Exploring Appropriate Business Models for Establishment of Water Quality Monitoring Service in Newfoundland and Labrador

by

© Kalen Thomson

A Thesis submitted to the
School of Graduate Studies
in partial fulfillment of the requirements for the degree of

Master of Science in Medicine
Applied Health Services Research
Division of Community Health and Humanities, Faculty of Medicine
Memorial University of Newfoundland

Submitted May 2017
St. John's, Newfoundland and Labrador

Abstract

The Government of Newfoundland and Labrador regularly tests public drinking water supplies to ensure the absence of contaminants. Private water supplies, including wells, fall outside the mandate of this testing regime. Over 50,000 wells are estimated to be in Newfoundland and Labrador servicing approximately one-fifth of the population. Having identified this service gap, the following thesis seeks to explore two main objectives: to assess and articulate the potential public health risk, and to explore business models for the establishment of a water quality monitoring service. A mixed-methods approach is taken, employing both qualitative data from interviews with health experts, municipal representatives, laboratory professionals and private well owners, and quantitative data in the form of a model for the potential exposure risk, and financial models exploring solutions. The result is a high-level business approach exploring the service gap in water quality monitoring for private well owners in Newfoundland and Labrador.

Acknowledgements

Many people have been instrumental in the creation of this thesis and research project and deserve recognition and thanks. This research project is funded in part by the Royal Bank of Canada (RBC) Blue Water Project (2013), the Harris Center (2013), Memorial University and the Mitacs-Accelerate Graduate Research Internship Program (2013). Thank you to Niraj Shukla at Mitacs and David Fay at Fay Environmental for facilitating that internship.

Thank you to my supervisors, Atanu Sarkar, Tom Cooper, and Cathy Donovan. Thank you also to Rick Audas and Cathy Peyton who facilitate the Atlantic Regional Training Center and the Master's in Applied Health Services Research, which this thesis is in partial fulfillment of.

Thank you to Kelly Vodden and Sarah Minnes of the Exploring Solutions for Rural Drinking Water Systems Project, Dorothea Hanchar of the provincial Department of Environment and Conservation, as well as Municipalities NL.

Most of all, I would like to offer my heartfelt thanks for the incredible support and patience of my family and friends.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Definition
ADD	Attention Deficit Disorder
ATSDR	Agency for Toxic Substances and Disease Registry
CALA	Canadian Association for Laboratory Accreditation
CCNL	Conservation Corps Newfoundland and Labrador
CDC	Centers for Disease Control
CIHI	Canadian Institute for Health Information
DBP	Disinfection by-product
DOEC	Department of Environment and Conservation, Government of Newfoundland and Labrador
DHCS	Department of Health and Community Services, Government of Newfoundland and Labrador
EPA	United States Environmental Protection Agency
HCGCDWQ	Health Canada Guidelines for Canadian Drinking Water Quality
IARC	International Agency for Research on Cancer
ICP-MS	Inductively Coupled Plasma Mass Spectrometer
IQ	Intelligence Quotient
LSD's	Local Service Districts
MAC	Maximum Acceptable Concentration
NL	Newfoundland and Labrador
PPB	parts per billion
SCC	Standards Council of Canada
TIA	Transient ischemic attack (mini-stroke)
TOC	Total Organic Carbon

List of Appendices

Introduction

Clean, safe drinking water is essential to all life and good health. Over the past century, establishing reliable water sources has been one of the most significant improvements to population health in North America (Hrudey, 2008). The reality is, there is still much work to be done in guaranteeing and maintaining all water supplies, especially private wells. A comprehensive approach to water safety requires action from municipal, provincial, and federal governments as well as individual private well owners to develop an approach to water that is well suited for the challenges of the years ahead. Contaminants in drinking water have, on rare occasions, caused tragedy in Canada like that in Walkerton, Ontario in 2000. Regular water quality monitoring is one way to ensure that tragedies such as Walkerton are not repeated.

The government of Newfoundland and Labrador is committed to providing residents with clean, safe drinking water in adequate supply. Current testing procedures see the regular monitoring of public supplies for bacteriological contaminants, and a rotating testing schedule for chemical and physical contaminants (DOEC, 2013). However, there is no practice of any regular monitoring of private water supplies in the province, except at the installation of new, drilled wells (DOEC, 2016e). This lack of information on the quality of private water wells in the province is a potential public health risk, and has also been identified in other jurisdictions in Canada, such as a 2006 expert panel review which was commissioned to determine the state of well water quality in Ontario (Novakowski et al., 2006). With regards to the water quality of wells in

Ontario, the first recommendation was an immediate province wide survey of water quality in all private wells to address a similar knowledge gap as what is currently seen in Newfoundland and Labrador. While the authors do not specify exactly what contaminants should be tested for in this survey, they do state that it should be "comprehensive" and include "all unregulated wells including rural wells, cottage wells, private wells in urban areas in addition to farm wells" (Novakowski et al., 2006, p. 49).

Bacteriological testing is available to private well owners on an on-demand basis from the Public Health Laboratory which is a division of Eastern Health and, therefore, ultimately funded by the Department of Health and Community Services (DHCS) (Eastern Health, 2015). This service is administered in partnership with Service NL which provides the distribution network for water sampling bottles, and will accept samples for delivery to the Public Health Laboratory. However, chemical and physical testing are not available to residents of the province on private water supplies because of geography and high cost; despite being water quality monitoring parameters set forth by Health Canada. It is known that promoting private well stewardship is one of the most effective ways at guaranteeing safe drinking water (Kreutzwiser et al., 2011), but the inaccessibility of water testing services, even for those who want to exercise good stewardship, is a large problem in Newfoundland and Labrador. The potential for contamination is very real, as the United States Geological Survey found 23% of 1,389 wells sampled across the US between 1991 and 2004 had at least one contaminant above health guideline values (De Simone et al., 2009).

While the most immediate health concerns in drinking water come from bacterial contaminants like *E.coli*, one cannot ignore the health risks from prolonged exposure to toxic chemical contaminants. There is an already established strong body of knowledge surrounding the risks of exposure to high levels of toxic chemicals; for example those in the ToxFAQ's database of the United States Agency for Toxic Substances and Disease Registry (ATSDR). Additionally, as addressed later in the literature review, there is a growing body of evidence that prolonged exposure to even low levels of some chemicals can pose a health risk. Moreover, this new evidence is most relevant to residents of Newfoundland and Labrador where the potential levels of exposure are lower than those that have previously been established elsewhere in the world.

The Health Canada Guidelines for Canadian Drinking Water Quality (HCGCDWQ) have established acceptable limits for levels of potentially toxic chemicals, and these guidelines were adopted by the province of Newfoundland and Labrador in 2001 (Health Canada, 2014b). Currently, public water supplies are subject to regular monitoring to ensure safety (DOEC, 2013). Private water sources, however, fall outside of the mandate of this testing regime, and, therefore, are the responsibility of the private well owners. Bacteriological testing is available free of charge through the public health laboratory and its regionalized satellite locations (Eastern Health, 2015). For physical and chemical testing, the Department of Environment and Conservation recommends residents seek the nearest accredited private laboratory (DOEC, 2013). According to the Groundwater Resources Manager with the provincial Department of Environment Water Resources Management Division, approximately 20% of the population has private wells (Guzzwell, 2001).

Research Objectives

Having identified this service gap, the following thesis seeks to explore two main objectives. The first objective is to assess the population health risk in the province and articulate this risk as best as possible. This is done through quantitative analysis of available water quality data, as well as an associated literature review of potential health risks from exposure to contaminants present in wells in Newfoundland and Labrador.

The second objective explores potential business models for the establishment of a water quality monitoring facility as a solution to the current service gap and builds on the first objective as an approach to risk reduction. Inspiration for these models is obtained through an analysis of qualitative data from interviews with health experts, municipal representatives, laboratory professionals and private well owners. The data is analyzed to identify barriers and challenges necessary to make the potential solutions effective. Three sensitivity models forecast projected income statements based on a best case scenario, worst case scenario and realistic scenario of service uptake. This creates a business approach that provides a high-level model for a potential solution to the existing service gap in water quality monitoring for private well owners in Newfoundland and Labrador.

Terminology and Background

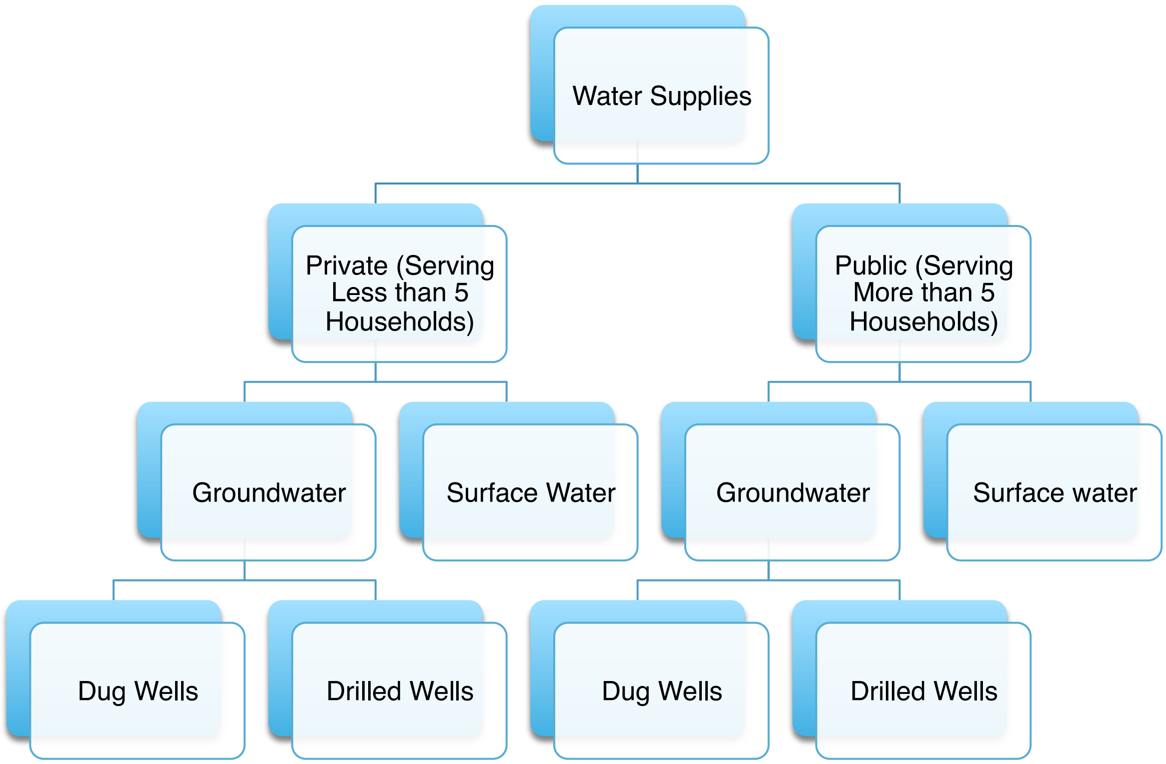


Figure 1. Water Supplies Summary

The focus of this study is on privately owned wells. To properly understand this focus, Figure 1 illustrates a break-down of the current water supply system in Newfoundland and Labrador. In the case of public water supplies, whether the source is groundwater or surface water, the water is treated and regularly monitored to ensure safety and quality (DOEC, 2013). Private sources, however, only have treatment systems if installed by the individual owner. While there are some private individuals who use surface water supplies, these are outside of the scope of this research, which focuses on those with private wells. Private wells can be drilled or dug, and Figure 2 is an example of a drilled well with proper casing and cover. Some private dwellings use springs as their water source, but this is considered inadvisable, as springs are particularly vulnerable to factors such as the weather, the seasons, and wildlife interactions (DHCS, 2009). Springs are not included in this study.

Photo credit: A. Sarkar

Figure 2. Drilled well with proper casing and cover

Water testing deals with parameters of several different forms. For the purposes of this thesis, the author chooses to group contaminants as health parameters, aesthetic parameters, environmental parameters and disinfection by-products, as presented in Figure 3. Health parameters refer to those contaminants in water which have a direct adverse health impact when consumed in concentrations in excess of guideline values (Health Canada, 2014b). Aesthetic parameters are those contaminants which may make water have an unpleasant odour or taste, or may leave stains when used on laundry, but do not have a direct adverse health effect. Environmental parameters refer to certain aspects of water that can affect the larger ecosystem as a whole, but not have a direct effect on an individual human consumer. Finally, disinfection by-products refer to unwanted chemicals that result from the interaction of chlorine with organic matter present in the water.

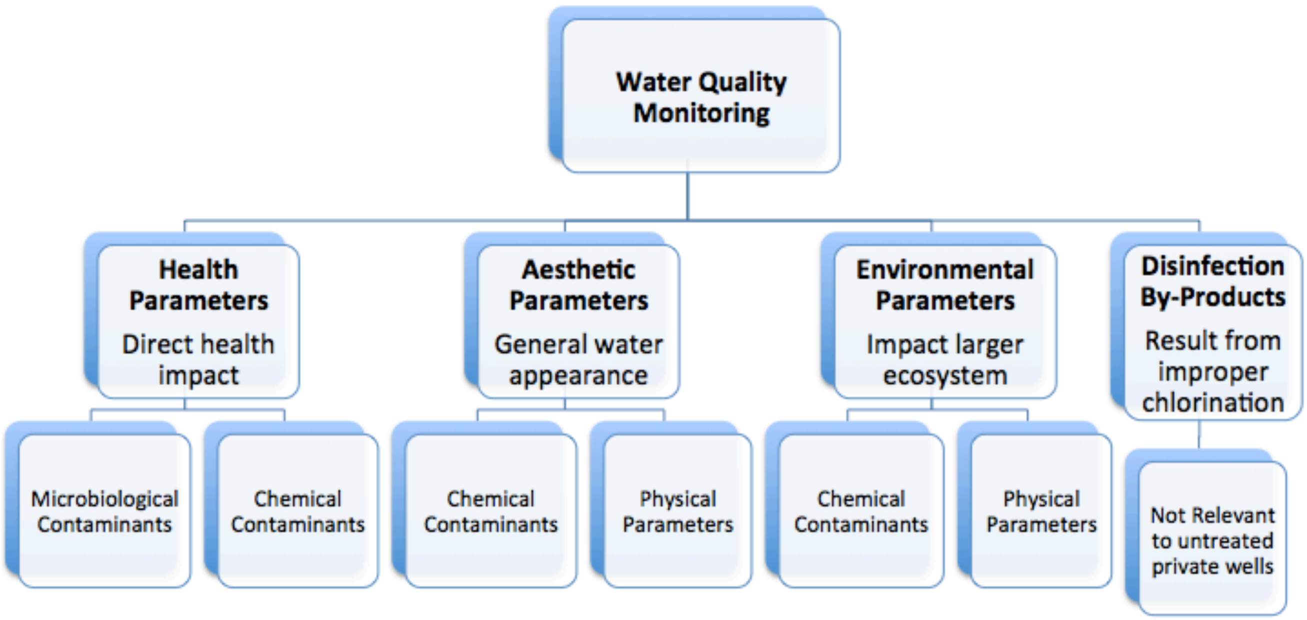


Figure 3. Water Quality Monitoring Summary

In general, threats to health are posed by microbiological contaminants or chemical contaminants. Microbiological contaminants typically refer to bacteria. Fecal bacteria, like *E. coli,* are the foremost concern for water safety (Health Canada, 2014b). One example that is familiar to Canadians is the tragedy in Walkerton (Ontario) in the year 2000. Tragically in this case, *E.coli* contamination in the city water supply resulted in seven deaths (CBC News, 2010). While the issue in Walkerton was a publicly administered system, and the issue has largely been attributed to operator error as well as out-dated and unsafe infrastructure, the water source was a well (Hrudey, 2011). Parasites are also considered microbiological contaminants. While parasites are less of a problem in Newfoundland and Labrador, one particular species, *Giardia lamblia*, causing giardiasis, is the most concerning (DOEC, 2009). According to Newfoundland and Labrador Communicable Disease Surveillance (2016), the province saw 23 cases of giardiasis in 2015. Symptoms include gastrointestinal upset, liver or respiratory infections, and central nervous syndromes or muscular symptoms (DOEC, 2009).

In addition to microbiological contaminants, there are a host of potential chemical contaminants that are also considered health parameters. Health Canada recommends 91 separate physical and chemical parameters be monitored for concentrations in water if they are relevant to a particular region (Health Canada, 2014b). Thirty-nine of these are tested in Newfoundland as part of the routine municipal water tests (DOEC, 2013) and 14 of these are considered health parameters and are presented later in Table 6. In the case of some chemical parameters, lower concentrations of these chemicals are considered safe by the Health Canada Guidelines (Health Canada, 2014b).

In addition to health parameters, aesthetic parameters are also a concern when monitoring water quality. While these aesthetic parameters are not a public health concern, research has shown that aesthetic parameters affect perceptions of water quality and improving water taste and smell was the reason half of private well owners in a Hamilton, Ontario area survey use filtration devices (Jones et al., 2006). Several chemical contaminants and physical parameters are considered aesthetic parameters and are listed later in this document in Table 7. Physical parameters refer to the color and appearance of water, total dissolved solids, and pH. Turbidity is a measure of the cloudiness of water, and for many, this gives an idea of the perceived quality (Health Canada, 2014a).

Turbidity can also impede the effectiveness of water treatment, by the creation of disinfection by-products (Health Canada, 2014a).

Disinfection by-products (DBP's) are chemicals such as trihalomethanes or halogenated acetic acids that result from chlorination of water containing a high level of organic matter (DOEC, 2014a). While these have recently gained some attention in the public and the scientific literature (Chowdhury et al., 2011; Guilherme et al., 2014), these contaminants are only possible in water supplies that are already being chlorinated. These are an issue of public water supplies and fall outside of the scope of this thesis. While the risk is acknowledged for small municipal systems, DBP's are not a concern for private well owners who do not have chlorination systems installed.

Understanding the distinctions between the above broad categories in contaminants is essential for examining current testing regimes, and developing a water quality monitoring service for private well owners. Testing and monitoring procedures for microbiological contaminants are very different from those necessary to detect physical or chemical concentrations. For example, because the HCGCWQ value for *E.coli* is zero, a simple presence/absence test, like the Colitag procedure (outlined later in this thesis) can be used. In the case of chemical contaminants, these are considered safe for consumption at lower concentrations, and therefore more sophisticated and expensive laboratory equipment is required to measure these concentrations, which can be on the order of parts per billion (Health Canada, 2014b). The cost of this equipment is an important consideration when constructing a water quality monitoring business model, especially since microbiological testing is already available in the province and it is not necessary to duplicate this service. Estimations for these costs are included later in the thesis in Table 9.

As mentioned, the Government of Newfoundland is committed to providing residents with clean, safe drinking water in adequate supply. This responsibility is shared by four departments: Health and Community Services (DHCS); Environment and Conservation (DOEC); Municipal Affairs; and Service NL. Representatives from each of these departments sit on the Safe Drinking Water Committee and meet regularly (Drinking Water Safety Annual Report, 2012). The Department of Environment and Conservation is the lead department of the four, with its representative serving as committee chair (Drinking Water Safety Annual Report, 2012).

Health Canada, in its *Guidelines for Canadian Drinking Water Quality,* has set forth the guidelines for safe drinking water in the country (2014b). This document specifies acceptable ranges for levels for microbiological, physical and chemical, and radiological parameters to ensure water quality and safety.

Municipally administered water supplies in the province are tested regularly for total coliforms and *E. coli* on schedules laid out by the provincial government in the *Drinking Water Manual* that are based on system distribution size (DHCS, 2012). For example, distribution systems serving less than 5,000 people are to have 4 bacteriological samples tested per month (DHCS, 2012). Colonies of these fecal bacteria are the most pressing concern for immediate sickness from water supplies (Health Canada, 2014b). In addition, the Drinking Water Manual also specifies these water supplies are tested twice annually on a rotating schedule for a total of 30 chemical and physical parameters (DHCS, 2012). The Health Canada Guideline values for parameters tested in

Newfoundland and Labrador with a maximum acceptable concentration (MAC) are included as Appendix A. Currently these samples for chemical testing of public water supplies are shipped to Ottawa to a private laboratory where the tests are performed, because a facility to handle this volume of tests does not exist in Newfoundland and Labrador (Sarkar et al., 2012). As mentioned, this testing regime applies to municipally administered supplies and the responsibility lies with the individual well owners to schedule and avail of existing test services within the province or seek services outside of the province (DOEC, 2016c). Private well water tests are only required when a new drilled well is installed and registered and are the responsibility of the driller (DOEC, 2016e). Unregistered wells or dug wells, like that in Figure 4, do not fall under this requirement.

Photo credit: A. Sarkar

Figure 4. Dug well with appropriate, vented cover

Regionalized Laboratories

Currently, a regionalized approach to water quality testing exists for bacteriological testing in the province (Eastern Health, 2015). As part of the Eastern Health Regional Health Authority, the main Public Health Laboratory is located at the Dr. Leonard A. Miller Center in St. John's. This Public Health Laboratory has six satellite locations distributed across the province in Clarenville, Gander, Grand Falls, Corner Brook, St. Anthony and Happy Valley-Goose Bay (Eastern Health, 2015). For bacteriological testing, this approach makes clear sense. Bacteriological samples must make it from the tap to the testing facility within 24 hours (Eastern Health, 2015). The province of Newfoundland and Labrador spans 370,000 square kilometers, including Labrador (Statistics Canada, 2011). Especially when one considers Labrador and the Northern Peninsula, a sample making it to St. John's within 24 hours can be quite a challenge, hence the presence of facilities in Goose Bay and St. Anthony respectively.

Figure 5. Newfoundland and Labrador Public Health Laboratory and Satellite Locations

Testing Schedule

While currently decisions around testing schedule frequency are at the discretion of the body having authority over a specific region, Health Canada recommends that private well owners have bacteriological testing done two or three times a year, especially after the spring thaw, after a long dry spell and after heavy rains (Health Canada, 2008). Health Canada also states that wells should be tested “occasionally” for physical and chemical parameters. (Health Canada, 2008). The term “occasionally” is subject to interpretation. For the purposes of creating a model, a complete water test once every two years is assumed. This is in line with the recommendation from the Well Aware project of the Conservation Corps of Newfoundland and Labrador, which recommends testing for chemical contaminants once every two years (CCNL, 2013). In addition, the province of Nova Scotia recommends that private wells be tested for chemical contaminants every one to two years, or earlier if a change in quality is detected (Province of Nova Scotia, 2014).

Business Foundations

Exploring the possibility of a new water quality monitoring service in Newfoundland and Labrador requires a business approach as is created in this thesis. According to the textbook, *Business Plan, Business Reality: Starting and Managing Your Own Business in Canada*, a new business must use projected financial statements as part of the business plan (Skinner, 2015). Furthermore, one of these projected financial statements, the projected income statement, should show three years of expected sales, costs, expenses and profit (Skinner, 2015). This framework is used later in the thesis for the sensitivity models created to outline a potential water quality monitoring testing facility.

Another textbook, *Simple Tools and Techniques for Enterprise Risk Management* by Chapman, describes sensitivity analysis as a technique for evaluating potential projects (2015). The technique involves modifying a single variable and projecting the effect of changes in that variable on the business. However, the goal of this technique is not to assess the likelihood of these changes. Another textbook, calls sensitivity analysis “the most widely used risk analysis technique.” (Brigham et al., 2017, p.346). Chapman goes on to outline a further tool in the preparation of financial statements based on three scenarios, one optimistic, one pessimistic, and one realistic (2015). Again, these scenarios do not examine the likelihood of any of the three events occurring but do provide a feel for the risk, and the potential of a proposed project.

New Brunswick Analytical Services Laboratory as a Case Study

Inspiration for solutions can often come from examining existing services in similar jurisdictions. An examination of the case of the Analytical Services Laboratory of the Department of Environment and Local Government in New Brunswick, offers a glimpse into potential solutions for the province of Newfoundland and Labrador. As part of this research project, an in person tour and interviews of laboratory personnel were conducted and are presented later in the results section.

Methods

A research design using a mixed methods approach was utilized to accomplish the two main objectives of this thesis. These objectives are:

1). To assess the public health risk from exposure to contaminants in Newfoundland and Labrador private well water.

2). To explore a business model for a water testing laboratory that addresses the above risk.

Health Risk Modeling

The Newfoundland and Labrador Water Resources Portal is an online resource providing information on public water supply type, location, source and the population serviced by the water supply. In the province of Newfoundland and Labrador, there are 179 public water groundwater wells that supply 88 communities serving a population of approximately 39,339 (DOEC, 2014b). For public supplies, samples at both the water source and tap are regularly taken and tested by the Department of Environment and Conservation of the provincial government to monitor this water quality, and these results are published through the Water Resources Portal (DOEC, 2013). Reports on private water supplies, such as wells, however are not published, in the Newfoundland and Labrador Water Resources Portal because these sources are not monitored. The Newfoundland and Labrador Center for Health Information was also searched for this data, and none was found (NLCHI, 2016).

Because private wells are not regularly monitored in Newfoundland and Labrador, the data does not exist to construct a detailed model of potential exposure. To substitute for this data, a proxy model was created using the public water supply data available through the Newfoundland and Labrador Water Resources Portal. This model is similar to the spatial model proposed in the white paper by the Drinking Water Exposure Group of the California Department of Public Health (Vanderslice et al., 2006). This model is for situations in which there is no data available for a given set of wells, as in Newfoundland and Labrador. In such an instance, estimates can be made on a regional scale, based on available groundwater quality data. For this reason, the public water quality reports present the best data to estimate the risk to private well owners and were used to create a proxy model. A scan of available public supply source water quality reports was performed for communities supplied by groundwater wells. Tap water test results were not included in this model, because of the potential confounder of contamination within home plumbing systems, and to avoid any bias that may be added by removal of contaminants by water treatment.

Included in this proxy model were 2,292 public well source water quality reports of tests ranging from September 23, 2001, to July 11, 2013. Through this process, key contaminants were identified based on Health Canada guideline values (HCGCDWQ) for toxic chemicals. These contaminants were arsenic, barium, cadmium, chromium, lead, mercury and selenium. Once these contaminants were identified, a review of the literature was conducted to identify the health risks from each of these individual contaminants at exposure levels comparable to those found in Newfoundland and Labrador public water supply wells.

Business Models – Water Quality Monitoring Service

Having identified and described the health risks, the next step was to develop and explore potential solutions to decrease this risk and address the service gap. Interviews and consultations with representatives from key groups in the province were conducted. These conversations provide a glimpse into the public perception of need and the demand for water quality monitoring through qualitative data. The interviews also provide information on basic technical equipment required to operate a water quality testing laboratory, and this information is supplemented with a review of technical literature, and consultation with industry suppliers. While these interviews were open-ended, and allowed to develop organically which is a strength of qualitative research put forth by Kvale and Brinkmann in their 2009 book. Included as Appendix B is a sample of the information letter used to inform potential participants of the study. Finally, the consent form used for participants is also included as Appendix C. A guide of questions used is included as Appendix D. All of these documents were included in the ethics application and approved for use in this research.

Purposive sampling was used in the approach to the interviews conducted (Dudovskiy, 2016). This method allowed the opportunity to address various stakeholders across regions of the province. Furthermore, the method fits the study based on the limited capacity for interviews, and using the judgement of the research team to gain a representative sample (Dudovskiy, 2016). Firstly, Municipalities NL was approached and an invitation for participation was sent to community representatives. Representatives were asked to get in touch with the researchers if they felt a large number of their residents received their drinking water from private wells. Five representatives responded and were interviewed and are considered representatives of municipal government. In addition, a representative of the provincial Department of Environment and Conservation was interviewed for a total of government representatives (n=6). Health professionals (n=4) and laboratory professionals (n=4) were also interviewed. Information from laboratory professionals included a tour of the New Brunswick Analytical Services Laboratory with unstructured interviews, which offers a relevant case study in Atlantic Canada. Finally, private well owners (n=5) across the province were interviewed to assess the need and determine the demand from the ultimate end service user. In the case of municipal representatives and medical professionals, these interviews were conducted with at least one participant from each of the three main regions of the island (east, west and central). In the case of private well owners, these interviews were conducted with participants from the east and west regions of the island, as well as participants from Labrador. A summary of interviews performed is presented in Table 1.

Table 1. Summary of Interviews Performed

Stakeholder Demographic	Number of Interviews
Government Representatives	6
Well Owners	5
Health Professionals	4
Laboratory Professionals	4
Total	19

Interviews were analyzed for high-level themes and issues of barriers and challenges to water quality monitoring in the province. These barriers and challenges are identified and discussed. In addition to barriers and challenges, interviews with laboratory professionals were used to inform technical data for the assembling of a laboratory testing facility. For retrieving price quotes, e-mail requests were sent to three scientific suppliers available in eastern Canada, Mandel Scientific, PerkinElmer and Fisher Scientific. E-mail replies were received from all three suppliers, and estimate quotes were provided for the equipment sold by that particular supplier. In cases where a piece of equipment was available from multiple suppliers, the least expensive estimate was used.

Three sensitivity models are created based on three theoretical levels of service uptake. Using forecasting tools proposed by Chapman, three sensitivity models are presented based on three potential scenarios, one optimistic, one realistic and one pessimistic (2015). In other words, a best case scenario, worst case scenario and a reasonable forecast of service uptake. The first scenario is a situation where all 50,000 wells in the province participate in biennial testing, and therefore there is a sample volume of 25,000 per year. The second scenario assumes a 25% compliance rate and therefore 6,250 tests per year. The third scenario estimates 1000 samples in the first year, as a potential worst case scenario. Cost and revenue projections for each of the three scenarios are presented based on the tests currently performed on public water supplies. Business sustainability of these models is considered, and therefore, the models contain projections for growth, depreciation of equipment and other cost aspects, which are explained in the notes on financial statements.

Ethics

In accordance with the requirements of TCPS-2 a proper ethics application for the conducting of this research was filed with the Health Research Ethics Authority. In addition, the author of this study received training and certification according to the TCPS-2 requirement. A copy of this certification is included as Appendix E.

Results Part 1: Health Risks Proxy Model

The results show that MAC exceedances of arsenic, barium, cadmium, chromium, lead, mercury and selenium occurred at least once in past public supply groundwater source tests. Contaminants were found in a wide range of concentrations above the guideline value. These results are summarized in Table 2.

Table 2. Chemical contaminants found in public supply groundwater sources in Newfoundland and Labrador in excess of Health Canada Guideline values

Contaminant (Health Canada guideline value mg/L) [a]	Total number of test results in excess of Health Canada guideline value	Exceedance range (mg/L)
Arsenic (0.01)	43	0.011-0.044
Barium (1.0)	7	1.03-1.66
Cadmium (0.005)	1	0.0056
Chromium (0.05)	1	0.1
Lead (0.01)	41	0.011-0.183
Mercury (0.001)	1	0.0021
Selenium (0.01)	2	0.012-0.023

[a](Health Canada, 2014b)

Of the contaminants found, the data was analyzed to examine the distribution of contamination as a portion of the number of communities with public well groundwater sources. This data came from 88 communities, with a total of 179 distinct wells. This discrepancy in numbering is due to the presence of more than one water source in some communities. These results are summarized in Table 3, and percentages of both number of communities, and number of water supplies, or wells, are included.

Table 3. Distribution of chemical contaminants found in excess of Health Canada Guideline values in public supply groundwater sources in Newfoundland and Labrador

Contaminant	Number of communities with contaminant in excess (percentage of communities n=88)	Number of public wells with contaminant in excess (percentage of wells n=179)	Number of private wells potentially contaminated (proxy model)	Population potentially at risk to exposure (proxy model)
Arsenic	11 (12.5)	16 (8.9)	4,450	10,680
Barium	2 (2.3)	2 (1.1)	550	1,320
Cadmium	1 (1.1)	1 (0.6)	300	720
Chromium	1 (1.1)	1 (0.6)	300	720
Lead	18 (20.5)	21 (11.7)	5,850	14,040
Mercury	1 (1.1)	1 (0.6)	300	720
Selenium	2 (2.3)	2 (1.1)	550	1,320
Total				29,520

All of the seven chemicals found in excess of the Health Canada guideline values pose serious potential health risks. However, of particular concern is the portion of water supplies having shown arsenic (9%) and lead (12%) contamination. Given that there are 50,000 wells estimated in the province, this proxy model suggests that approximately 4,450 wells could be contaminated with arsenic, and approximately 5,850 wells could be contaminated with lead. The combined exposure to barium, cadmium, chromium, mercury and selenium is also notable, with approximately 2,000 wells potentially contaminated.

According to the 2011 census, the average household size in the province of Newfoundland and Labrador is 2.4 persons (Statistics Canada, 2013a). Assuming that wells are contaminated with only one chemical, and that private wells are generally one well per house and extrapolating based on the number of wells that have shown contaminated test results, 10,680 people are at risk for exposure to arsenic, 14,040 are at risk of exposure to lead, and the remaining contaminants, barium, cadmium, chromium, mercury and selenium pose a potential risk to 4,800 residents of Newfoundland and Labrador. As Table 3 demonstrates, this model represents a risk from drinking water contaminants to 29,520 people, or 5.6% of the province's population (Statistics Canada, 2013a). In Newfoundland and Labrador, 14.5% of the population are children aged 14 or younger (Statistics Canada, 2013b). Therefore, this model also represents a risk of exposure to drinking water contaminants to 4,280 children in the province. This risk is of particular concern from a health perspective, since children are more susceptible to health impacts from drinking water contaminants, especially lead (ATSDR, 2007c).

Literature Review: Health Risks

To begin to articulate the potential risk, it is necessary to identify what the key health risks are from exposure to these chemicals via drinking water. Health Canada has made decisions on the guidelines for MAC, and these are based on the best judgment of officials and experts in the field (Health Canada, 2014b). These maximum guidelines values are included in Appendix A. The Health Canada Guideline Values, adopted by the province of Newfoundland and Labrador in 2001 indicate contaminant concentrations that are considered to pose an acceptable health risk based on chronic consumption. Furthermore, guideline values sometimes change as more evidence is presented. For example, the guideline value for the safe consumption of selenium is currently under debate (Gore, Fawell, & Bartram, 2010). Should guideline values be lowered, as arsenic was recently by Health Canada (2006), even more of the population would be considered at risk.

Motivations for examining the public health risk to private well owners based on secondary data are inspired by primary research which has found evidence of direct contamination in private wells. In particular, a preliminary report funded by the Harris Center has found private wells to be contaminated with bacteria, fluoride and arsenic in western Newfoundland (Sarkar et al., 2012). While this report is limited in scope, having tested only 45 wells concentrated in one geographic region of the province, it does provide some initial clues that there are water quality issues in the province. Furthermore, the report finds that well owners in the community were unaware of any issues with their water, because the contaminants found were tasteless, colorless and odorless. Another

Newfoundland study from 2007 found 49 of 52 sources surveyed had arsenic concentrations in excess of the guideline value (Rageh et al., 2007). Again, long term monitoring was not performed, and although it is stated that predominantly groundwater sources are used, it is not clear exactly what portion of these results came from surface water sources. These results contribute to a need to have more long-term data.

The Harris Center report also found that community members felt a need to have access to a laboratory for testing of their water (Sarkar et al., 2012). Local media has also taken up the issue, as the St. John's *Telegram* printed an article on January 19, 2015 discussing the need for a private water testing facility in the province (Fitzpatrick).

The urgency of the situation was captured less than a week later, with another newspaper article, *Poison in the Water,* detailing test results in the New World Island area, in the central part of the province, showing high levels of arsenic in drinking water wells (Fitzpatrick, 24 January 2015). These water tests were initiated by Dr. Daniel Hewitt, a local physician who suspected unusually high rates of certain illnesses in the community may stem from an environmental cause. There is no causal relationship established, but Dr. Hewitt's clinical suspicion lead to his initiating the testing. While levels of contaminants in Newfoundland and Labrador are often less than those found in other parts of the world, for example India or Bangladesh, this was not the case here. Some of Dr. Hewitt's tests reportedly show drinking water arsenic levels up to 200 ppb (Fitzpatrick, 24 January 2015). These results are comparable with levels found elsewhere in the world where arsenic and associated health risks have long been documented, such as Romania, with levels up to 176 ppb (Gurzau & Gurzau, 2001), or Bangladesh, where although some results are found up to 1000ppb, significant health effects, such as skin lesions, are found at levels below 300ppb (Dhar et al., 1997).

Since many possible chemicals exist, health risks are identified by medical condition and then evidence of which chemicals increase risk for that condition is presented. Information is taken from the Agency for Toxic Substances and Disease Registry (ATSDR) of the US Department of Health and Human Services, the Health Canada Guidelines for Canadian Drinking Water Quality (HCGCDWQ), and more recent evidence from the peer-reviewed literature. The Health Canada guideline values are established by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. In the introduction to the guidelines document, it is explained that these values are established based on current, published scientific research with consideration of the availability of treatment and analytical technologies (Health Canada, 2014b).

Cancer

When examining the health risks from prolonged exposure to low levels of toxic chemicals at or just above the Health Canada guideline value in drinking water, developing cancer is the primary health concern. The risk of kidney cancer is increased with exposure to lead and cadmium (ATSDR, 2007c; Health Canada, 2014); the risk of stomach cancer is increased with exposure to chromium (ATSDR, 2012b); and exposure to arsenic increases the risk of bladder, liver and skin cancer (Morales, Ryan, Kuo, Wu, & Chen, 2000; Cabrera & Gomez, 2003). In addition, a systematic review of 17 studies found a relationship between high arsenic exposure from drinking water and lung cancer

(Celik et al., 2008). This finding is particularly surprising, as the relationship between arsenic and lung cancer is more commonly associated with exposure via cigarette smoke. The exact level at which arsenic increases the risk of developing cancer is debated. Some suggest that the threshold level is an intake of about 400 µg/day (Hindemarsh, 2000), and up until 2006 the guideline value set by Health Canada was 50 µg/day (Health Canada, 2006). However, the current Health Canada guideline value for drinking water is 10 µg/L (Health Canada, 2014b). Any laboratory for drinking water testing would certainly be obligated to accept this value as the standard.

Cardiovascular Risks

There is growing evidence to suggest that prolonged exposure to chemicals via drinking water increases the risk of hypertension. Specifically, arsenic (Abhyankar, Jones, Guallar, & Navas-Acien, 2012; Kunrath et al., 2013), barium, (ATSDR, 2007b), and though still a debated issue, lead (Kopp, Barron, & Tow, 1988; Houston & Johnson, 1999; Scinicariello, Abadin, & Murray, 2011) are all causes for concern. A 2013 study published in the *Annals of Internal Medicine*, shows that exposure to even low levels of arsenic (less than 0.10 mg/L) may increase the risk for cardiovascular disease (Moon et al., 2013). In addition, a recent US study found that lower level exposure to arsenic is associated with an increased risk of stroke (Lisabeth et al., 2010), though this was a retrospective study done based on arsenic estimations known to be at the zip code level in Michigan. While it is by no means a causal relationship, it suggests an interesting association that may well be another source of risk in Newfoundland and Labrador, especially since the exposure may in some cases be from a lifetime of drinking water with low-level concentrations of contaminants. A further challenge of a study such as this is the confounding of more directly related exposures, such as those from smoking and other lifestyle choices.

Neurological Risks

The neurological system is particularly vulnerable to lead and mercury exposure, and weakness and difficulty controlling muscles can result from long-term exposure to lead (ATSDR, 2007c). Recent research in the United States and Canada has found that low-level exposure to lead has been found to cause an increased risk for Attention Deficit Disorder (ADD) in children (Eubig, Aguiar, & Schantz, 2010; Boucher et al., 2012). This work looks at blood lead levels of less than 10 μg/L.

A reduction in child IQ and cognitive function has been associated with foetal lead exposure (Bellinger, Stiles, & Needleman, 1992; Cummins & Goldman, 1992). Research in Bangladesh, Mexico and China has also shown exposure to drinking water arsenic to decrease child IQ scores (Calderon et al., 2001; Wang et al., 2007; Hamadani et al., 2011). While these exposures were at levels not comparable to North America, recent evidence out of Maine supports this association even at low levels of arsenic exposure (Wasserman et al., 2014).

Kidney Risks

Kidney disease and decreased kidney function have been shown in adults, adolescents and children from exposure to low-levels of lead (Fadrowski et al., 2010; Fels et al., 1998; Kim et al., 1996; Muntner, He, Vupputuri, Coresh, & Batuman, 2003; Sommar et al., 2013). In the case of Fadrowski et al., again blood levels of less than 10 μg/L were associated with reduction in glomerular filtration rate, a common clinical measurement of kidney function, though causal relationship was not established. Furthermore, research in mice has shown that chronic exposure to low levels of cadmium at or around the safe limit can cause kidney damage (Thijssen et al., 2007).

Diabetes

Evidence has shown that low-level chronic exposure to arsenic in drinking water may increase the risk of Type 2 Diabetes (Maull et al., 2012; James et al., 2013; Jovanovic et al., 2013; Navas-Acien, Maull, & Thayer, 2013). New evidence in Canada from June 2015 also supports this association (Feseke et al., 2015) based on a cross-sectional study including 3,151 participants, measurements of urinary arsenic were shown to have an increased odds ratio of 1.81 for Type 2 diabetes when comparing the highest quartile of urinary arsenic concentration with the lowest quartile; although the authors of this study acknowledge that an additional study is needed to strengthen this association, and again, this does not establish causality.

Reproductive Outcomes

Reproductive outcomes are also a risk from contaminant exposure by drinking water, and women who are pregnant or could become pregnant should be particularly wary. Arsenic can cross the placental barrier and be found in foetal tissues, posing a developmental risk for unborn children (ATSDR, 2007a). Lead exposure during pregnancy may result in low birth weight, premature births, and learning and growth difficulties (Xie et al., 2013). Also, new research has shown low-level lead exposure is associated with an earlier age for menopause (Eum, Weisskopf, Nie, Hu, & Korrick, 2014). While the evidence is still limited, there has been some research suggesting an association between low-level lead exposure and decreased semen quality in men (Wirth & Mijal, 2010).

Selenosis

Selenium is an essential element in small quantities. The United States Department of Health and Human Services cautions that long-term exposure to concentrations above guideline values can result in a condition called selenosis (ATSRD, 2003). Selenosis is characterized by brittle hair, nails and some numbness or other neurological effects (ATSDR, 2003).

Chemical contaminants and potential associated health risks are summarized in Table 4.

Table 4. Drinking water contaminants and associated health risks summary

Health risk	Contaminant causing increased health risk at exposure above guideline values	Health Canada Guideline Values (mg/L)
Bladder Cancer	arsenic	arsenic (0.01)
Liver Cancer	arsenic	barium (1)
Lung Cancer	arsenic, cadmium	cadmium (0.005)
Kidney Cancer	lead, cadmium	chromium (0.05)
Skin Cancer	arsenic	lead (0.01)
Stomach Cancer	chromium	mercury (0.001)
Cardiovascular Disease	arsenic	selenium (0.01)
Hypertension	arsenic, barium, lead	
Stroke	arsenic	
Neurological Weakness	lead, mercury	
Attention Deficit Disorder (ADD)	lead	
Decreased Intelligence Quotient (IQ)	arsenic, lead	
Kidney Damage	cadmium, lead	
Diabetes	arsenic	
Reproductive Risks	arsenic, lead	
Selenosis	selenium	

[a] (Health Canada, 2014b)

Based on this wide range of diseases, the series of health risks represents a potential burden of disease that could have serious economic implications in Newfoundland and Labrador. It is scientifically incorrect to use a proxy model to draw conclusions. Ideally, data would be available to calculate the population attributable risk for these exposures. However, this calculation would require information on the disease incidence rates in the population exposed to contaminants from drinking well water as well as disease incidence rates in the population not exposed to contaminants from drinking water. Unfortunately, this information is not currently known. Since there is no mechanism to get the data, this is an attempt at an overview of the situation. It is important to note that the studies conducted in the US and Denmark on long-term low exposure of arsenic found some association on increased risk ratio for diabetes and coronary heart disease (Brauner et al., 2014; James et al., 2015). In a US study, a positive association between inorganic arsenic exposure in drinking water and coronary heart disease was also found. These results showed a hazard ratio of 1.38 per 15 μg/L of exposure to inorganic arsenic in drinking water even when adjusted for age, sex, first-degree family history of coronary heart disease, and blood LDL cholesterol levels (James et al., 2015). A Danish study found an association between arsenic exposure in drinking water and diabetes, with an incidence rate ratio or 1.03 per 1 μg/L of arsenic over a 10 year period (Brauner et al., 2014). Given news reports of some arsenic tests in New World Island for example showing arsenic concentrations up to 200 ppb, or 200 μg/L, this represents a considerable risk (Fitzpatrick, 24 January 2015). Determining the portion of the economic burden and disease incidence attributable to contaminant exposure in drinking water in Newfoundland and Labrador is an opportunity for further research.

What can be looked at is the total economic burden from these diseases, though again, without specific information on the portion of this economic burden that can be attributed to contaminants from drinking well water. Estimating this economic burden is difficult, but some data for 2010-2011 is available for the province in specific case mix groups from the Canadian Institute for Health Information (CIHI). For example, as shown in Table 5, according to CIHI, an estimated $190,269 was spent treating cancer of the urinary system in Newfoundland and Labrador in 2010-2011 (27 cases at $7,047 estimated average per case). In addition, an estimated $6,505 was spent treating each case of skin cancer in the province. Diabetes treatment costs in 2010-2011 were estimated at $3,072,130 in the province (590 cases at $5,207 per case). At this point in time, there is no information on exactly how many cases of the following illnesses are caused by exposure to contaminants in private well water in Newfoundland and Labrador.

Table 5. Treatment Costs by Case Mix Group in 2010-2011 in Newfoundland and Labrador (CIHI, 2014)

Condition	Estimated Total Average Cost ($)	Estimated Average Cost per case ($)	Number of Cases
Bladder, renal cancer	190,269	7,047	27
Skin cancer	Data unavailable	6,505	Data unavailable
Liver, pancreas cancer	378,240	9,456	40
Bowel, stomach, intestine cancer	541,730	7,739	70
Diabetes	3,072,130	5,207	590
Stroke	3,251,997	8,813	369
TIA (mini-stroke)	791,508	3,716	213

There are further economic considerations that may add to the problem. For example, these figures do not take into account the economic impact of days sick and off work or the financial burden on families from time taken away from work for sick children. Though it is unknown what portion of these conditions and costs are due to exposure to contaminants in well water, this lack of data further articulates the need for water quality monitoring to help understand the problems more fully.

Results Part 2: Development of the Business Models

Geological and Temporal Variation

The establishment of a private water quality monitoring service naturally leads to the question of what is an appropriate testing schedule. Health Canada recommends that private well water be tested "periodically," though defers to provincial regulations for further details on just what periodically means (Health Canada, 2015). The need for regular monitoring is exemplified in a study tracking 37 wells in Bangladesh for a period of 2 years, 11 of these wells were shown to have significant temporal variation in arsenic concentration and only one of these was regularly connected with the seasons (Dhar et al, 2008). Research also suggests that water levels can contribute to the amount of arsenic in groundwater wells, such as an alpine case study that found drought conditions led to an increase in arsenic concentrations (Pili, 2013). While this is only a single case study that attributes the changes in arsenic concentration to a specific type of pyrite, it does indicate that depending on the geology there is possibility for variation. This possibility for variation suggests that some kind of regularity should be applied to water testing in Newfoundland and Labrador.

Furthermore, there are many factors that may potentially affect water quality. Specifically in Newfoundland and Labrador, some of these factors include recreational activities, climate change, mining, natural sources, rural sewage systems and transportation (Dawe, 2004). In this study by Dawe (2004), these factors were catalogued based on analyzing water quality data available since 1986 for 65 sites in Newfoundland and Labrador. While these sites were surface water sources and not groundwater wells, the research still entertains the possibility of changing trends in water quality, and illustrates the need for information on private groundwater wells.

Water Testing Laboratories and Business

The scholarly literature was also reviewed for support in regards to the economics of water testing laboratories as well as searching for similar models for water testing laboratories. Economics here is used broadly to refer to the business and financial feasibility of a laboratory testing facility. Google Scholar was used to perform the search, and the results returned little information on either dimension of water testing service. This lack of peer-reviewed published literature suggests that approaching this kind of business sustainability issue in a population similar to that of Newfoundland and Labrador is a novel idea and a necessary area for scholarly contribution.

While no specific literature has been published on the economics of water testing facilities, there has been some work done on the importance of water quality management (Ongley, 2000). Ongley (2000) focuses on the policy, technical, institutional and financial implications of water quality management. In addition, one study looked at the increased value in land prices in the Chesapeake Bay Region in the eastern United States from perceptions around positive water quality (Leggett & Bockstael, 2000).

While no articles were found in the scholarly literature on models for a water quality monitoring service, one important study examined issues around the privatization of service (Avery, 2000). This study included considerations of the core values of a service, stability of private providers, costs, regulatory challenges, performance monitoring and any potential conflicts of interest from a privatized model.

Technical Equipment Requirements

Information on equipment requirements and technical capacity was collected from interviews with laboratory professionals, on tours of existing laboratories, and with quotes from industry suppliers by phone and e-mail.

Water quality monitoring parameters can be organized into groups, as was done in the introduction. These groups are health parameters, aesthetic parameters, environmental parameters, and disinfection by-products and are illustrated in the previously referenced Figure 3. When considering a comprehensive water testing facility, the ultimate goal would be a program that examines all of the above parameters, as well as having the capacity to perform tests for municipal water supplies, which are currently sent out of province (Sarkar et al., 2012). Testing municipal water supplies would require equipment for testing disinfection by-products, and while outside of the scope of this study, is an opportunity for further research. The following looks at each of the testing parameter groups and provides information on technical laboratory equipment required.

Analytical Devices: Health Parameters

The health parameters from the HCGCDWQ are listed in Table 6, along with the analytical device capable of testing that parameter in the detection range necessary. Based on these parameters and on the advice of one interviewee, the laboratory will require an inductively coupled plasma mass spectrometer (ICP-MS) with auto sampler, an ion chromatograph and a turbidity meter. A photo of such a unit is found in Figure 6.

Table 6. Drinking water testing health parameters

Drinking Water Parameter	Health Canada MAC (mg/L unless otherwise indicated)[a]	Analytical Device for Testing
Fluoride	1.5	Ion Chromatograph
Nitrite	3.2	Ion Chromatograph
Nitrate	45	Ion Chromatograph
Turbidity	1 (NTU)	Turbidity Meter
Antimony	0.006	ICP-MS
Arsenic	0.01	ICP-MS
Barium	1	ICP-MS
Boron	5	ICP-MS
Cadmium	0.005	ICP-MS
Chromium	0.05	ICP-MS
Lead	0.01	ICP-MS
Mercury	0.001	ICP-MS
Selenium	0.01	ICP-MS
Uranium	0.02	ICP-MS

[a](Health Canada, 2014b)

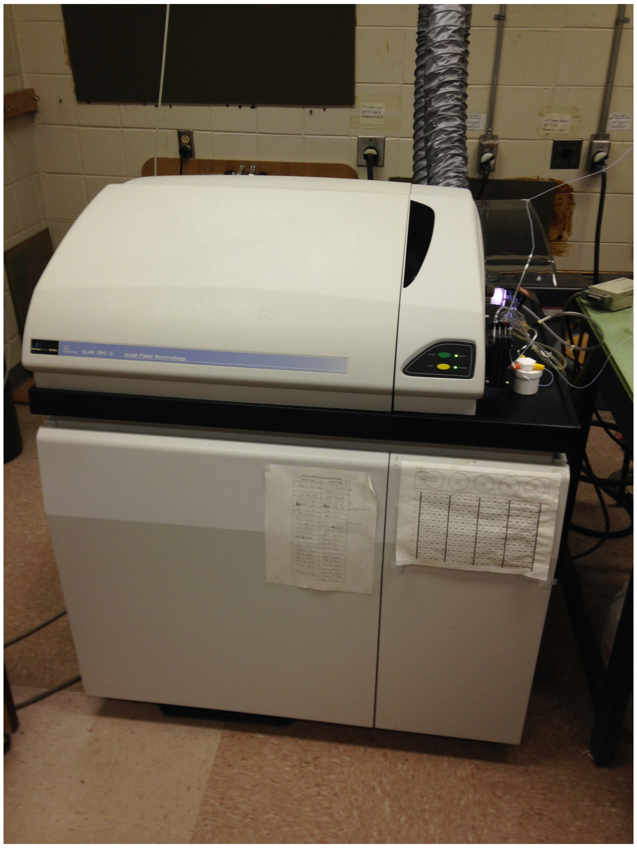


Photo credit: K. Thomson

Figure 6. Sample ICP-MS unit. Elan DRC II model shown

Equipped with an auto sampler, an ICP-MS can handle about 200 samples a day (M. Green, Product Manager, Inorganics, Mandel Scientific Inc., Personal Communication, 11 August, 2014). An ICP-MS requires argon to operate, and this is an important consideration from a cost and facilities perspective which one laboratory professional pointed out during an interview.

Photo credit: K. Thomson

Figure 7. Large argon canister to supply ICP-MS

Based on the advice of one interview participant, the ion chromatograph used for the health parameter suite should be used exclusively for negatively charged ions to save time on switching out the columns, which would be required if switching to positive ion detection.

Analytical Devices: Aesthetic Parameters

Equipment required in addition to perform testing of aesthetic parameters is a spectrophotometer to measure color, and a pH meter. Building on the earlier advice of dedicating one ion chromatograph to negative ions for health parameters, purchase of a second ion chromatograph dedicated to positive ions could save on time and costs.

Aesthetic parameters, values from the HCGCDWQ and analytical devices required are summarized in Table 7.

Table 7. Drinking water testing aesthetic parameters

Drinking Water Parameter	Health Canada MAC (mg/L unless otherwise indicated)	Analytical Device for Testing
Chloride	250	Ion Chromatograph
Color	15 (TCU)	Spectrophotometer
pH	6.5-8.5	pH meter
Sulphate	500	Ion chromatograph
Total Dissolved Solids	500	Filter and analytical balance
Copper	1	ICP-MS
Iron	0.3	ICP-MS
Manganese	0.05	ICP-MS
Sodium	200	Ion Chromatograph
Zinc	5	ICP-MS
Hardness as CaCO3	None in place	calculated from Ca and Mg
Calcium	None in place	Ion Chromatograph
Magnesium	None in place	Ion Chromatograph

Analytical Devices: Environmental Parameters

Additionally required to perform tests for environmental parameters is a conductivity meter and a discrete analyzer for analysis of elements like phosphorous and nitrogen. These are summarized in Table 8.

Table 8. Drinking water testing environmental parameters

Drinking Water Parameter	Analytical Device for Testing
Conductivity	conductivity meter
Alkalinity	alkalinity meter
Total Kjeldahl Nitrogen	discrete analyzer
Total Phosphorus	discrete analyzer
Ammonia	discrete analyzer
Aluminum	ICP-MS
Nickel	ICP-MS
Potassium	ion chromatograph

For retrieving price quotes, e-mail requests were sent to three scientific suppliers available in eastern Canada: Mandel Scientific, PerkinElmer and Fisher Scientific. E-mail replies were received from all three suppliers, and estimate quotes were provided for the equipment sold by that particular supplier in these personal communications. In cases where a piece of equipment was available from multiple suppliers, the lowest cost estimate was used. The following table presents estimated costs for the above equipment divided by parameter set (M. Green, Product Manager, Inorganics, Mandel Scientific Inc., Personal Communication, 11 August, 2014; A. Chalhoub, Territory Manager, Eastern Canada, PerkinElmer, Personal Communication, 12 August, 2014; C. Ford, Account Representative, Newfoundland and Labrador, Fisher Scientific, Personal Communication 6 August, 2014).

Table 9. Estimated costs of analytical devices in CND $1000

Analytical Devices - Health Parameters		Analytical Devices - Aesthetic Parameters		Analytical Devices - Environmental Parameters	
Device	Est. Cost	Device	Est. Cost	Device	Est. Cost
ICP-MS	180	pH Meter	0.5	Conductivity Meter	1
Auto sampler	20	Spectrophotometer	6	Discrete Analyzer	65
Ion Chromatograph	30	Ion Chromatograph	30		
Analytical Balance	2.8				
Turbidity Meter	10				
Total cost	242.8	Total Cost	36.5	Total Cost	66

Interview Results: Barriers and Challenges to Water Quality Monitoring, Well Owner's Perspective

Attempting to implement an adequate water quality monitoring service for private well owners in the province presents a unique set of challenges and barriers. Identification and insight into these potential barriers came from open-ended interviews performed with government representatives, health professionals and individual private well owners in the province. Interviews were transcribed with the support of the Memorial University Health Research Unit. These transcriptions were analyzed and high-level themes identified. While individuals from many key stakeholder groups were interviewed, responses fell into two key perspectives: that of the well owner and that of the laboratory operator.

Themes identified from the interviews from the well owner's perspective are summarized in Figure 8. The themes identified were cost, geography and accessibility, well owner age, trust in the service, a need for public education, reporting challenges and reliability of testing service.

Challenges: Well Owner's Perspective

Figure 8. Water Quality Monitoring Well Owner Barriers and Challenges

Cost

In general, well owners interviewed felt that water quality monitoring should be provided free of charge as a government service. However, each well owner was also questioned further on appropriate pricing, if the service could not be free. A price of $100 was proposed in each interview and asked if that would be too expensive for a once a year test. Four out of 5 well owners interviewed thought this was a reasonable price that they would be willing to pay themselves. One individual responded “Oh, $100.00 would definitely be reasonable.”

Geography, Accessibility

Geography of the province is a barrier one might expect coming from residents of rural Newfoundland and Labrador. While no well owner interviewed felt that driving to the nearest Service NL center was particularly prohibitive for themselves, many made comments with regards to others in the community. For example, “The availability of [testing] you know, I mean you tell a person that they got to come up and get a bottle and make sure it gets to Corner Brook before Thursday dinner time, half of them are seniors, I think a lot of it...feels like too much for them you know” was the response of one municipal representative when asked about challenges for their community.

The issue of availability of testing service with regards to opening hours did come up with one well owner. “I mean if you got working families, I mean they’re not easily going to get somewhere between the hours of 9-5 Monday to Friday. So you’re definitely going to want something that’s past those hours.”

Age of Well Owners

Forty percent of the population of Newfoundland and Labrador resides in rural areas (Statistics Canada, 2012). Of that population, a large portion are senior citizens. According to interview conversations, this older demographic presents further challenges. As one participant said, “Rural areas mean an elderly population of small means….

Transportation, getting things like going back and forth, calling people up and long distance calls like these are all you know to you or me no big deal but for them it's a bit of deal." Also with regards to cost of testing concern for seniors came up, "A fairly large population of seniors like, low income like, $100.00 to them is a lot of money."

Public Education

Interview conversations supported the perception of an education gap amongst rural well owners, and this was one of the stronger themes identified. For example, when discussing the available microbiological testing from the Public Health Laboratory with a municipal representative, the response was "I think a lot of [the well owners] are misunderstanding what they're getting tested for. Like they think they're getting this full blown test...they think it's this whole realm of tests." Well owners interviewed who had water testing performed believed that because of this microbiological testing service they availed of, they had safe drinking water.

"The biggest thing if this [laboratory] is going to be set up is an education campaign so that we can explain why it's being done and why it should be done… anything to help get the message across." Interviews also suggested that one of the ways to bridge the education gap would be to partner with local municipal government. For example, one municipal representative stated "We could explain to the people you know why [testing] needs to be done or what's the rationale for it, not saying that you couldn't explain it, it's just that they know us."

Reliability

Many residents felt that a trained, professional, coming directly to the home to take samples was the best way to ensure the reliability of samples taken. "Even if say you had some kind of service set up that came into your town, and it was something that was consistent." Furthermore, this is a measure increasing convenience for individual well owners. While well owners would appreciate this service, it of course would represent a substantial cost, which is discussed later. One of the laboratory professionals also explained an issue with nitric acid for taking samples. She explained, "Because sometimes the elements and trace metals can adhere to the sides of the bottle...normally we would add [nitric] acid to stabilize everything in the solution. I'm not comfortable giving that [chemical] out."

Trust

In interview discussions, private well owners were asked who they would like to see running a water quality monitoring service in the province, the private or public sector. While some had no preference, several individuals felt that they would prefer government, as opposed to the private sector. Comments made were things like "Working in the public sector is the person who comes in not on a deadline that you go to have so many tests done at a certain time...and if you don't you're out the door.... You get companies that are in this to make money, that's how they make money." No one responded that they would prefer the private sector administer the service. The biggest reason for this preference was trust, and concerns that a private laboratory would be motivated by wanting to sell something to the individual well owner.

Reporting Challenges

The issue of who would ultimately interpret the results for individual well owners was raised in two laboratory interviews. Since these are ultimately health parameters, one of the laboratories in particular felt that they did not want to be responsible for explaining health risks to individual well owners.

Interview Results: Barriers and Challenges to Water Quality Monitoring, Laboratory Operator's Perspective

The other category of identified barriers and challenges from interview analysis are from the laboratory operator or owner's perspective. These themes, sample volume, maintenance, geography, administrative costs, accreditation fees, insurance and invoice lag time, are summarized graphically in Figure 9.

Challenges – Laboratory Operator's Perspective

Figure 9. Water Quality Monitoring Laboratory Operator Barriers and Challenges

Sample Volume

The private laboratory professionals interviewed for this study expressed concerns over the long-term viability and profitability of a laboratory dedicated to drinking water testing in the province. The primary concern was the number of tests per year needed to sustain such a venture, and provide an appropriate return on investment. In particular, it was felt that without a government mandate requiring repeat testing, not enough tests would be submitted per year, based on the current climate of public opinion towards well water in the province.

Maintenance

Each laboratory interviewed stressed the importance and need for proper maintenance of equipment, and all stated that they used the manufacturer's service contract for laboratory equipment. It was estimated in interview that maintenance contracts could run over $20,000 for a single ICP-MS unit. One professional said, "I would advise that if you're buying something or going to [set up a laboratory], be it in private industry or public or whatever, being in Newfoundland where we are, get a service contract. Pay the money for a service contract every year."

Administrative Costs

Administrative overhead can be a substantial cost of an operation. One laboratory interviewed explained that currently, within their operation each invoice created costs the company about $125, considering creating the invoice, billing, mailing, data entry, banking fees, etc. This laboratory suggested that the client should be one entity, for example, the provincial government to alleviate these costs and streamline the process. It was estimated by the same laboratory that the administrative overhead cost could be reduced to about $50.

Invoice Lag time

In addition to the administrative costs of having multiple individual clients, the same laboratory interviewed also raised issues of invoice lag. Should the invoices be made to individual well owners, there is an administrative challenge and cost associated with collecting on numerous, relatively small invoices. They suggested that for them as a private laboratory, this currently is a deterrent to pursuing and promoting drinking water testing.

The same laboratory further elaborated on the lag time related to submitting a bid to government. To submit a bid to the provincial government, one must already have the equipment and accreditation. They stated, “This is a $500,000 investment just to bid, with no revenue collected for almost a year,” and suggested that this was too risky, with no guarantee of getting the contract.

Insurance

One laboratory interviewed raised the issue of commercial liability insurance, especially since the testing is related to health.

Accreditation Fees

All laboratories interviewed pointed out the importance of accreditation, and that this is a significant cost. One laboratory estimated yearly accreditation fees for drinking water parameters to be between $20,000 and $30,000.

Interview Results: Tour of New Brunswick Analytical Services Laboratory

In New Brunswick, a water quality testing service is available to private well owners through the Analytical Services Laboratory, administered through the Department of Environment and Local Government. A tour of this laboratory, as well as interviews with key personnel and area heads was conducted to help understand the service provided by this laboratory. The following section summarizes the information gathered while on this tour. Residents are able to avail of a variety of testing services at a reduced price, which provides revenue. The remainder of the laboratory's operational budget, about 50% is made up from government subsidy. Available tests, and their associated cost are included as Appendix F.

According to personnel interviewed, the distribution network for this laboratory is in partnership with Service New Brunswick. Residents are able to not only acquire sample bottles, but also deliver water samples, through most Service New Brunswick sites throughout the province. This allows for a convenient system for sample delivery. In New Brunswick, issues with quality control are addressed through a detailed instruction manual that comes with the sample bottles.

It was also explained that in New Brunswick, all new wells that are drilled, about 2,000 annually, include a fee of $122 plus tax for a complete water chemistry test charged by the driller at the time of well installation. This gives the well owner a voucher for a complete water chemistry analysis test, including microbiological and chemical testing, which they have one year to redeem. By incorporating this charge with the installation of the well, more tests are redeemed, because residents have already paid for the testing. This information aids in creating the New Brunswick Groundwater Chemistry Atlas, discussed below (New Brunswick Department of Environment, 2008).

According to staff at the Analytical Services Laboratory, for the 2013 calendar year, there were 5,791 water quality samples that were tested from private wells in the province of New Brunswick. Of the 5,791 samples, 1,010 of these were from residents who redeemed their well voucher.

Business Model

Business Model: Financial Modeling

It would be remiss to propose a model for a water quality monitoring service without considering business sustainability – broadly defined here as the laboratory meeting its medium and long-term financial goals without significant government funding. While there are many possible revenue streams such as research grants or corporate contracts, the core business being modelled is for private well water quality testing. For a laboratory to be sustainable, this would be dependent on repeat and routine testing.

Using forecasting tools proposed by Chapman and outlined earlier in this thesis, three sensitivity models are presented based on three potential scenarios, a best case scenario, worst case scenario, and a reasonable forecast of service uptake (2015). These three sensitivity models are based on three distinct theoretical levels of legislative support from the provincial government and each has inherent assumptions that guide the model.

1. Sensitivity Model 1 - All well owners participate in biennial testing. Assumes a strongly enforced requirement for complete biennial testing of all private wells. This is the best case scenario from a service uptake perspective.
2. Sensitivity Model 2 - Requires mandatory testing that is not enforced, and therefore a 25% compliance rate is assumed. This is a reasonable case scenario from a service uptake perspective.

3. Sensitivity Model 3 - Requires voluntary sample submission, and assumes 1000 samples in the first year, with growth following in subsequent years because of transmission by word of mouth. This is a worst case scenario from a service uptake perspective.

Projected revenue, projected expenses, and a projected income statement for each of the three scenarios is presented, with notes on the financial statements following in the discussion section of this thesis. Projections are presented for three years, as recommended by Skinner (2015). All of these scenarios assume that a full suite of tests appropriate to private wells will be required, and include the purchasing of laboratory equipment for testing health, aesthetic and environmental parameters, as described above.

Business Model: Sensitivity Model 1

This first scenario is theoretically based on a firm government mandate, requiring all private well owners to have full water testing completed. In this scenario, the mandate is strongly enforced on a biennial schedule. This kind of strong legislative support allows the model to assume 100% compliance from all private well owners in the province. While this scenario presents a host of other logistical challenges, such as who will pay in the situation of low income homes, the projections do give a sense of the possible financial situation if the entire province were to come on board with the testing program.

First, three year revenue projections for this Sensitivity Model 1 are presented in Table 10. Given this level of compliance, a steady 25,000 samples each year is assumed (one half of the 50,000 wells in the province). The price for a full suite of testing is set at $100, based on support of this price in interviews with private well owners. Furthermore, a service of individual parameter monitoring is offered to residents who require additional testing, more often than the biennial schedule, due to a known problem with an individual contaminant. The price for this service is set at $25, and the volume of testing is assumed at 10% of clients. This balance shows well water chemistry analysis to be 98% of revenue activities, with individual parameter monitoring rounding out the remaining 2%. Quality control testing is not included in these testing volumes.

Table 10. Sensitivity Model 1 Projected Revenue

SALES ACTIVITIES	Dec-16	Dec-17	Dec-18
Well water chemistry analysis	$2,500,000	$2,500,000	$2,500,000
Individual Parameter Monitoring	$50,000	$50,000	$50,000
TOTAL SALES ($)	**$2,550,000**	**$2,550,000**	**$2,550,000**

SALES ACTIVITIES (%)			
Well water chemistry analysis	98.0%	98.0%	98.0%
Individual Parameter Monitoring	2.0%	2.0%	2.0%

ASSUMPTIONS REGARDING SALES

Scenario is based on introduction of mandatory biennial testing of drinking water, and therefore, assumes a consistent 25,000 samples a year (based on estimated 50,000 wells in province). $100 per testing suite.

Individual Parameters refers to clients with known risk to specific contaminant. Estimated at 10% of clients. $25 per parameter.

Second, expenses for Sensitivity Model 1 are presented in Tables 11 and 12. As this scenario assumes a steady volume of testing per year at 25,000 samples, expenses are consistent over the three-year projection. To meet capacity, one ICP-MS instrument was purchased, as well as two of each of the other analytical instruments required. A three-year straight-line depreciation of analytical equipment is assumed. Initial marketing funding is included as a rollout of the service, and then reduced in subsequent years. Higher marketing expenses are included initially in this model, because of the enforced expectation that all well owners in the province should participate in the program. In the interest of fairness to the well owners, this will require a fair amount of communication. Direct labour wages are based on 3 laboratory technicians at $60,000 per year required to meet the volume of testing. General Inflation and taxes are not included in this model. Expenses for maintenance, rent, utilities, shipping, interest, as well as human resources are all assumed and elaborated on in the notes on financial statements.

Table 11. Sensitivity Model 1 Projected Expenses

	Dec-16	Dec-17	Dec-18
Analytical Equipment Purchase	$163,533	$163,533	$163,533
Sample Bottles	$150,000	$150,000	$150,000
Argon	$40,000	$40,000	$40,000
Total Material Costs ($)	*$353,533*	*$353,533*	*$353,533*
Direct Labour Wages	$180,000	$180,000	$180,000
Repairs & Maintenance	$16,400	$16,400	$16,400
Rent / utilities	$28,800	$28,800	$28,800
TOTAL EXPENSES ($)	**$578,733**	**$578,733**	**$578,733**
EXPENSES (%)			
Analytical Equipment Purchase	28.3%	28.3%	28.3%
Sample Bottles	25.9%	25.9%	25.9%
Argon	6.9%	6.9%	6.9%
Total Material Costs (%)	*61.1%*	*61.1%*	*61.1%*
Direct Labour Wages	31.1%	31.1%	31.1%
Repairs & Maintenance	2.8%	2.8%	2.8%
Rent / utilities	5.0%	5.0%	5.0%
TOTAL EXPENSES (%)	**100.0%**	**100.0%**	**100.0%**

▼
ASSUMPTIONS REGARDING EXPENSES

3 year straight-line depreciation of analytical equipment assumed.
2x of each analytical instrument purchased to handle production capacity, except 1x ICP-MS.
Sample bottles estimated at $6 per household.
Argon assumed at $40,000 per year.
Maintenance assumed at 10% of equipment.
Rent assumed at $1,600/month plus 50% assumed utilities.

Table 12. Sensitivity Model 1 Projected Operating Expenses

	Dec-16	Dec-17	Dec-18
Advertising	$250,000	$125,000	$125,000
Shipping & Delivery	$250,000	$250,000	$250,000
Total Adv./Delivery Costs ($)	*$500,000*	*$375,000*	*$375,000*
Management Salaries	$100,000	$100,000	$100,000
Office Salaries	$50,000	$50,000	$50,000
Accreditation Fees	$30,000	$30,000	$30,000
Office Expenses	$2,000	$2,000	$2,000
Insurance	$15,000	$15,000	$15,000
Bank Charges	$10,000	$10,000	$10,000
Interest on L.T.D.	$50,000	$50,000	$50,000
Total Admin. Expenses ($)	*$257,000*	*$257,000*	*$257,000*
TOTAL EXPENSES ($)	**$757,000**	**$632,000**	**$632,000**
EXPENSES (%)			
Advertising	33.0%	19.8%	19.8%
Shipping & Delivery	33.0%	39.6%	39.6%
Total Adv./Delivery Costs (%)	*66.0%*	*59.4%*	*59.4%*
Management Salaries	13.2%	15.8%	15.8%
Office Salaries	6.6%	7.9%	7.9%
Accreditation Fees	4.0%	4.7%	4.7%
Office Expenses	0.3%	0.3%	0.3%
Insurance	2.0%	2.4%	2.4%
Bank Charges	1.3%	1.6%	1.6%
Interest on L.T.D.	6.6%	7.9%	7.9%
Total Admin Expenses (%)	34.0%		

ASSUMPTIONS REGARDING EXPENSES

Initial marketing campaign introducing new service in first year. Reduced in subsequent years.
Interest assumed at 10%. $500,000 guaranteed government loan for initial equipment purchase.
Shipping assumed at $10 per sample.

As can be seen in the income statement shown in Table 13, Sensitivity Model 1 forecasts a considerable profit of over $1.2 million in the first year. Based on the volume of tests assumed for this model, a price per test of $53.43 would be required to break even in the first year.

Table 13. Sensitivity Model 1 Projected Income Statement

	Dec-16	Dec-17	Dec-18
Total Revenue	$2,550,000	$2,550,000	$2,550,000
Total Cost of Revenue	$578,733	$578,733	$578,733
Gross Profit	*$1,971,267*	*$1,971,267*	*$1,971,267*
Revenue Expenses	$500,000	$375,000	$375,000
Admin Expenses	$257,000	$257,000	$257,000
Total Expenses	*$757,000*	*$632,000*	*$632,000*
OPERATING PROFIT	**$1,214,267**	**$1,339,267**	**$1,339,267**

Business Model: Sensitivity Model 2

Sensitivity Model 2 is theoretically based on a mandatory testing requirement that is not enforced. Even though, the testing is considered required, there is no penalty for non-compliance. A 25% compliance rate is here assumed for the purposes of creating the sensitivity model.

Again, three-year revenue projections for Sensitivity Model 2 are presented first in Table 14. Given the assumed 25% compliance rate, 6,250 samples are assumed in the first year. Given that news of the service will spread via word of mouth and public education campaigning, a 10% growth rate for the first three years is projected. The price for a full suite of testing is set at $100, based on support of this price in interviews with private well owners. Furthermore, a service of individual parameter monitoring is offered to residents who require additional testing, more often than the biennial schedule, due to a known problem with an individual contaminant. The price for this service is set at $25, and the volume of testing is assumed at 10% of clients. This balance shows well water chemistry analysis to be 97.6% of revenue activities, with individual parameter monitoring rounding out the remaining 2.4%. Quality control testing is not included in these testing volumes.

Table 14. Sensitivity Model 2 Projected Revenue

SALES ACTIVITIES	Dec-16	Dec-17	Dec-18
Well water chemistry analysis	$625,000	$687,500	$756,250
Individual Parameter Monitoring	$15,625	$17,188	$18,908
TOTAL SALES ($)	**$640,625**	**$704,688**	**$775,158**
SALES ACTIVITIES (%)			
Well water chemistry analysis	97.6%	97.6%	97.6%
Individual Parameter Monitoring	2.4%	2.4%	2.4%

ASSUMPTIONS REGARDING SALES
Scenario is based on introduction of mandatory biennial testing of drinking water (unenforced) with a voluntary 25% compliance. 6,250 samples first year. $100 per testing suite.
Assumes 10% growth in samples per year, based on word of mouth and public health information campaigns.
Individual Parameters refers to clients with known risk to specific contaminant, requiring specific testing. Estimated at 10% of clients. $25 per parameter.

Expenses for Sensitivity Model 2 are presented in Tables 15 and 16. As this scenario assumes a 10% growth rate in samples tested each year, material costs grow proportionately over the three-year projection. Equipment start-up costs are lower in this model than in the previous model because only one of each instrument is required to meet capacity. A three-year straight-line depreciation of analytical equipment is assumed. Initial marketing funding is included as a rollout of the service, and then reduced in subsequent years. Direct labour wages are based on 2 laboratory technicians at $60,000 each per year. Because this model assumes significantly less testing volume compared with Sensitivity Model 1, one less laboratory technician is required. General inflation and taxes are not included in this model. Expenses for maintenance, rent, utilities, shipping, interest as well as human resources are all assumed and elaborated on in the notes on financial statements.

Table 15. Sensitivity Model 2 Projected Expenses

	Dec-16	Dec-17	Dec-18
Analytical Equipment Purchase	$115,100	$115,100	$115,100
Sample Bottles	$37,500	$41,250	$45,378
Argon	$20,000	$22,000	$24,200
Total Material Costs ($)	*$172,600*	*$178,350*	*$184,678*
Direct Labour Wages	$120,000	$120,000	$120,000
Repairs & Maintenance	$11,500	$11,500	$11,500
Rent / utilities	$28,800	$28,800	$28,800
TOTAL EXPENSES ($)	**$332,900**	**$338,650**	**$344,978**

EXPENSES (%)

Analytical Equipment Purchase	34.6%	34.0%	33.4%
Sample Bottles	11.3%	12.2%	13.2%
Argon	6.0%	6.5%	7.0%
Total Material Costs (%)	*51.8%*	*52.7%*	*53.5%*
Direct Labour Wages	36.0%	35.4%	34.8%
Repairs & Maintenance	3.5%	3.4%	3.3%
Rent / utilities	8.7%	8.5%	8.3%
TOTAL EXPENSES (%)	**100.0%**	**100.0%**	**100.0%**

ASSUMPTIONS REGARDING EXPENSES

3 year straight-line depreciation of analytical equipment assumed.
Sample bottles estimated at $6 per household.
Argon assumed at $20,000 for the first year, with a 10% growth rate.
Maintenance assumed at 10% of equipment cost.
Rent assumed at $1,600/month plus 50% utilities.

Table 16. Sensitivity Model 2 Projected Operating Expenses

	Dec-16	Dec-17	Dec-18
Advertising	$100,000	$50,000	$50,000
Shipping & Delivery	$62,500	$62,500	$62,500
Total Adv./Delivery Costs ($)	*$162,500*	*$112,500*	*$112,500*
Management Salaries	$100,000	$100,000	$100,000
Office Salaries	$50,000	$50,000	$50,000
Accreditation Fees	$30,000	$30,000	$30,000
Office Expenses	$2,000	$2,000	$2,000
Insurance	$15,000	$15,000	$15,000
Bank Charges	$10,000	$10,000	$10,000
Interest on L.T.D.	$35,000	$35,000	$35,000
Total Admin. Expenses ($)	*$242,000*	*$242,000*	*$242,000*
TOTAL EXPENSES ($)	**$404,500**	**$354,500**	**$354,500**
EXPENSES (%)			
Advertising	24.7%	14.1%	14.1%
Shipping & Delivery	15.5%	17.6%	17.6%
Total Adv./Delivery Costs (%)	*40.2%*	*31.7%*	*31.7%*
Management Salaries	24.7%	28.2%	28.2%
Office Salaries	12.4%	14.1%	14.1%
Accreditation Fees	7.4%	8.5%	8.5%
Office Expenses	0.5%	0.6%	0.6%
Insurance	3.7%	4.2%	4.2%
Bank Charges	2.5%	2.8%	2.8%
Interest on L.T.D.	8.7%	9.9%	9.9%
Total Admin Expenses (%)	59.8%		

▼

Initial marketing campaign introducing new service in first year. Reduced in subsequent years.

Interest assumed at 10%. $350,000 guaranteed government loan for initial equipment purchase.

Shipping assumed at $10 per sample.

The income statement for Sensitivity Model 2 shown in Table 17 shows a negative balance of expenses over income in the first year. However, forecasted growth shows a minor profit in the second year. Based on the volume of tests assumed in this model, a price per test of $117.98 would be required to break even in the first year. Since this model does not include taxes, this could only be achievable given a complete tax credit. It is also important to note that this model is again based on a situation where testing has been prescribed as mandatory.

Table 17. Sensitivity Model 2 Projected Income Statement

	Dec-16	Dec-17	Dec-18
Total Revenue	$640,625	$704,688	$775,158
Total Expenses	$332,900	$338,650	$344,978
Gross Profit	*$307,725*	*$366,038*	*$430,180*
Revenue Expenses	$162,500	$112,500	$112,500
Admin Expenses	$242,000	$242,000	$242,000
Total Expenses	*$404,500*	*$354,500*	*$354,500*
OPERATING PROFIT	**-$96,775**	**$11,538**	**$75,680**

Business Model: Sensitivity Model 3

Sensitivity Model 3 is based on the introduction of a water quality monitoring service without any regulatory support. In this instance, sample submission will be voluntary. Three-year revenue projections for Sensitivity Model 3 are shown in Table 18. Given the voluntary nature of sample submission, 1000 samples are assumed to be submitted in the first year, and this number represents a worst case scenario. A 10% growth rate for the first three years is projected given that news of the service will spread via word of mouth and public education campaigning. As in the preceding models, the price for a full suite of testing is set at $100, based on support for this price in interviews with private well owners. Furthermore, a service of individual parameter monitoring is offered to residents who require additional testing, more often than the biennial schedule, due to a known problem with a particular contaminant. The price for this service is set at $25, and the volume of testing is assumed at 10% of clients. Based on assumed volumes, well water chemistry analysis represents 97.6% of revenue activities, with individual parameter monitoring rounding out the remaining 2.4%. Quality control testing is not included in these testing volumes.

Table 18. Sensitivity Model 3 Projected Revenue

SALES ACTIVITIES	Dec-16	Dec-17	Dec-18
Well water chemistry analysis	$100,000	$110,000	$121,000
Individual Parameter Monitoring	$2,500	$2,750	$3,025
TOTAL SALES ($)	**$102,500**	**$112,750**	**$124,025**
SALES ACTIVITIES (%)			
Well water chemistry analysis	97.6%	97.6%	97.6%
Individual Parameter Monitoring	2.4%	2.4%	2.4%

ASSUMPTIONS REGARDING SALES
Scenario is based on voluntary sample submission and assumes 1000 sample submissions in the first year. Assumes 10% growth in samples per year, based on word of mouth and public health information campaigns.
$100 per testing suite.
Individual Parameters refers to clients with known risk to specific contaminant, requiring specific testing. Estimated at 10% of clients. $25 per parameter.

Expenses for Sensitivity Model 3 are presented in Tables 19 and 20. As this scenario assumes a 10% growth rate in samples tested each year, material costs grow proportionately over the three-year projection. One of each instrument is required to meet capacity. A three-year straight-line depreciation of analytical equipment is assumed. Initial marketing funding is included as a roll-out of the service, and then reduced in subsequent years. Direct labour wages is based on requiring two laboratory technicians at $60,000 per year. General Inflation and taxes are not included in this model. Expenses for maintenance, rent, utilities, shipping, interest as well as human resources are all assumed and elaborated on in the notes on financial statements.

Table 19. Sensitivity Model 3 Projected Expenses

	Dec-16	Dec-17	Dec-18
Analytical Equipment Purchase	$115,100	$115,100	$115,100
Sample Bottles	$6,000	$6,600	$7,260
Argon	$2,000	$2,200	$2,420
Total Material Costs ($)	*$123,100*	*$123,900*	*$124,780*
Direct Labour Wages	$120,000	$120,000	$120,000
Repairs & Maintenance	$11,500	$11,500	$11,500
Rent / utilities	$28,800	$28,800	$28,800
TOTAL EXPENSES ($)	**$283,400**	**$284,200**	**$285,080**
EXPENSES (%)			
Analytical Equipment Purchase	40.6%	40.5%	40.4%
Sample Bottles	2.1%	2.3%	2.5%
Argon	0.7%	0.8%	0.8%
Total Material Costs (%)	*43.4%*	*43.6%*	*43.8%*
Direct Labour Wages	42.3%	42.2%	42.1%
Repairs & Maintenance	4.1%	4.0%	4.0%
Rent / utilities	10.2%	10.1%	10.1%
TOTAL EXPENSES (%)	**100.0%**	**100.0%**	**100.0%**

▼ ASSUMPTIONS REGARDING EXPENSES

3 year straight-line depreciation of analytical equipment assumed.
Sample bottles estimated at $6 per household.
Argon assumed at $2,000 for the first year, with a 10% growth rate.
Maintenance assumed at 10% of equipment cost.
Rent assumed at $1,600/month plus 50% utilities.

Table 20. Sensitivity Model 3 Projected Operating Expenses

	Dec-16	Dec-17	Dec-18
Advertising	$100,000	$50,000	$50,000
Shipping & Delivery	$10,000	$11,000	$12,100
Total Adv./Delivery Costs ($)	*$110,000*	*$61,000*	*$62,100*
Management Salaries	$100,000	$100,000	$100,000
Office Salaries	$50,000	$50,000	$50,000
Accreditation Fees	$30,000	$30,000	$30,000
Office Expenses	$2,000	$2,000	$2,000
Insurance	$15,000	$15,000	$15,000
Bank Charges	$10,000	$10,000	$10,000
Interest on L.T.D.	$35,000	$35,000	$35,000
Total Admin. Expenses ($)	*$242,000*	*$242,000*	*$242,000*
TOTAL EXPENSES ($)	**$352,000**	**$303,000**	**$304,100**
EXPENSES (%)			
Advertising	28.4%	16.5%	16.4%
Shipping & Delivery	2.8%	3.6%	4.0%
Total Adv./Delivery Costs (%)	*31.3%*	*20.1%*	*20.4%*
Management Salaries	28.4%	33.0%	32.9%
Office Salaries	14.2%	16.5%	16.4%
Accreditation Fees	8.5%	9.9%	9.9%
Office Expenses	0.6%	0.7%	0.7%
Insurance	4.3%	5.0%	4.9%
Bank Charges	2.8%	3.3%	3.3%
Interest on L.T.D.	9.9%	11.6%	11.5%
Total Admin Expenses (%)	68.8%		

Initial marketing campaign introducing new service in first year. Reduced in subsequent years.

Interest assumed at 10%. $350,000 guaranteed government loan for initial equipment purchase.

Shipping assumed at $10 per sample.

Table 21. Sensitivity Model 3 Projected Income Statement

	Dec-16	Dec-17	Dec-18
Total Revenue	$102,500	$112,750	$124,025
Total Expenses	$283,400	$284,200	$285,080
Gross Profit	*-$180,900*	*-$171,450*	*-$161,055*
Revenue Expenses	$110,000	$61,000	$62,100
Admin Expenses	$242,000	$242,000	$242,000
Total Expenses	*$352,000*	*$303,000*	*$304,100*
OPERATING PROFIT	**-$532,900**	**-$474,450**	**-$465,155**

The income statement for Sensitivity Model 3 shown in Table 21 shows a model that is not profitable. As can be seen, this level of testing demand does not present a viable scenario without considerable financial support from government, or a much higher price per testing suite. For example, based on the assumptions of this sensitivity model, to break even in the first year would require a price of $635.40 per complete testing suite.

Discussion

The discussion will first elaborate on the business model with notes on the financial statements, and will then explore several of the broader issues raised from the analysis of the interviews and the construction of the model.

Technical Equipment Requirements

A key aspect, of establishing a water quality monitoring service, is a laboratory outfitted with the equipment necessary to perform the full suite of tests required to ensure safe drinking water. It should be noted, that there are many approaches to establishing a laboratory capable of testing well water samples, and the estimates presented in Table 9 and used in the sensitivity models are simply one such configuration, as shared by interview participants. Professionals will have their own experience to draw on which is valuable, but also inherently biased based on their own preferences and what equipment they have come to use.

Notes on Financial Statements

Sensitivity Models

Business models for establishing an appropriate water quality monitoring service help to create an initiative that both addresses the identified risk, and examines sustainability. These models are based on offering a service that addresses the barriers and challenges identified from the interview portion of this thesis.

In Sensitivity Model 1, a best case scenario is assumed where all well owners in the province participate in biennial testing. While this model shows a profitable venture, that is easily financially sustainable, with profits of $1.2 million in the first year, this is assuming full compliance, and would likely require a strongly enforced legislative mandate. However, the exact mechanism of this enforcement and associated costs are not explored. While the ideal in terms of creating a financially sustainable service, this is generally considered unlikely and unrealistic given logistical considerations such as the current political climate, and other challenges mentioned above, like cost for low income families and complete adherence with the testing schedule.

In the case of Sensitivity Model 2, three year projections show a profit of $75,680 by year three, despite a year 1 deficit of $96,775. This change is based on an assumed growth rate of testing compliance of 10% per year, given word of mouth and general awareness of the testing service. This model is the reasonable case scenario and could likely be achieved in the province given legislative support to introduce mandatory testing, as well as public education on the service.

Finally, Sensitivity Model 3, which represents a worst case scenario, is not financially sustainable without considerable financial support, that would likely come from the provincial government, to make up for the projected deficit of $532,900 in the first year. While it is possible that this model could become viable over time with enough increase in public awareness, it is likely that this will take too long to be financially reasonable.

Pricing

When considering a public service, especially with regards to health, pricing is an important concern. Based on the interview data, in which 4 out of 5 residents felt that $100 was a reasonable cost for once a year testing, that price was used in the sensitivity models. The models are actually based around testing that occurs once every two years, so this cost is even less than that which was agreed to by interview participants. It is also important to consider the concern that the persons interviewed showed for other members of their communities with regards to cost, especially the elderly. Perhaps there can be some method of subsidization created with the provincial government for those individuals who cannot afford the testing if the price is set at $100.

Facilities

The centralized laboratory will require a facility from which to operate. For the purposes of this model, a facility was envisioned in a central location. The idea here being that it will be more convenient and perhaps cheaper for shipping from rural areas in the province. Rent is estimated at $2,000 a month based on prices in Grand Falls-Windsor. Utilities have been assumed at 20% of rent.

Accreditation

Accreditation is an important, but expensive process, required by the Department of Environment and Conservation for drinking water testing (DOEC, 2016c). Two accreditation bodies, the Canadian Association for Laboratory Accreditation (CALA, 2016) and the Standards Council of Canada (SCC, 2016), exist in Canada as options specific to laboratory accreditation. There is a substantial cost however associated with the initial accreditation process and continued annual fees. To maintain accreditation, laboratories must regularly be performing testing, and submit to periodic review from the accreditation body (SCC, 2015). Fees here are estimated at $30,000 a year, using the higher end of the estimate given in KI interviews.

Insurance

Commercial liability insurance is an important cost consideration when dealing with such an important aspect of individual health, and will represent a substantial cost.

Individual well owners will need to be able to rely on the report that they receive, and backing up these claims will require sufficient insurance coverage. Public liability insurance is estimated at $15,000 per year. This high estimate is based on the sensitive nature of ensuring public health and the reality that an error could have serious health consequences.

Human Resources

Staff is an important consideration for establishing and estimating laboratory costs. Based on the above model, the laboratory will require one director/manager level employee, one administrative assistant, and two laboratory technicians. One laboratory technician will be primarily responsible for health parameters and the ICP-MS, and the other will be primarily responsible for aesthetic and environmental parameters and ion chromatography. It will be important that the director have experience as a laboratory technician so as to fill gaps created by vacation, or sick time of the two laboratory technicians. The director will also be considered to take on the necessary quality control portfolio required for accreditation. The salary for the management position is estimated at $100,000 per year, the salary for each of the laboratory technicians is estimated at $60,000 per year, and the salary of the administrative assistant is estimated at $50,000 per year.

Shipping

Partnership with the existing Services NL delivery system as used by the Public Health Laboratory for bacteriological testing is an important part of the functionality of this model. A cost of $10 for sample based on either pick up, or shipping by bus or courier is factored into the forecasting. There is further opportunity for exploring partnerships with municipal governments in the province to help alleviate shipping costs, as well as aid in the testing schedule. For example, if all the tests from a given community are submitted at a single time, gathered and delivered by a municipal employee, greater organization and regulation of the testing schedule can be maintained. However, this partnership would not work for all wells in the province, as many are in unincorporated areas, and some municipalities may not have a sufficient employee base to take on additional responsibilities.

Marketing

In each of the above scenarios, marketing is an important part of service use. Advertisement of the service will help growth, and in sensitivity models 1 and 2, promote the new testing regulations. There is an important added benefit for public education and public awareness that should be considered when creating the advertising campaign. Issues with public education are addressed later in the discussion.

Laboratory Costs

Estimates of the cost of important laboratory supplies like argon and sampling bottles are included. The price of sampling containers ($6) is based on consultation with industry professionals and bulk ordering of snap tight sampling bottles, and the inclusion of a small ice pack for shipping.

Other Costs

Other costs like loan financing, banking charges, and office expenses are also included to help make the financial forecasts as realistic as possible. The interview results suggested a cost of $125 per invoice in terms of management fees, however this seems unreasonably high and is not validated as a competitive industry standard and may reflect that this company is not writing many invoices.

Broader Issues

Public Education

It is popular to believe in Canada that our water is safe and that the supply is unlimited. The public lacks understanding of potential risks from waterborne contaminants (Hexemer, 2002), procedures for proper testing (Jones et al., 2006), and of practices for proper well maintenance (Simpson, 2004). Potential campaigns through television, the internet, and delivered print media should be mounted to address the deficit of understanding surrounding water.

The core issue addressed in this thesis is the lack of testing for private water sources in the province of Newfoundland and Labrador. Regular water quality tests are not required, and there is no legislation requiring periodic confirmation of the safety of water supplies for the close to 50,000 private wells (DOEC, 2013). One study conducted in Ontario, by a Memorial University trained researcher, found that only 8% of respondents with private wells sought regular testing of their water (Jones et al., 2006). While some might argue that it is the prerogative of the well owner, not to avail of testing, one has to wonder if this decision is made with adequate understanding of the risks. Health Canada has established maximum acceptable concentration guidelines of potential contaminants for the safety of individuals. Although this decision was the prerogative of the individual well owner, one must also consider that the cost for treatment of these associated illnesses will be indirectly borne by the public through the public health care system in Canada. This may actually represent a hidden financial burden from water contaminants that had not previously been considered.

In the very least, a public education campaign around water quality, potential contaminants, and testing services available should be considered. The public will need to understand not just why water testing is important, but also what services are available for the public to use. If regulatory changes are introduced, these will also need to be explained to elicit compliance. Moreover, a well-conceived marketing plan would need to be partnered with the rolling out of any new services, to ensure adequate use and sustainability of the service.

While the key service gap is in the actual testing and monitoring services available, public education is another large problem. Understanding the distinct differences between the potential contaminants in the water, whether they are microbiological, inorganic, or chemical is complicated for a layperson. Furthermore, understanding the treatment methods available is even more challenging.

In one experiment in Southern Ontario, even when testing bottles were delivered to the door less than 50% of households responded (Hexemer et al., 2008). Despite the convenience provided by this study, the response rate was still low. This further emphasizes the need for a new approach to public education in Canada, and testifies to the public attitude that water quality is not a concern, despite evidence to the contrary in the literature (Ritter et al., 2002). If the public truly understood the potential health risks, better stewardship of private wells would certainly ensue (Kreutzwiser et al., 2011).

In Newfoundland and Labrador, a specific issue was found with available testing services. As mentioned previously, microbiological testing of drinking water is a service currently provided free of charge by the Public Health Laboratory and administered by the Department of Health and Community Services (Eastern Health, 2015). This service tests for total coliforms, using the *Colitag* testing system. Relatively inexpensive, at about \$6 a test, this protocol provides a presence/absence reading for total coliforms (Hydrodyne Systems, 2013). This public health laboratory was toured as part of the preparation of the thesis, and the testing process was outlined by one of the laboratory professionals working. A proprietary capsule is added to the sample bottle, and sample bottles are incubated overnight. The next day, sample bottles are compared with a control, looking for a yellow color in the water. If samples are at least as yellow, or more yellow than the control, coliforms are deemed to be present. Further testing is then required for the presence of *E.coli.* This is done through exposure to UV light and again, comparison with a control. In this instance, the comparison is for fluorescence. If sample bottles fluoresce at least as much or more than the control, then *E.coli* is determined to be present (Hydrodyne Systems, 2013). Figure 10 presents a flow chart of this testing procedure.

Results of these tests performed by the Public Health Laboratory are reported back to the individual well owner via a telephone system as well as a mailed out report (Eastern Health, 2015). Interpretation is also offered if necessary by a department of health officer or public health inspector at Service NL (Eastern Health, 2015). Interview results suggested some public misconception around the wording of these reports, and individuals felt that their water was safe to drink after public health laboratory testing. However, a full testing suite was not performed, and the drinking water is only known to be safe from total coliforms, as an indicator of recent fecal contamination. As a result of recent issues around this reporting language, the language of the report is in the process of being changed to offer more clarity of what that result means and what else is required to ensure safe drinking water. While this was primarily a problem in the report, at least in the sample interviewed, it had created an educational challenge that was misleading to the well owners.

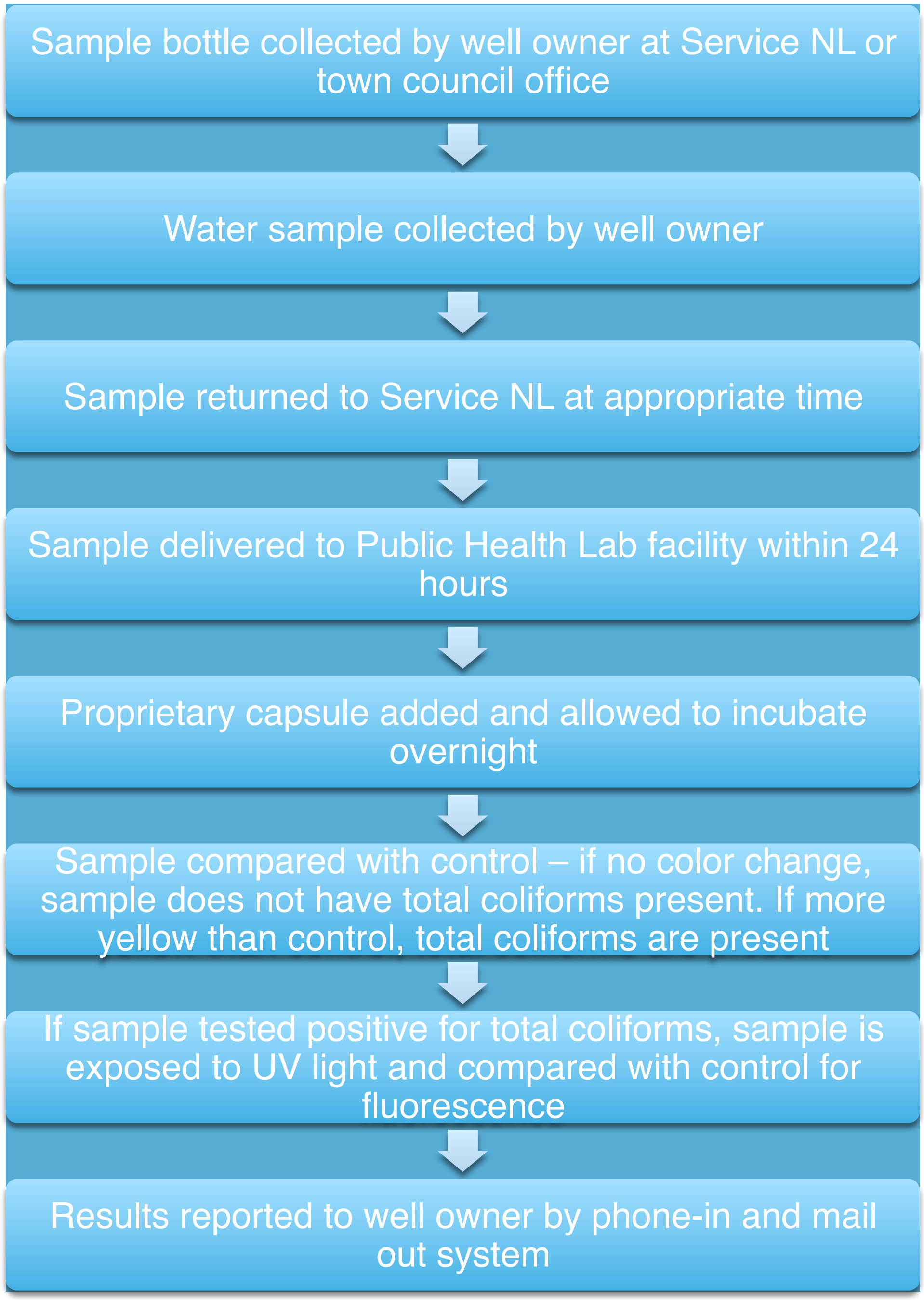


Figure 10. Summary of Colitag Testing Procedure in Newfoundland and Labrador

Age of Well Owners

Analysis of the interview data showed that many individuals interviewed were concerned for the seniors in their community. Reference was also made to the fixed incomes of senior citizens and the potential for a $100 charge for testing being cost prohibitive. As was mentioned in the notes to the financial statements, perhaps some kind of subsidy for low income-seniors could be developed to mitigate this issue.

Reliability

Sampling reliability is another potential issue in terms of providing adequate water quality monitoring service. As was shown in the interview results, nitric acid is required for immediate treatment before transport for chemical testing. This particular professional felt it was not appropriate to give this chemical out to just anyone.

Geography, Accessibility

Private wells are found primarily in rural parts of the province in local service districts (LSD's), or smaller municipalities where cost and geography prohibit the establishment and maintenance of public water supplies. Furthermore, rural houses are often farther apart than urban houses adding to the cost of providing water service to all houses in the community. This rural aspect of private wells in the province is a key dimension of the challenges faced when seeking to implement a water quality monitoring service that is both affordable and accessible.

Accessibility of testing services is another important issue. As mentioned, bacteriological testing (total coliforms and *E. coli*) is available to private well owners from the Public Health Laboratory (Service NL, 2013). The testing performed by the Public Health Laboratory considers total coliforms, and fecal coliforms, which are the most pressing, immediate concern for sickness (Health Canada, 2014b). However, this test has only examined the water for evidence of microbiological risk, and there are many more parameters that should be monitored to ensure safety from chemical and physical parameters. To avail of these physical and chemical tests, the Department of Environment and Conservation recommends residents seek the nearest accredited laboratory (DOEC, 2013). The DOEC website lists four laboratories, however only two of these are in the province, and these are concentrated in the St. John's area (DOEC, 2016d). Accessibility of these laboratories because of the province's geography is a potential issue for residents.

Rural Newfoundland and Labrador covers a large landmass, and communities are spread out, often several hours drive from major centers. This distribution of communities creates a very real challenge when attempting to gather water samples and deliver these for analysis. Many town offices will stock sampling packages, including bottles and instructions to avail of the currently provided microbiological testing service. These sample bottles can be returned to certain Service NL centers for delivery to the Public Health Laboratory for testing. Even with this extended delivery network, the nearest Service NL office is often several hours drive away from the homes of the individual well owners.

Labrador

Labrador presents a unique set of challenges and costs when providing water quality monitoring service, including collection and delivery of samples. The business projections of this thesis include an assumed shipping cost of $10 per sample. Depending on service uptake in Labrador, this may be an insufficient estimate, and shipping costs will need to be readdressed. Greater distance to Service NL centers, or other collection sites may prove an additional challenge in recruiting service uptake.

Results Reporting

Results of water tests performed must ultimately be delivered to the individual well owner. As previously mentioned, water quality reports, and the intimate understanding of the associated risks from specific contaminants is a complex issue. Explanation of various contaminants, as well as the associated health risks is often necessary, not to mention discussing water treatment options and how to address the identified issue. Therefore, the responsibility for the interpretation of the results and recommendations made thereafter is an important question. In addition to the challenges with interpretation, there are also challenges with the delivery of reports. Possible delivery options include traditional mail, a phone-in retrieval system, personalized telephone delivery and reports delivered over the internet. Traditional mail may seem the obvious choice but there are postal costs associated with this as a widespread policy. A phone-in retrieval system would avoid postal costs, but this may not be a practical delivery system in terms of user understanding, because of the lengthy list of parameters tested. Personalized phone calls delivering the results are perhaps the most expensive solution, though these phone calls could include interpretation services as well. Likely, an internet-based system will be the most cost-effective and prompt way to deliver information. However, not all residents of rural Newfoundland and Labrador, especially the elderly, have access to the internet. In the event of water tests that show a supply to be toxic and an immediate danger to the consumer, such as when *E.coli* presence is found, internet delivery should be supplemented with some phone calls to the most at risk homes, because of the immediate need to stop water consumption.

In situations of known contamination, residents are counselled to speak with a department of health officer or public health inspector at Service NL with regards to any health concerns from drinking water (Eastern Health, 2015). The introduction of more testing to individuals may represent a considerable increase in workload for these officials. In the event that a chemical water quality monitoring service is initiated, partnership with the DHCS to provide adequate interpretation services should be pursued, so as to be prepared to adequately meet demand. This will likely require a capacity expansion on the part of the DHCS, especially in the case of time sensitive test results. It is essential from a public health perspective that any residents with unsatisfactory test results be notified immediately of this result, and advised to discontinue consumption of the contaminated water because of the health risk. The cost for interpretation of results has not been included in the sensitivity models in this thesis.

Laboratory Administration

Any of the models described above could be a public or private venture. However, well owners interviewed stated they would prefer the laboratory be administered by the public sector. Reasons given included trust, access to resources and a belief that a publicly administered laboratory would not be profit driven and therefore trying to color information to increase sales of water treatment systems. This would suggest that if a water quality monitoring service is to be implemented, the provincial government should take the lead.

Private Sector

Each of the above scenarios could be mounted as a solution from the private sector. Allowing the private sector to take the lead in establishing new testing facilities could be appealing from a governmental perspective. For starters, if the laboratory is publicly funded, the expectation may be that the service is available free of charge, or at low cost. Private laboratories, as a business will be assumed to have some cost associated with the service.

There are considerable challenges offered by the private sector approach. For starters, private testing facilities currently exist in the province and are not used to their full extent. Furthermore, water quality testing is a complicated venture, and issues with public education and results reporting have already been discussed.

Public trust is another key issue surrounding the private sector approach. Will the public have enough faith in a privately funded laboratory to utilize the service? Interviews in this thesis showed some well owners think businesses are just out to make money. More widespread use of testing is key in guaranteeing the safety of the water supply and protecting public health.

The cost of private tests might also be a deterrent. As Sensitivity Model 3 shows, a full gamut of water tests could cost up to $635.40 just to recoup costs, if only 1000 tests per year are performed. Convenience and cost must both be considered in a solution that is affordable.

Public Sector

A government led, publicly administered laboratory will overcome potential barriers of trust with the general public, based on the small sample of interviews conducted in this study. One option is a totally publicly funded model in which testing is provided free of charge to residents. This will ensure the greatest compliance, and would also work well in conjunction with introducing legislation requiring regular water quality monitoring. An alternative is a publicly funded system that works in conjunction with a partial cost recovery model, for example, using the price of $100 per test that the sensitivity models in this thesis use. This would be similar to the model currently working in New Brunswick. Affordable testing services could be provided in this way, as means of a compromise and making a water quality monitoring service that is more economical for the government and providing a sustainable solution.

Mobile Collection Unit

A mobile collection unit would ensure reliability of sampling, as trained professionals take the samples, and was a suggestion that came forth from a municipal representative in an interview. One can imagine this would ensure greater use of testing service, as the onus is not on individual well owners to remember to have to submit samples for testing. While the convenience for the individual well owner is another aspect of value added by this collection unit, it was not included in the sensitivity models, because initial calculations suggested this notion would be cost prohibitive, and quite complicated. Further exploration of a mobile collection unit model is an opportunity for further research.

Partnerships

It cannot be ignored that infrastructure for some water testing service already exists in the province, as has already been discussed. Microbiological testing is currently performed by the Public Health Laboratory of the Department of Health and Community Services, and this service should continue as part of complete water quality monitoring. An important partnership will see any new additional service building on this already existing testing network. Promotion of water testing could ensure more widespread testing of important microbiological parameters in the province as well.

Furthermore, an existing delivery system for bacteriological testing exists in the province. Residents can deliver water samples to Service NL offices, and pickups are made to get these samples to the nearest Public Health Laboratory (Eastern Health, 2015). A partnership with Service NL would capitalize on an existing delivery network, and provide residents with a more convenient drop off location, though it is noteworthy that many rural communities are still several hours drive from the nearest Service NL Office.

Partnering with the Department of Environment and Conservation to perform municipal tests is an important area of long-term growth for the water quality monitoring service. Currently, the province of Newfoundland sends water samples to a private laboratory in Ottawa for testing (Sarkar et al., 2012). There is potential for cost reduction, specifically because of expensive time sensitive shipping, if these tests were to be performed within the province of Newfoundland and Labrador. Exploring the specifics of this cost reduction is another opportunity for further research.

Another important partnership to consider is town councils. As the KI interviews with municipal officials suggested, a recurring theme was the issue of public education and public trust. In areas where town councils exist, partnerships with these representatives will provide a means of interaction with residents from someone they already know and trust. Water testing is a complicated suite of parameters, and to ensure public trust and utilization of the service for the benefit of their health, residents must trust the information they are receiving.

Groundwater Profiling

The installation of a water quality monitoring service provides an opportunity for more than just the improved health of individual well owners. Currently, water quality profiling of private wells for physical and chemical parameters is not performed. The establishment of an in-province facility like the one posed in this study provides the opportunity to begin a systematic cataloguing of water quality tests for private wells in the province. Such a dataset will be able demonstrate long-term trends in the environment in the province. Similar data is recorded in other jurisdictions, for example New Brunswick (New Brunswick Department of Environment, 2008). While maps exist outlining general areas of risk for exposure to arsenic, fluoride and uranium, (DOEC 2016a; 2016b; 2016f) these are incomplete, as one community based study found high levels of arsenic in an area outside of the DOEC map (Sarkar et al., 2012). There will be value for government in terms of environmental and public health data, as well as a valuable source of information for researchers.

Legislative Implications

The risk assessment portion of this research has shown a possible list of adverse health outcomes as a result of exposure to drinking water contaminants. These illnesses represent a potential contribution to health care costs that requires further examination and data to fully understand. Biennial testing of private water supplies for example would be an improvement on the current practices and would provide data which could be further analyzed to understand this potential problem.

Leadership on this kind of issue is necessary for the introduction of a water quality monitoring service to be successful. A strong mandate from the government requiring testing would send a message to residents that clean drinking water is important. As Sensitivity Model 2 suggests, a strong government mandate requiring testing of private well water may result in enough service uptake to have a financially sustainable service. Ultimately, this would be one of the fastest catalysts at improving public education around drinking water quality and health.

New Brunswick Analytical Services Laboratory

When compared with Newfoundland and Labrador, New Brunswick is the larger of the two provinces, with a population of about 750,000 compared to the population of around 500,000 people in Newfoundland and Labrador (Statistics Canada, 2013). It is estimated that one-fifth of the population of Newfoundland and Labrador is serviced by private wells (n=100,000) (Guzzwell, 2001), while two-fifths of the population of New Brunswick is serviced by private wells (n=300,000) (Pupek, 2000). The provinces also are similar in that there are few private laboratories performing drinking water testing.

New Brunswick provides a model of a publicly funded laboratory, with a partial cost recovery model. This hybrid system provides a service that is more affordable for both residents and government. The result is a laboratory that presumably has a higher level of public trust, because it is both backed by the reputation of the New Brunswick government and CALA accredited. Further examination of this model should be used to guide consideration of potential services in Newfoundland and Labrador.

Value is added to the service performed in New Brunswick by the New Brunswick Groundwater Chemistry Atlas (New Brunswick Department of Environment, 2008). This online resource catalogues important information on groundwater wells in the province including location and depth. The database also includes water chemistry profiling of 28 parameters. The visual representation of test results on a map is of great value to public health, as one can see where issues exist with groundwater contamination and track available water quality data. There are also further benefits to industry, which can make similar use of this information. This record of water quality tests also provides a valuable baseline for comparison over time. There are maps available in Newfoundland and Labrador estimating areas of risk for exposure to arsenic, fluoride and uranium (DOEC 2016a; 2016b; 2016f). However, these maps are limited in that community focused research has found areas of arsenic contamination outside of these predictive maps (Sarkar et al., 2012). These maps are further restricted in that they only refer to 3 potential contaminants.

Limitations

On undertaking this research project, the author felt strongly motivated to produce a model that was viable and affordable and to prove that change could be made. Perhaps this bias can be attributed to a certain level of naivety in the junior researcher. While this fervour does not provide particular scientific value, what does provide value is the exploration of potential solutions surrounding an issue, as well as a critical evaluation of the limitations of that exploration. The following section critically addresses several of these limitations.

Limitations: Health Risks Literature Review

In many cases, the literature is still being developed with respect to specific health risks from exposure to low levels of contaminants. Specifically, there is a paucity of data on the risks of long-term exposure to low levels of chemicals from drinking water. Many confounders that cannot be eliminated limit retrospective studies and ecological studies. Much of the data comes from exposure in animal models, however these too are limited by the differing physiology, and the duration of exposure. These limitations present an opportunity for future research. We must also consider that in the cases of home drinking water, individuals are at risk of exposure to contaminants over a prolonged period of time, potentially their entire life. Given that many diseases are multifactorial, exposure to contaminants from drinking water may be contributing to the development of that disease.

Limitations: Sample Size

One of the chief limitations of this research is the small sample size of the interviews. This is a reality of the scope of the project and the funding and time constraints. The themes extracted from the interviews are high-level, and conversational pieces that came from the interviews. There is room for further research to see if these themes are reproducible from a statistically significant perspective. In the interim, based on what could be achieved, they provide a glimpse into what people of the province as well as related officials are thinking and helped to inform the initial explorations of this study. Furthermore, the purposive sampling method has a certain level of bias inherently built in, because participants are not collected at random, and the researcher's judgement is used in determining who to approach about conducting interviews.

Limitations: Proxy Model

There are some limitations associated with the proxy model and estimating public health risk. Public supply source water data is used in place of private supply source water tests because this is the best available information. This emphasizes the need for water quality monitoring of private water supplies, so as to ensure an acceptable level of risk to public health. The population calculations of the model are also based on census data that is averaged for the entire province, on the assumption that one well serves one household. Given the presence of community wells that often serve multiple families, this estimation might actually present a figure less than the actual number of people at risk.

Another limitation is from the health risks potentially associated with exposure to the identified contaminants. The Health Canada Guideline values are based on risks from prolonged exposure to the contaminant at that concentration. The public test results used are for groundwater source tests before any treatment facility is reached. While many test results were found at contaminant levels, subsequent tests did fall within acceptable parameters. It is not known if this is because of temporal variation, potential laboratory error, or perhaps from intervention on the parts of the towns administering the water supplies. More research should be done to quantify and further understand any interventions taken. The real concern presented by this data is to residents of the province drinking ground source water from their private well. Since these water supplies are not tested for physical or chemical parameters, it is not known whether this water is safe to drink. Given that most private well owners do not have expensive water treatment systems installed at home, especially for physical and chemical parameters, it is reasonable to assume that these numbers represent a proxy for the potential risk to private well owners in the province.

Limitations: Continued Testing Compliance

A limitation of this model is an inability to predict well owner compliance over time. While the sensitivity models forecast financial statements based on three assumed volumes of tests submitted, it is difficult to make predictions with certainty over time. For example, if a well owner has two consecutive tests that do not show any chemical contaminants, will they perceive value in continued testing and continue to use the water quality monitoring service? While the evidence from the literature review portion of this thesis suggests the possibility for temporal variation in chemical concentrations in drinking water, it is difficult to say what effect this will have on the behavior of individual well owners. The danger is that well owners who took part in the initial uptake of the service may not continue to utilize the water testing service and this could affect the sustainability of the service.

Recommendations and Conclusion

Through this mixed methods approach study two main objectives have been accomplished to explore issues around an important service gap in the province of Newfoundland and Labrador. First, the public health risk is articulated as best as possible given the available data. Quantitative methods, including a proxy model of the risk to public health identifies the public health risk in the province. Second, models for the establishment of water quality monitoring service, and specifically a water testing laboratory are explored. Qualitative information has suggested themes that illustrate the demand for the service, as well as potential barriers to overcome. Quantitative information, including high-level financial models further illustrates a business approach to the service gap currently existing.

The proxy model created shows a public health risk in the province of Newfoundland and Labrador. This model finds 4,450 wells and 10,680 people at risk for exposure to levels of arsenic in excess of MAC's, 5,850 wells and 14,040 people at risk of exposure to levels of lead in excess of MAC's, and 2,000 wells and 4,200 people at risk for exposure to barium, cadmium, chromium, mercury or selenium. In total, this model shows 5% of the province's population at risk of exposure to chemical drinking water contaminants. This is a theoretical risk that has potential financial implications for the cost of treatment and disease. Public water supplies are monitored and have mechanisms in place to ensure public safety. Engineering solutions exist to remove contaminants from private household water supplies, however, because of a lack of data, these measures are not taken. With increased risk for cancer, cardiovascular disease, kidney damage, diabetes, neurological damage and developmental disorders, quality of life for residents of primarily rural parts of the province is a potential issue. These risks are avoidable.

Interviews conducted with private well owners, government representatives, health professionals and laboratory professionals suggested several barriers and challenges to be overcome if water quality monitoring service were to be established in Newfoundland and Labrador - these can be summarized from two perspectives. From the perspective of well owners, these barriers include but are not limited to cost, accessibility, trust of the service, well owner age and public education. While from the laboratory operator perspective further barriers are administrative costs, maintenance, geography and invoice lag time.

The barriers and challenges identified in this study for water quality monitoring for private well owners in the province of Newfoundland and Labrador lead to a key recommendation. A new approach to public education should be explored to raise awareness of the importance of water quality monitoring, as well as potential health risks from exposure to drinking water contaminants. Potential exposure to chemical contaminants in drinking water poses a possible health risk to residents of Newfoundland and Labrador. As our understanding of the multifactorial nature of disease develops, further appreciation of exactly what role this risk plays will develop. Analysis of any public health issue must be done with consideration of the limited amount of resources able to be devoted to public health. There may be value in doing a cost benefit analysis of a private well water testing facility relative to the risk posed by other public health issues, such as smoking cessation, the prevention of diabetes and hypertension, mental health issues and preventing the spread of communicable disease.

The high-level business models explored to establish a centralized water quality monitoring facility include considerations of the identified challenges in interviews, the facility costs, the laboratory equipment required, maintenance, staff required, supply costs and accreditation costs. Three sensitivity models were used to outline different potential testing volumes, based on theoretical scenarios. These show potential profits and losses based on various assumed testing samples per year. In Sensitivity Model 1, where all private wells are assumed to be tested on a biennial schedule giving a testing volume of 25,000 samples per year, a price per test of $53.43 would be required to break even. In Sensitivity Model 2, where 25% of private well owners participate in the biennial testing program giving a testing volume of 6,250 samples per year, a price of $117.98 per test is required to break even. Finally, in Sensitivity Model 3, where a testing volume of 1000 samples per year is assumed, a price of $635.40 per test would be required to break even. A complete water testing facility in the province of Newfoundland and Labrador is possible if these costs can be met, whether it be through charging these prices to the residents, covering the cost fully by the provincial government, or some sort of subsidy combination but a cost benefit analysis will be required

Ensuring safe and clean drinking water for public health is an important concern and a commitment of the provincial government. The business strategy presented explores potential solutions to this service gap. However, it is unlikely that this venture will be viable without support from government. This support could be regulatory, in the form of requiring residents to perform water quality monitoring tests, or it could be financial and subsidize the deficit forecasted by the financial model. Furthermore, partnerships should be explored to include municipal governments to aid in sample delivery, and to help provide a testing schedule that is manageable for the laboratory. If all samples are gathered and delivered together from a given community, based on a predetermined testing schedule, then substantial cost savings can be made.

Water is essential to life. Complete and regular testing should be done for all sources of contamination, inorganic or microbial. In the coming years, fresh water will globally be one of the most valuable natural resources, and the time is now to take action to ensure and protect our supply, for the health of the residents of Newfoundland and Labrador.

References

Abhyankar, L. N., Jones, M. R., Guallar, E., & Navas-Acien, A. (2012). Arsenic exposure and hypertension: A systematic review. *Environmental Health Perspectives, 120*(4), 494-500. doi:10.1289/ehp.1103988; 10.1289/ehp.1103988

Agency for Toxic Substances and Disease Registry (ATSDR) (1999). Toxicological profile for mercury. U.S. Department of Health and Human Services Public Health Service. Retrieved from http://www.atsdr.cdc.gov/tfacts46.pdf. Accessed on 1 August 2014.

Agency for Toxic Substances and Disease Registry (ATSDR) (2003). Toxicological profile for selenium. U.S. Department of Health and Human Services Public Health Service. Retrieved from http://www.atsdr.cdc.gov/tfacts92.pdf. Accessed on 1 August 2014.

Agency for Toxic Substances and Disease Registry (ATSDR) (2007). Toxicological profile for arsenic (update). U.S. Department of Health and Human Services Public Health Service website. Retrieved from http://www.atsdr.cdc.gov/tfacts2.pdf. Accessed on 1 August 2014.

Agency for Toxic Substances and Disease Registry (ATSDR) (2007). Toxicological profile for barium and compounds (update). U.S. Department of Health and Human Services Public Health Service. Retrieved from http://www.atsdr.cdc.gov/toxfaqs/tfacts24.pdf. Accessed on 1 August 2014.

Agency for Toxic Substances and Disease Registry (ATSDR) (2007). Toxicological profile for lead (update). U.S. Department of Health and Human Services Public Health Service. Retrieved from http://www.atsdr.cdc.gov/tfacts13.pdf. Accessed on 1 August 2014.

Agency for Toxic Substances and Disease Registry (ATSDR) (2012). Toxicological profile for cadmium. U.S. Department of Health and Human Services Public Health Service. Retrieved from http://www.atsdr.cdc.gov/toxfaqs/tfacts5.pdf. Accessed on 1 August 2014.

Agency for Toxic Substances and Disease Registry (ATSDR) (2012). Toxicological profile for chromium. U.S. Department of Health and Human Services Public Health Service. Retrieved from http://www.atsdr.cdc.gov/toxfaqs/tfacts7.pdf. Accessed on 1 August 2014.

Avery, G. (2000). Outsourcing Public Health Laboratory services: A blueprint for determining whether to privatize and how. *Public Administration Review*, *60*(4), 330-337.

Bakker, K. (July 2009). Water security: Canada's challenge. *Policy Options.* Retrieved from http://www.irpp.org/en/po/canadas-water-challenges/water-security-canadas-challenge. Accessed on 15 July 2016.

Bellinger, D. C., Stiles, K. M., & Needleman, H. L. (1992). Low-level lead exposure, intelligence and academic achievement: A long-term follow-up study. *Pediatrics, 90*(6), 855-861.

Boucher, O., Jacobson, S. W., Plusquellec, P., Dewailly, E., Ayotte, P., Forget-Dubois, N., . . . Muckle, G. (2012). Prenatal methylmercury, postnatal lead exposure, and evidence of attention deficit/hyperactivity disorder among Inuit children in arctic Quebec. *Environmental Health Perspectives, 120*(10), 1456-1461. doi:10.1289/ehp.1204976; 10.1289/ehp.1204976

Bräuner, E. V., Nordsborg, R. B., Andersen, Z. J., Tjønneland, A., Loft, S., & Raaschou Nielsen, O. (2014). Long-term exposure to low-level arsenic in drinking water and diabetes incidence: a prospective study of the diet, cancer and health cohort. *Environmental Health Perspectives*, *122*(10).

Brigham, E., Ehrhardt, M., Gessaroli J., and Nason, R. (2017). Financial Management: Theory and Practice (Third Canadian Edition). Toronto: Nelson Education.

Cabrera, H. N., & Gomez, M. L. (2003). Skin cancer induced by arsenic in the water. *Journal of Cutaneous Medicine and Surgery, 7*(2), 106-111. doi:10.1007/s10227-002-0139-9

Calderon, J., Navarro, M. E., Jimenez-Capdeville, M. E., Santos-Diaz, M. A., Golden, A., Rodriguez-Leyva, I., . . . Diaz-Barriga, F. (2001). Exposure to arsenic and lead and neuropsychological development in Mexican children. *Environmental Research, 85*(2), 69-76. doi:10.1006/enrs.2000.4106

Canadian Association of Laboratory Accreditation (CALA) (2013). CALA Directory of Laboratories*.* Retrieved from http://67.22.232.63/index.php

Canadian Association of Laboratory Accreditation (CALA) (2015). CALA Program Description. Retrieved from http://www.cala.ca/P02-01-English_Prog_Desc.pdf

Canadian Association of Laboratory Accreditation (CALA) (2016). Quality Assurance. Retrieved from http://www.cala.ca/. Accessed 2 August 2016.

Canadian Institute for Health Information (CIHI) (2014). Patient Cost Estimator. Retrieved from http://www.cihi.ca/cihi-ext-portal/internet/en/documentfull/spending+and+health+workforce/spending/pce_application. Accessed on 15 July 2014.

CBC News (17 May 2010). Inside Walkerton. Retrieved from http://www.cbc.ca/news/canada/inside-walkerton-canada-s-worst-ever-e-coli-contamination-1.887200. Accessed on 2 August 2016.

Celik, I., Gallicchio, L., Boyd, K., Lam, T. K., Matanoski, G., Tao, X., . . . Alberg, A. J. (2008). Arsenic in drinking water and lung cancer: A systematic review. *Environmental Research, 108*(1), 48-55. doi:10.1016/j.envres.2008.04.001; 10.1016/j.envres.2008.04.001

Chapman, R. J. (2015). Simple Tools and Techniques for Enterprise Risk Management (2nd Edition). Wiley Finance: Chichester.

Chowdhury, S., Rodriguez, M. J., & Sadiq, R. (2011). Disinfection by-products in Canadian provinces: associated cancer risks and medical expenses. *Journal of Hazardous Materials*, *187*(1), 574-584.

Conservation Corps Newfoundland and Labrador (CCNL) (2013). Water Testing. Retrieved from http://www.ccnl.ca/wellaware/water-testing.php. Accessed on 2 August 2016.

Cummins, S. K., & Goldman, L. R. (1992). Even advantaged children show cognitive deficits from low-level lead toxicity. *Pediatrics, 90*(6), 995-997.

David, F., & David, F. R. (2017). Strategic Management: A Competitive Advantage Approach, Concepts and Cases. Boston: Pearson.

Dawe, P. (2006). A statistical evaluation of water quality trends in selected water bodies of Newfoundland and Labrador. *Journal of Environmental Engineering and Science, 5*(1), 59-73. doi:10.1139/s05-019

Department of Environment and Conservation (DOEC) (2009). Giardia (Beaver Fever). Retrieved from http://www.health.gov.nl.ca/health/publichealth/envhealth/giardia_2009.pdf. Accessed on 2 August 2016.

Department of Environment and Conservation (DOEC) (2012). Drinking Water Safety in Newfoundland and Labrador Annual Report. Retrieved from http://www.env.gov.nl.ca/env/waterres/reports/drinking_water/annual_report_2012.pdf. Accessed on 24 April 2016.

Department of Environment and Conservation (DOEC) (2013). Chemical and Physical Monitoring. Retrieved from http://www.env.gov.nl.ca/env/waterres/regulations/policies/physical_monitoring.html. Accessed on 2 August 2016.

Department of Environment and Conservation (DOEC) (2014). Disinfection By-Products (DPB's). Retrieved from http://www.env.gov.nl.ca/env/waterres/quality/drinkingwater/DBPs.html. Accessed on. Accessed on 20 July, 2014.

Department of Environment and Conservation (DOEC) (2014). Newfoundland and Labrador Water Resources Portal. Retrieved from http://maps.gov.nl.ca/water/. Accessed on 10 July 2014.

Department of Environment and Conservation (DOEC) (2016). Arsenic in Well Water. Retrieved from http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/well/arsenic.html. Accessed on 2 August 2016.

Department of Environment and Conservation (DOEC) (2016). Fluoride in Well Water. Retrieved from http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/well/fluoride.html. Accessed on 2 August 2016.

Department of Environment and Conservation (DOEC) (2016). Groundwater Wells: What you Need to Know, Monitoring, Maintenance and Retrofitting. Retrieved from http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/groundwater_wells/monitoring.pdf. Accessed on 2 August 2016.

Department of Environment and Conservation (DOEC) (2016). Laboratories for Water Quality Analysis. Retrieved from http://www.env.gov.nl.ca/env/waterres/quality/labs.html. Accessed on 2 August 2016.

Department of Environment and Conservation (DOEC) (2016). Responsibilities of Driller, Owner and Others. Retrieved from http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/well/responsibilities.html. Accessed on 24 April 2016.

Department of Environment and Conservation (DOEC) (2016). Uranium in Well Water. Retrieved from http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/well/uranium.html. Accessed on 2 August 2016.

Department of Health and Community Services (DHCS) (2009). Roadside Spring Water. Retrieved from http://www.health.gov.nl.ca/health/publichealth/envhealth/roadsidespringwater2009.pdf. Accessed on 8 August 2016.

Department of Health and Community Services (DHCS) (2012). Drinking Water Manual. Retrieved from http://www.health.gov.nl.ca/health/publichealth/envhealth/drinking_water_manual_1-8.pdf. Accessed on 29 March 2016.

Department of Health and Community Services (DHCS) (2013). Drinking Water Quality. Retrieved from http://www.health.gov.nl.ca/health/publichealth/envhealth/drinkingwater.html. Accessed on 1 June, 2014.

De Simone, L.A., Hamilton, L.C., & Gilliom, R.J. (2009). Quality of water from domestic wells in principal aquifers of the United States, 1991-2004: overview of major findings. *United States Geological Survey.* Retrieved from http://pubs.usgs.gov/circ/circ1332/includes/circ1332.pdf. Accessed on 29 March 2016.

Dhar, R. K., Biswas, B. K., Samanta, G., Mandal, B. K., Chakraborti, D., Roy, S., ... & Abdul Hadi, S. (1997). Groundwater arsenic calamity in Bangladesh. *Current Science*, *73*(1), 48-59.

Dhar, R. K., Zheng, Y., Stute, M., van Geen, A., Cheng, Z., Shanewaz, M., . . . Ahmed, K. M. (2008). Temporal variability of groundwater chemistry in shallow and deep aquifers of Araihazar, Bangladesh. *Journal of Contaminant Hydrology, 99*(1-4), 97-111. Retrieved from http://www.sciencedirect.com/science/article/pii/S0169772208000375. Accessed on 2 August 2016.

Dudovskiy, J. (2016). Purposive Sampling. Retrieved from http://research-methodology.net/sampling-in-primary-data-collection/purposive-sampling/. Accessed on 7 August 2016.

Eastern Health (2015). Water Testing Overview. *Public Health Lab.* Retrieved from http://publichealthlab.ca/water-testing/. Accessed on 2 August 2016.

Eubig, P. A., Aguiar, A., & Schantz, S. L. (2010). Lead and PCBs as risk factors for attention deficit/hyperactivity disorder. *Environmental Health Perspectives, 118*(12), 1654-1667. doi:10.1289/ehp.0901852; 10.1289/ehp.0901852

Eum, K. D., Weisskopf, M. G., Nie, L. H., Hu, H., & Korrick, S. A. (2014). Cumulative lead exposure and age at menopause in the nurses' health study cohort. *Environmental Health Perspectives, 122*(3), 229-234. doi:10.1289/ehp.1206399; 10.1289/ehp.1206399

Fadrowski, J. J., Navas-Acien, A., Tellez-Plaza, M., Guallar, E., Weaver, V. M., & Furth, S. L. (2010). Blood lead level and kidney function in US adolescents: The third national health and nutrition examination survey. *Archives of Internal Medicine, 170*(1), 75-82. doi:10.1001/archinternmed.2009.417; 10.1001/archinternmed.2009.417

Fels, L. M., Wunsch, M., Baranowski, J., Norska-Borowka, I., Price, R. G., Taylor, S. A., . . . Stolte, H. (1998). Adverse effects of chronic low level lead exposure on kidney function--a risk group study in children. *Nephrology, Dialysis, Transplantation : Official Publication of the European Dialysis and Transplant Association - European Renal Association, 13*(9), 2248-2256.

Feseke, S. K., St-Laurent, J., Anassour-Sidi, E., Ayotte, P., Bouchard, M., & Levallois, P. (2015). Arsenic exposure and type 2 diabetes: Results from the 2007-2009 Canadian Health Measures Survey. *Health Promotion and Chronic Disease Prevention in Canada, 35*(4), 63-72.

Fitzpatrick, A. (2015, January 19) Need to be well aware – water well that is. *The Telegram.* Retrieved from http://www.thetelegram.com/News/Local/2015-01-19/article-4011892/Need-to-be-well-aware-%26mdash%3B-water-well,-that-is/1. Accessed on 2 August 2016.

Fitzpatrick, A. (2015, January 24) Poison in the water. *The Telegram.* Retrieved from http://www.thetelegram.com/section/2015-01-24/article-4018866/Poison-in-the-water/1. Accessed on 2 August 2016.

Gore, F., Fawell, J., & Bartram, J. (2010). Too much or too little? A review of the conundrum of selenium. *Journal of Water and Health, 8*(3), 405-416. doi:10.2166/wh.2009.060; 10.2166/wh.2009.060

Guilherme, S., & Rodriguez, M. J. (2014). Occurrence of regulated and non-regulated disinfection by-products in small drinking water systems. *Chemosphere*, *117*, 425-432.

Gurzau, E. S., & Gurzau, A. E. (2001). Arsenic in Drinking Water from Groundwater in Transylvania, Romania: an Overview. In Cambell et al. (Ed). *Arsenic Exposure and Health Effects IV*. Amsterdam: Elsevier.

Guzzwell, G.K. (2001). Groundwater Development and Protection Newfoundland and Labrador. *Clean and Safe Drinking Water Workshop, Department of Environment and Conservation.* Retrieved from http://www.env.gov.nl.ca/env/waterres/training/adww/safedrinking/09_presentation_keith_guzzwell.pdf. Accessed on 2 August 2016.

Hamadani, J. D., Tofail, F., Nermell, B., Gardner, R., Shiraji, S., Bottai, M., . . . Vahter, M. (2011). Critical windows of exposure for arsenic-associated impairment of cognitive function in pre-school girls and boys: A population-based cohort study. *International Journal of Epidemiology, 40*(6), 1593-1604. doi:10.1093/ije/dyr176; 10.1093/ije/dyr176

Health Canada (2006). Guidelines for Canadian Drinking Water Quality: Arsenic Guideline Technical Document. Retrieved from http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/water-arsenic-eau/alt/water-arsenic-eau-eng.pdf. Accessed on 2 August 2016.

Health Canada (2008). What's in Your Well? A Guide to Well Water Treatment and Maintenance. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/well-puits-eng.php. Accessed on 1 August 2016.

Health Canada (2014). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Turbidity. Retrieved from http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/water-turbidity-turbidite-eau/index-eng.php?page=3#a2.1. Accessed on 8 August 2016.

Health Canada (2014). Guidelines for Canadian Drinking Water Quality—Summary Table. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/pubs/water-eau/sum_guide-res_recom/sum_guide-res_recom_2014-10_eng.pdf. Accessed on 3 August 2016.

Health Canada (2015). Drinking Water and Your Health. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/health-sante/index-eng.php. Accessed on 2 August 2016.

Hexemer, A. M., Pintar, K., Bird, T. M., Zentner, S. E., Garcia, H. P., & Pollari, F. (2008). An investigation of bacteriological and chemical water quality and the barriers to private well water sampling in a south-western Ontario community. *Journal of Water and Health, 6*(4), 521-525. doi:10.2166/wh.2008.070; 10.2166/wh.2008.070

Hindmarsh, J. T. (2000). Arsenic, its clinical and environmental significance. *The Journal of Trace Elements in Experimental Medicine, 13*(1), 165-172. doi:10.1002/(SICI)1520-670X(2000)13:1<165::AID-JTRA17>3.0.CO;2-R

Houston, D. K., & Johnson, M. A. (1999). Lead as a risk factor for hypertension in women. *Nutrition Reviews, 57*(9 Pt 1), 277-279.

Hrudey, S. E. (2008). Safe water? Depends on where you live! *Canadian Medical Association Journal*, *178*(8), 975-975. Retrieved from http://www.cmaj.ca/content/178/8/975.full?ijkey=8a4cde9a2a4d532fddd1dbceb164ebe86667c6c0&keytype2=tf_ipsecsha. Accessed on 31 July 2016.

Hrudey, S. (2011). *Safe drinking water policy for Canada: Turning hindsight into foresight* (Commentary (C.D. Howe Institute); no. 323. Toronto: C.D. Howe Institute.

Hydrodyne Systems Inc. (2013). Colitag. Retrieved from http://www.hydrodynesystems.com/colitag.htm. Accessed on 31 July 2016.

James, K. A., Marshall, J. A., Hokanson, J. E., Meliker, J. R., Zerbe, G. O., & Byers, T. E. (2013). A case-cohort study examining lifetime exposure to inorganic arsenic in drinking water and diabetes mellitus. *Environmental Research, 123*, 33-38. doi:10.1016/j.envres.2013.02.005; 10.1016/j.envres.2013.02.005

James, K. A., Byers, T., Hokanson, J. E., Meliker, J. R., Zerbe, G. O., & Marshall, J. A. (2015). Association between lifetime exposure to inorganic arsenic in drinking water and coronary heart disease in Colorado residents. *Environmental Health Perspectives*, *123*(2), 128.

Jones, A. Q., Dewey, C. E., Doré, K., Majowicz, S. E., McEwen, S. A., David, W. T., ...& Henson, S. J. (2006). Public perceptions of drinking water: a postal survey of residents with private water supplies. *BMC Public Health*, *6*(1), 94.

Jovanovic, D., Rasic-Milutinovic, Z., Paunovic, K., Jakovljevic, B., Plavsic, S., & Milosevic, J. (2013). Low levels of arsenic in drinking water and type 2 diabetes in middle Banat region, Serbia. *International Journal of Hygiene and Environmental Health, 216*(1), 50-55. doi:10.1016/j.ijheh.2012.01.001; 10.1016/j.ijheh.2012.01.001

Kim, R., Rotnitsky, A., Sparrow, D., Weiss, S., Wager, C., & Hu, H. (1996). A longitudinal study of low-level lead exposure and impairment of renal function. the normative aging study. *JAMA : The Journal of the American Medical Association, 275*(15), 1177-1181.

Kopp, S. J., Barron, J. T., & Tow, J. P. (1988). Cardiovascular actions of lead and relationship to hypertension: A review. *Environmental Health Perspectives, 78*, 91-99.

Kreutzwiser, R., de Loe, R., Imgrund, K., Conboy, M. J., Simpson, H., & Plummer, R. (2011). Understanding stewardship behaviour: Factors facilitating and constraining private water well stewardship. *Journal of Environmental Management, 92*(4), 1104-1114. doi:10.1016/j.jenvman.2010.11.017; 10.1016/j.jenvman.2010.11.017

Kunrath, J., Gurzau, E., Gurzau, A., Goessler, W., Gelmann, E. R., Thach, T. T., . . . Yeckel, C. W. (2013). Blood pressure hyperreactivity: An early cardiovascular risk in normotensive men exposed to low-to-moderate inorganic arsenic in drinking water. *Journal of Hypertension, 31*(2), 361-369. doi:10.1097/HJH.0b013e32835c175f; 10.1097/HJH.0b013e32835c175f

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. Sage.

Leggett, C. G., & Bockstael, N. E. (2000). Evidence of the effects of water quality on residential land prices. *Journal of Environmental Economics and Management, 39*(2), 121-144. doi:http://dx.doi.org/10.1006/jeem.1999.1096

Lisabeth, L. D., Ahn, H. J., Chen, J. J., Sealy-Jefferson, S., Burke, J. F., & Meliker, J. R. (2010). Arsenic in drinking water and stroke hospitalizations in Michigan. *Stroke; a Journal of Cerebral Circulation, 41*(11), 2499-2504. doi:10.1161/STROKEAHA.110.585281; 10.1161/STROKEAHA.110.585281

Maull, E. A., Ahsan, H., Edwards, J., Longnecker, M. P., Navas-Acien, A., Pi, J., . . . Loomis, D. (2012). Evaluation of the association between arsenic and diabetes: A national toxicology program workshop review. *Environmental Health Perspectives, 120*(12), 1658-1670. doi:10.1289/ehp.1104579; 10.1289/ehp.1104579

Moon, K. A., Guallar, E., Umans, J. G., Devereux, R. B., Best, L. G., Francesconi, K. A., . . . Navas-Acien, A. (2013). Association between exposure to low to moderate arsenic levels and incident cardiovascular disease. A prospective cohort study. *Annals of Internal Medicine, 159*(10), 649-659. doi:10.7326/0003-4819-159-10-201311190-00719

Morales, K. H., Ryan, L., Kuo, T. L., Wu, M. M., & Chen, C. J. (2000). Risk of internal cancers from arsenic in drinking water. *Environmental Health Perspectives, 108*(7), 655-661.

Muntner, P., He, J., Vupputuri, S., Coresh, J., & Batuman, V. (2003). Blood lead and chronic kidney disease in the general united states population: Results from NHANES III. *Kidney International, 63*(3), 1044-1050. doi:10.1046/j.1523-1755.2003.00812.x

Nanos, N. (July 2009). Canadians overwhelmingly choose water as our most important natural resource. *Policy Options.* Retrieved from http://www.irpp.org/en/po/canadas-water-challenges/canadians-overwhelmingly-choose-water-as-our-most-important-natural-resource/. Accessed on 29 March 2016.

Navas-Acien, A., Maull, E. A., & Thayer, K. A. (2013). Arsenic and diabetes: Navas-acien et al. respond. *Environmental Health Perspectives, 121*(3), A71-2. doi:10.1289/ehp.1206100R; 10.1289/ehp.1206100R

New Brunswick Department of Environment (2008). New Brunswick Groundwater Chemistry Atlas: 1994-2007. Sciences and Reporting Branch, Sciences and Planning Division, Environmental Reporting Series T2008-01. Retrieved from http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Groundwater-CompositionChimiqueLeau/GroundwaterChemistryAtlas-AtlasChimiqueLeauSouterraine.pdf. Accessed on 2 August 2016.

Newfoundland and Labrador Center for Health Information (NLCHI) (2016). Search. Retrieved from https://www.nlchi.nl.ca/. Accessed on 8 August, 2016.

Newfoundland and Labrador Communicable Disease Surveillance (February 4, 2016). Monthly Disease Report: December 2015. Retrieved from http://www.health.gov.nl.ca/health/publichealth/cdc/mdr/dec_2015.pdf. Accessed on 24 April 2016.

Novakowski, K, Beatty, B., Conboy, M.J., & Lebedin, J. (2006). Water well sustainability in Ontario: Expert Panel Report. *Ontario Ministry of the Environment.* Retrieved from http://www.greelycommunity.org/documents/Well%20Water%20Sustainability%20Jan%2006.pdf. Accessed on 31 July 2016.

Ongley, E.D., 2000. Water quality management: design, financing and sustainability considerations-II. Invited presentation at the World Bank's Water Week Conference: Towards A Strategy For Managing Water Quality Management, April 3-4, 2000, Washington, D.C. USA.

Pili, E., Tisserand, D., & Bureau, S. (2013). Origin, mobility, and temporal evolution of arsenic from a low-contamination catchment in alpine crystalline rocks. *Journal of Hazardous Materials, 262*, 887-895. Retrieved from http://www.sciencedirect.com/science/article/pii/S0304389412007108. Accessed on 2 August 2016.

Province of Nova Scotia (2014). Tips for Testing Your Well Water. Retrieved from https://www.novascotia.ca/nse/water/welltips.asp. Accessed on 2 August 2016.

Pupek, D. (2000). New Brunswick and Water Management. Abstract from presentation at *28th Atlantic Geoscience Society Colloquium and Annual General Meeting*, February 10-12, 2000.

Rageh, O. M., Coles, C. A., & Lye, L. M. (2007). Statistical analysis of Newfoundland drinking water sources containing arsenic. In *Ottawa Geo2007–60th Canadian Geotechnical Conference, 8th CGS/IAH-CHC Groundwater Conference, Ottawa, ON* (pp. 2287-2291).

Ritter, L., Solomon, K., Sibley, P., Hall, K., Keen, P., Mattu, G., & Linton, B. (2002). Sources, pathways, and relative risks of contaminants in surface water and groundwater: A perspective prepared for the Walkerton inquiry. *Journal of Toxicology and Environmental Health. Part A, 65*(1), 1-142

Sarkar, A., Krishnapillai, M., &Valcour, J. (2012). A Study of Groundwater Quality of Private Wells in Western Newfoundland Communities. The Harris Centre, Memorial University. Retrieved from http://www.mun.ca/harriscentre/reports/water/1011_WATER_Sarkar_Final.pdf. Accessed on 1 August 2016.

Scinicariello, F., Abadin, H. G., & Murray, H. E. (2011). Association of low-level blood lead and blood pressure in NHANES 1999-2006. *Environmental Research, 111*(8), 1249-1257. doi:10.1016/j.envres.2011.08.011; 10.1016/j.envres.2011.08.011

Simpson, H. (2004). Promoting the management and protection of private water wells. *Journal of Toxicology and Environmental Health. Part A, 67*(20-22), 1679-1704. doi:10.1080/15287390490492296

Skinner, J. (2015). Business Plan, Business Reality: Starting and Managing Your Own Business in Canada (Fourth Edition). Toronto: Pearson.

Sommar, J. N., Svensson, M. K., Bjor, B. M., Elmstahl, S. I., Hallmans, G., Lundh, T., . . .Bergdahl, I. A. (2013). End-stage renal disease and low level exposure to lead, cadmium and mercury; a population-based, prospective nested case-referent study in Sweden. *Environmental Health : A Global Access Science Source, 12*, 9-069X-12-9. doi:10.1186/1476-069X-12-9; 10.1186/1476-069X-12-9

Standards Council of Canada (SCC) (2015). Accreditation Program Overview. Retrieved from https://www.scc.ca/sites/default/files/publications/ASB_POV_ASB-Program-Overview_v0_2015-06-30.pdf. Accessed on 31 July 2016.

Standards Council of Canada (SCC) (2016). Laboratory Accreditation. Retrieved from https://www.scc.ca/en/accreditation/laboratories. Accessed on 31 July 2016.

Statistics Canada (2013). Household size by province and territory (2011 census). Statistics Canada. Retrieved from http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo31a-eng.htm. Accessed on 23 March 2016.

Statistics Canada (2013). Population by sex and age group by province and territory. Statistics Canada. Retrieved from http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo31a-eng.htm. Accessed on 23 March 2016.

Thijssen, S., Maringwa, J., Faes, C., Lambrichts, I., & Van Kerkhove, E. (2007). Chronic exposure of mice to environmentally relevant, low doses of cadmium leads to early renal damage, not predicted by blood or urine cadmium levels. *Toxicology, 229*(1-2), 145-156. doi:10.1016/j.tox.2006.10.011

VanDerslice J, Wolff C, Kuwabara Y, Malecki K, Cohn P, Flowers H, Fagliano J, Nuckols J, & Cantor K (2006). White Paper: Development of Methods for Tracking Exposures to Contaminants in Drinking Water. *Drinking Water Exposure Group, National Environmental Health Tracking Program.* Retrieved from http://www.ehib.org/projects/DWEG_White_Paper_2006_final.pdf. Accessed on 23 March 2016.

Wang, S. X., Wang, Z. H., Cheng, X. T., Li, J., Sang, Z. P., Zhang, X. D., . . . Wang, Z. Q. (2007). Arsenic and fluoride exposure in drinking water: Children's IQ and growth in Shanyin county, Shanxi province, China. *Environmental Health Perspectives, 115*(4), 643-647. doi:10.1289/ehp.9270

Wasserman, G. A., Liu, X., Loiacono, N. J., Kline, J., Factor-Litvak, P., van Geen, A., . . . Graziano, J. H. (2014). A cross-sectional study of well water arsenic and child IQ in maine schoolchildren. *Environmental Health : A Global Access Science Source, 13*(1), 23-069X-13-23. doi:10.1186/1476-069X-13-23; 10.1186/1476-069X-13-23

Wirth, J. J., & Mijal, R. S. (2010). Adverse effects of low level heavy metal exposure on male reproductive function. *Systems Biology in Reproductive Medicine, 56*(2), 147-167. doi:10.3109/19396360903582216; 10.3109/19396360903582216

Xie, X., Ding, G., Cui, C., Chen, L., Gao, Y., Zhou, Y., . . . Tian, Y. (2013). The effects of low-level prenatal lead exposure on birth outcomes. *Environmental Pollution (Barking, Essex : 1987), 175*, 30-34. doi:10.1016/j.envpol.2012.12.013; 10.1016/j.envpol.2012.12.013

Appendix A - Health Canada Guidelines for Canadian Drinking Water Quality (HCGCDWQ)

Parameter	Units	HCGCDWQ MAC[a]
Chloride	mg/L	250
Colour	TCU	15
Fluoride	mg/L	1.5
Nitrite	mg/L	10
pH		6.5-8.5
Sulphate	mg/L	500
Total Dissolved Solids	mg/L	500
Turbidity	NTU	1
Antimony	mg/L	0.006
Arsenic	mg/L	0.01
Barium	mg/L	1
Boron	mg/L	5
Cadmium	mg/L	0.005
Chromium	mg/L	0.05
Copper	mg/L	1
Iron	mg/L	0.3
Lead	mg/L	0.01
Manganese	mg/L	0.05
Mercury	mg/L	0.001
Selenium	mg/L	0.01
Sodium	mg/L	200
Uranium	mg/L	0.02
Zinc	mg/L	5

[a](Health Canada, 2014b)

Appendix B - Information Letter: Key Informant Interview

Information letter: KI interview

My name is Atanu Sarkar and I am an Assistant Professor of Environmental and Occupational Health in the Faculty of Medicine at Memorial University of Newfoundland.

My team and I will be conducting a project entitled "Exploring appropriate business models for establishment of water quality monitoring service in Newfoundland and Labrador", which is funded by the Harris Centre. This project will hopefully determine that well owners in Newfoundland and Labrador (especially those in remote communities) are in need of a water testing facility which is more accessible and cheaper than what is currently available in St. John's. This new facility would then provide, the people of these communities, a way to have their drinking water tested more regularly, preventing many health issues.

Municipalities, having their own public water supply systems, regularly treat their water to make it free from any forms of hazardous contamination. The Department of Environment and Conservation, Government of Newfoundland and Labrador tests water quality on all public water systems on a regular basis. However, private water sources (mainly wells) are outside this testing regime, so the responsibility lies with the well owners to monitor their own drinking water for decontamination. Approximately one fourth of the total population, of this province, uses private wells, but there are no laboratory facilities outside of the St. John's CMA available to the well owners, particularly those living in remote areas. For these communities, it is very inconvenient using the private laboratories in St. John's due to the high cost and their inaccessibility.

We are hopeful that this study will show that providing easy access to a high quality drinking water service for private wells, in this province, will eventually reduce health burdens of well owners and eventually save government money, regarding health care. We are approaching the town council members, experts (manufacturers of analytical technologies and prospective institutional partners), and government officials to recognize the benefits of having such a facility in the province.

If you decide to participate in this study, you will be asked by the interviewer, questions regarding water quality and water supply in your community/the communities not supplied by the public water system. Your identity will not be revealed at any stage. All personal and contact information will be kept secure by the research team in Newfoundland and Labrador. It will not be shared with others without your permission. Your name will not appear in any report or article published as a result of this study. We will give you a consent form and will begin the interview once you read the consent form and sign it.

Sincerely,

Atanu Sarkar
Assistant Professor (Environmental and Occupational Health)
2851 Division of Community Health and Humanities
Faculty of Medicine, Health Science Centre
Memorial University, St John's, NL, Canada A1B 3V6
Phone: 709-777-2360
Fax: 709-777-7382
Email: atanu.sarkar@med.mun.ca

Appendix C – Participant Consent Form

Consent to Take Part in Research: Key informants' interviews

TITLE: Exploring appropriate business models for the establishment of water quality monitoring service in Newfoundland and Labrador

INVESTIGATOR(S): Atanu Sarkar (Principal Investigator), Tom Cooper (Co- Principal Investigator), Kalen Thomson (Graduate Researcher)

SPONSOR: Harris Centre, Memorial University (RBC blue water project)

You have been invited to take part in a research study. Taking part in this study is voluntary. It is up to you to decide whether to be in the study or not. You can decide not to take part in the study. If you decide to take part, you are free to leave at any time.

Before you decide, you need to understand what the study is for, what risks you might take and what benefits you might receive. This consent form explains the study.

Please read this carefully. Take as much time as you like. If you like, take it home to think about for a while. Mark anything you do not understand, or want explained better. After you have read it, please ask questions about anything that is not clear.

The researchers will:
- discuss the study with you
- answer your questions
- keep confidential any information which could identify you personally
- be available during the study to deal with problems and answer questions

1. **Introduction/Background:**
   Municipalities having their own public water supply systems treat their water to make it free from any forms of hazardous contamination. The Department of Environment and Conservation, Government of Newfoundland and Labrador tests water quality of all the public water systems on a regular basis. However, private water sources (essentially wells) are kept outside this testing facility. The responsibility of the monitoring the private water sources lies with the well owners. Approximately one fourth of the total population of the province is dependent on private wells. But, there is no perceived affordable laboratory facility available to well owners, particularly who are living in remote areas. For these communities, it is very inconvenient using the existing private laboratories in St. John's due to high cost and their inaccessibility. Regular monitoring of private water sources is needed to prevent any form of adverse health outcomes.
2. **Purpose of study:**
   We intend to carry out a study exploring the feasibility of establishing and running a water quality monitoring service in this province. Our long term goal is the have a comprehensive business model for a functioning laboratory in this province, providing affordable and accessible and high quality water testing facility to the communities. We believe that this study will give us a proper direction to establish the laboratory and to make the business

model sustainable – either publicly or privately funded. The facility will ensure health promotion and reduction of impending disease burden and eventually saving scarce financial resources.

3. Description of the study procedures:

You will be asked to participate in an interview. The interview will take place at your office or outside (if you prefer and the site will be according to your preference). The questions will be relevant to our study. We will carry out similar interviews for other persons and after the end of all the interviews we will analyze the responses. We may audio record the entire discussion (subject to your permission). The interview will take approximately one hour.

4. Length of time:

The interview will last approximately one hour.

5. Possible risks and discomforts:

Risks: There may be an emotional risk by remembering some past memories of water borne diseases.
Discomforts: You may feel discomfort in answering some questions. You are free to decline to answer any questions you wish.
Inconveniences: There may be an inconvenience to participate due to personal or professional commitment.

6. Benefits:

It is not known whether this study will directly benefit you.

7. Liability statement:

Signing this form gives us your consent to be in this study. It tells us that you understand the information about the research study. When you sign this form, you do not give up your legal rights. Researchers or agencies involved in this research study still have their legal and professional responsibilities.

8. What about my privacy and confidentiality?

Protecting your privacy is an important part of this study. Every effort to protect your privacy will be made. For example, the interviews are anonymous, so your identity and your responses will not be revealed.

When you sign this consent form you give us permission to

- Collect information from you
- Share information with the people conducting the study

Access to records
The members of the research team will see study records. However, these records will not identify you by name.

Use of your study information
The research team will collect and use only the information they need for this research study.

Your designation and contact information will be kept secure by the research team in Newfoundland and Labrador. It will not be shared with others without your permission. Your name will not appear in any report or article published as a result of this study.

Information collected for this study will kept for five years.

If you decide to withdraw from the study, you may choose whether you want your information used by the research team.

Information collected and used by the research team will be stored at the office of Dr. Atanu Sarkar (#2851 Division of Community Health and Humanities, Health Sciences Center, Memorial University, St John's. NL). He is the person responsible for keeping it secure.

Your access to records
You may ask the researcher (and Dr. Atanu Sarkar later) to see the information that has been collected about you.

9. Questions or problems:

If you have any questions about taking part in this study, you can meet with the principal investigator Dr. Atanu Sarkar who is in charge of the study at Memorial University of Newfoundland. His contact information follows bellow:

Principal Investigator's Name and Phone Number
Dr. Atanu Sarkar, Tel: 709 777 2360, Email: atanu.sarkar@med.mun.ca

Or you can talk to someone who is not involved with the study at all, but can advise you on your rights as a participant in a research study. This person can be reached through:

Ethics Office

Health Research Ethics Authority

709-777-6974 or by email at info@hrea.ca

After signing this consent you will be given a copy.

Signature Page

Study title: Exploring appropriate business models for the establishment of water quality monitoring service in Newfoundland and Labrador

Name of principal investigator: Dr. Atanu Sarkar

Name of graduate researcher: Kalen Thomson

To be filled out and signed by the participant:

Please check as appropriate:

I have read the consent [and information sheet].	Yes { }	No { }
I have had the opportunity to ask questions/to discuss this study.	Yes { }	No { }
I have received satisfactory answers to all of my questions.	Yes { }	No { }
I have received enough information about the study.	Yes { }	No { }
I have spoken to ___ (Researcher) and he/she has answered my questions	Yes { }	No { }
I understand that I am free to withdraw from the study • at any time • without having to give a reason	Yes { }	No { }
I understand that it is my choice to be in the study and that I may not benefit.	Yes { }	No { }
I understand how my privacy is protected and my records kept confidential	Yes { }	No { }
I agree to be audio taped	Yes { }	No { }
I agree to take part in this study.	Yes { }	No { }

____________________ __________________ ______________

Signature of participant Name printed Year Month Day

<u>To be signed by the investigator or person obtaining consent</u>

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

____________________ __________________ ______________

Signature of investigator Name printed Year Month Day

Telephone number: ____________________

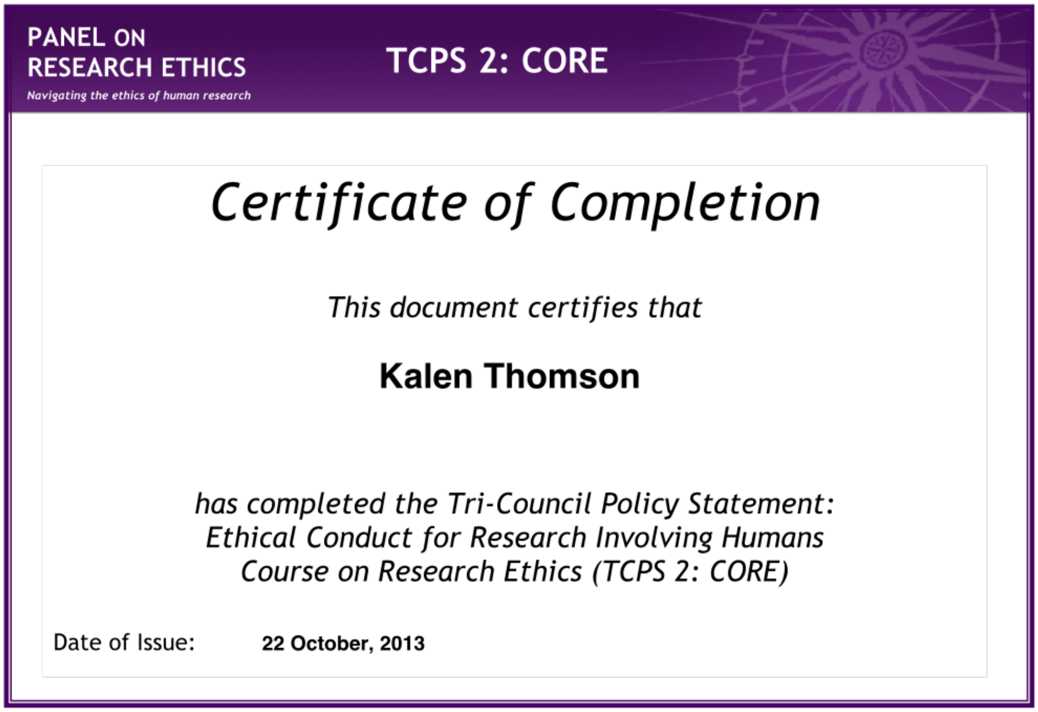
Appendix D - Interview Guidelines

Key Informant's interview – points (guide):
What is your opinion on water supply in this province, particularly the areas not on public water and sewer systems?
What is your opinion on quality of water of private sources, such as wells, springs, ponds etc?
Are you satisfied with your own well/spring water? Why?
Have you ever had any problems with your own well water?
Do the communities depending on wells test the water samples regularly?
Do you think water monitoring is essential? If yes/or no, why?
What do you think that the major challenges of water testing in your community?
Do you think that a water testing laboratory would help to monitor the water quality in those communities?
How much would you pay to have your water tested?
Who would you like running the laboratory – the private or the public sector?
What are your suggestions on making the laboratory most effective, in terms of affordability, accessibility and sustainability?
Who can be the major partners in running the laboratory?
Is there anything else we should consider about private water well water testing?

Laboratory Tour and Interview – points (guide):

What laboratory equipment is on site?
What tests are the laboratory capable of performing?
Cost information: Ballpark equipment costs and maintenance costs?
Cost to the laboratory per test?
How many tests per hour/8 hour day could an experienced laboratory technician perform?
Is there any fee or charge to the client per test?
How are samples currently delivered?
How are results reported?

Appendix E - Ethics Certification



PANEL ON
RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Kalen Thomson

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **22 October, 2013**

Appendix F – New Brunswick Analytical Services Laboratory Fee Schedule

Inorganic Chemistry

Parameter	Price	Parameter	Price
Alkalinity	$6.00	Manganese	$6.00
Aluminum	$6.00	Mercury	$18.00
Ammonia	$6.00	Nickel	$6.00
Antimony	$6.00	Nitrate	Calc'd
Arsenic	$6.00	Nitrate/ Nitrite	$6.00
Biochemical Oxygen Demand	$22.00	Nitrite	$6.00
Boron	$6.00	Nitrogen, Total	$15.00
Barium	$6.00	Nitrogen, Total Kjeldahl	$15.00
Bromide	$6.00	pH	$4.00
Cadmium	$6.00	Phosphorous, Total High Level	$15.00
Calcium	$6.00	Phosphorous, Total Low Level	$12.00
Chemical Oxygen Demand	$18.00	Potassium	$6.00
Chloride	$6.00	Selenium	$6.00
Chlorophyll "A"	$35.00	Sodium	$6.00
Chromium	$6.00	Sulfate	$6.00
Colour	$4.00	Solids, Suspended	$9.00
Conductivity	$4.00	Solids, Total	$9.00
Copper	$6.00	Solids, Total Dissolved	$9.00
Carbon, Total Organic	$8.00	Solids, Total Volatile	$5.00
Fluoride	$6.00	Solids, Total Volatile Suspended	$7.00
Grease	$40.00	Thallium	$6.00
Hardness	Calc'd	Turbidity	$4.00
Iron	$6.00	Uranium	$6.00
Lead	$6.00	Vanadium	$6.00
Magnesium	$6.00	Zinc	$6.00

Organic Chemistry

Parameter	Price
Hydrocarbons (water)	$79.44
(soil)	$140.19
(oil – pure product)	$56.07
Pentachlorophenol	$80.00
Volatiles	$93.46
Benzo(a)pyrene	$116.81
MTBE	$30.00
HCFC	$30.00
PAH's (water)	$116.81
PAH's (soil)	$195.65
Full CWA	$257.94

Microbiology

Parameter	Price
Total Coliforms and E-Coli	$35.00
Heterotrophic Plate Count	$15.00
Enterococcus	$25.00
Faecal Coliforms	$15.00
Pseudomonas	$25.00

Packages

Package	Price
Metals Package	$60.00
Potable Water Package	$91.59
CWA (Municipalities) Package	$91.59
Brown Water Package	$26.00

All prices listed do not include applicable tax

Effective – March 29, 2012

Source: C. Ottens, Quality Assurance Officer, NB Analytical Services Laboratory, Personal Communication, 6 August 2014