owner of a property on which a flowing well is located must cap and seal the well in a manner which prevents the overflow of water from the well casing.	The well driller must take reasonable precautions to prevent a well from flowing out of control, particularly in areas of the province that in the opinion of the minister have a history of flowing wells and must, before drilling a well investigate if the area has a history of flowing wells. The owner of a flowing well must ensure that the well is fitted with a capping device or some other device of a type approved by the minister that prevents or minimizes the flow of water to waste.
Well management and aquifer protection	The person responsible for constructing the well must ensured that water bearing formations that contain contaminants are sealed off. There may be no artificial openings to a well.	A well may not be constructed in manner that allows surface water to enter the well. The owner of a well must maintain the well at all times in a manner sufficient to prevent the entry of surface water and other foreign materials into the well. In the course of drilling a well in a water control area if the driller encounters salty, sulphurous or other water that might impair the quality of potable groundwater, the well driller must seal off that water by a method approved by the minister. A person may not use a well for waste disposal without the written approval of the minister.
Wells on Crown Land		
Surface Sealing / Filling the Annulus.	The minimum 3.8cm annular space must be filled with grout from the bottom of the casing to the pitless adapter. If the casing is longer than 12 m and the well is part of a central supply a person may fill the lower 12m of the annular space with grout and the remaining annular space with clean fill.	Casing must be surrounded with a cement grout of no less than 5cm thick.

Prov	PEI	NFLD
	Casing may not be installed in a central supply well unless the entire length of the annular space is filled with grout using a grout pump. No less than 6 22kg bags of bentonite may be used in grouting a well.	
Flood Proofing the well	Casing must extend at least 30cm above ground.	Where a well is located in a place where surface water will pass over or near the opening, the well driller must fill the area surrounding the well with clay or clean earth for at least 5 m grade it to an elevation of at least 60 cm above the highest known surface water level.
Protection of the well head		
Change of purpose		
Well Location / Siting	A well cannot be constricted: - within 3 horizontal meters from any part of a building -inside a foundation or structure. -anywhere surface water other than rain will pass over the top of the well. The following distances from contaminant sources must be adhered to for all wells: -3 metres from a sewer line -6 metres from a sewer collection main -100 metres from a wastewater treatment system -15 metres from a septic tank -15 metres from a sewage disposal field -15 metres from a rock pit; -90 metres from a manure storage facility -150 metres from a solid waste disposal site -5 metres from a petroleum storage tank of 1,200 litres or less -15 metres from a petroleum storage tank greater than 1,200 litres - 45 metres from a commercial chemical storage facility -6 metres from an existing or abandoned well. No well may be constructed within: -1.5 metres of any property boundary or underground electrical cables, except for Those that supply power to pumping equipment.	A well must be located so that it is accessible for cleaning, treatment, repair, testing and inspection. A well driller must locate a well far enough away from sources of pollution so as not to contaminate the well by seepage or groundwater flow. This includes: -30m from a cesspool. -16m from a seepage (leaching) pit, filter bed, soil absorption field, earth pit privy, or similar disposal unit. -60m from a cesspool or seepage pit that is more than 4m deep unless the well is cased in a manner adequate to prevent seepage from the cesspool or seepage pit into the well. -16m from a septic tank, concrete vault privy, sewer of tightly jointed tile or sewer connected foundation drain. -3m from a sewer of cast iron with leaded or approved mechanical joints, independent clean water drain or cistern. -1m from a pumphouse floor drain, cast iron with leaded joints, draining to ground surface. -approval is required to construct a well near a garbage dump or sanitary landfill that may contaminate a well. A well driller may not locate a well under a building unless the building allows access to the well for cleaning, treatment, repair, testing and inspection. The centre line of a well must clear any part of an adjacent building by at least 2m.
Well Depth/Deepening		
Pump/Equipment Installation	No person shall install pumping equipment so that there exists a clearance of less than 1.25 cm between the pumping equipment and the sidewall of the well. Pumps may only be connected through a properly installed pitless adapter or a well seal.	The person who install a pump must seal the top of the well casing with a well cap commercially manufactured for the purpose and approved by the minister; and disinfect the pump before installation by a method approved by the minister.

Prov	PEI	NFLD
	Hand pumps must be installed in a manner that seals the top of the casing. It is prohibited to make a hole in the wall of the casing except to install a pitless adapter on the pumping equipment. A water sampling port or a tap at a point between the well and any water treatment device in mandatory. A pump installed to pump water for human consumption must be cleaned and disinfected with chlorine in the same manner as a new well.	
General Well Construction specifications	No person shall construct a well other than in a manner which maintains existing natural protection against contaminants. No person shall use, or permit the use of, in the construction of a well, -pitless adapters -well seals; -piping and fittings; -pumping equipment -any other equipment, materials or devices unless necessary and these conform to the standards prescribed by the American Society of Testing Materials – ASTM, American Water Works Association – AWWA, Canadian Standards Association – CSA or the National Sanitation Foundation – NSF. Well casing must be at least 12m in length. The width of the annular space may not be less than 3.8cm.	Casing must be new material that is a standard pipe size and weight according to the specifications of the Canadian Society of Testing Materials (CSTM), or the American Society of Testing Materials (ASTM). Unless the casing is used a suction pump the well must be fitted with an air vent that has an inside diameter of not less than 6 mm and that extends at least 30 cm above the land surface at the well opening. The open end must shielded and screened to prevent the entry of contaminants. Underground connections to the casing must be made water tight with a commercial seal approved by the minister.