MEMORIAL UNIVERSITY

THE HARRIS CENTRE
Memorial University

A STUDY OF GROUNDWATER QUALITY OF PRIVATE WELLS
in Western Newfoundland Communities

Dr. Atanu Sarkar, Dr. Mano Krishnapillai, Dr. James Valcour

August 2012

This research project was funded under the The Harris Centre – RBC Water Research and Outreach Fund. The intellectual property vests with the author(s). For more information about the The Harris Centre – RBC Water Research and Outreach Fund or to obtain hard copies of this report, please contact the Harris Centre.

A Study of Groundwater Quality of Private Wells in Western Newfoundland Communities

FINAL REPORT

Prepared by
Dr Atanu Sarkar
Division of Community Health & Humanities, Faculty of Medicine
Dr Mano Krishnapillai
Environmental Science, Grenfell Campus
Dr James Valcour
Division of Community Health & Humanities, Faculty of Medicine
Memorial University

Funded by:
The Leslie Harris Centre of Regional Policy and Development
Memorial University of Newfoundland

Scope and objectives

The Government of Newfoundland and Labrador is committed to providing the public with clean and safe drinking water. In order to achieve this goal a number of actions have been initiated. For example, the *multi-barrier approach* includes source protection, water treatment, water system operation and maintenance, water quality monitoring and reporting, regulatory inspection and mitigation planning, and operator education and training (DOEC, 2001). Public water supply systems treat water to ensure free from any microbiological contamination. The Department of Environment and Conservation (DOEC) also measure 39 non-microbial parameters of the *Guidelines for Canadian Drinking Water Quality* (GCDWQ) as the indicators of water quality. Private water sources are outside this mandate and lack mandatory treatment and monitoring guidelines. This can potentially pose a threat to those people who rely on private water as a source for drinking water. The DOEC expressed serious concern about this gap and suggested an exploration of the issues regarding community perceptions and the quality of private water sources. The Department of Health and Community Services (DOHCS) provides free services to analyze the domestic water for coliform bacteria. However, there is a low utilization of this service indicating lack of awareness and accessibility of the service.

Approximately 30% of the population of the province uses groundwater for household purposes. Of those, approximately 75% (i.e. 23% of the total population) are dependent on private wells (DOEC 2010a). Most of the private well users live in small rural communities. As per current guidelines, well owners are expected to monitor groundwater quality just after sinking new wells. Non-compliance with the requirements of the certificates of environmental approval and GCDWQ guidelines are also major problems. Some contaminants can take years to appear in the groundwater and thus initial satisfactory reports will not guarantee a safe source of drinking water for subsequent years. Regular monitoring of groundwater is needed to prevent any form of adverse health outcomes.

Changing land use patterns and landscape due to forestry, agriculture, irrigation, animal farming (manure piles), industrialization (mining), natural disaster (flood), human habitation (septic systems, garden pesticides), and chemical spilling (gasoline, diesel, home heating) can significantly change the groundwater. There is also risk of well contamination due to leaching of metals from galvanized well liners. The risk of contamination can be higher if well liners are older than 15 years of age and immersed in waters below a pH of 7 (indicating an acidic environment resulting in increased rates of galvanization dissolution) (Guzzwell et al., 2000). In addition, if unused older wells are unmaintained, for example, they often remain improperly plugged or sealed, surface water or run-off can infiltrate underground water, resulting in contamination of ground water supplies. The current method of waste disposal in most rural communities uses nearby landfills or burning in incinerators. As the majority of the landfills are not properly designed, the chances of leaching toxic chemicals into the local aquifers and water sources are greater.

Reports from various communities have indicated the presence of aluminum, ammonia, antimony, arsenic, cadmium, copper, fluoride, lead, magnesium, manganese, and selenium in groundwater samples in Newfoundland and Labrador (DOEC 2010b). A report by the DOEC (2010c) demonstrated that several areas of Newfoundland had levels of uranium and arsenic that exceed the drinking water guideline in public water supplies. However, there is no such information on microbial and chemical contamination of groundwater from private sources,

despite having an estimated 20,000 drill wells and almost equal number of dug wells in the whole province (DOEC 2010a).

Rationale

The communities along the Humber River of the Western Health region were selected for the study. The reasons for selection of the Western region were as follow:

- With the exception of five major communities (Corner Brook, Deer Lake, Reidville, Pasadena, and Steady Brook), all other communities around the Humber river, basin and estuary, used private groundwater (i.e. dug and drilled wells) and/or springs (DOEC 2010d). In fact, one study showed that approximately 31% of the respondents from this region used untreated private wells, which was higher than the provincial average of 24% (Howse 2003). There was no fully serviced shared groundwater system in these areas. A few partially serviced systems do exist (DOEC 2010a).
- The Department of Environmental Science (Memorial University's Grenfell Campus in Corner Brook) has been actively engaged in teaching and research. In fact, Dr Mano Krishnapillai, Associate Professor at Grenfell Campus has been co-principal investigator of this project.
- Presence of a pulp and paper mill at Corner Brook, which has extensively used vast forest land in the area for raw material and which possibly contaminates surrounding land and water sources with mercury from the harvested area.
- A recent report showing that while the lower Humber and Humber arm were within the fluoride belt, the upper Humber was under the uranium belt (DOEC 2010c).

Before the study we identified following knowledge gaps:

- Absence of profiles of groundwater quality in private wells
- Lack of information of population perspectives of drinking water quality and its monitoring, impacts of environmental contamination, management and mitigation strategies, coping mechanisms, high risk groups, sustainable solution, and community partnership

The study was initially planned with the following objectives:

- To determine the presence of microbiological contaminants in private groundwater samples
- To explore the community perspective on groundwater quality and its monitoring, consumption pattern, impacts of environmental contamination, management and mitigation strategies, sustainable solutions, and community partnership
- To analyze the existing reports on private groundwater quality

Research plans and analysis

Community Selection

Eight communities were selected to participate in the study (see study area in appendix I). The selection was based on whether the communities didn't have public water supply and relied upon individual wells as the principal source of water. Municipal authorities were contacted and the purpose of the study was explained. One community refused to participate. Seven municipalities

agreed to contact the households to arrange a focus group discussion. Only three communities agreed to participate and members of the four remaining communities did not want to share their individual water related issues with others. However, there was no objection to testing individual well water in all seven communities. In three communities we carried out focus group discussion lasting for one and one half hours each.

Water Samples

We developed a schedule detailing when water samples were to be collected (see Appendix II). Two water samples were collected from 45 water sources (24 drilled wells, and 21 dug wells) as described in protocols by DOEC. Water samples were collected between May to June in 2011 and sent to the laboratory of the Department of Services for microbiological analyses in Corner Brook and to the office of DOEC (Corner Brook). DOEC received the samples to ship to Ottawa (Exova Accutest) for physical and chemical testing. The province of Newfoundland and Labrador does not have an accredited laboratory for physical and chemical testing, therefore DOEC send their samples for routine testing to this lab in Ottawa. DOEC extended support by accepting our samples for analyses of the same physical and chemical parameters for analysis in Ottawa. Individual household test results were shared with the household by telephone and by post. The information on population perspectives on water quality, its monitoring, consumption pattern, impacts of environmental contamination, management and mitigation strategies, sustainable solution, and community partnership were collected during telephone conversation. Sampling was repeated in the fall (October/November) on 20 sources (9 drilled wells, 11 dug wells). Not all sites from the spring sampling were sampled due to some operational difficulties and non-availability of several well owners.

DOHCS provides current guideline values on microbial and chemical (aesthetic and contaminant) water quality to assess human health vulnerability. The water should be free from total and fecal coliform and their presence is considered *substandard* and *unsatisfactory* respectively[1]. Out of 39 regularly tested non-microbial parameters of GCDWQ, 24 have some public health importance[2].

Key Informants' Interviews and Focus Group Discussion (FGD)

[1] *Total coliform bacteria* are common in the environment (soil or vegetation) and are generally harmless. If a lab detects only total coliform bacteria in drinking water, the source is probably environmental and fecal contamination is unlikely. However, if environmental contamination can enter the system, pathogens could get in too. It is important to find and resolve the source of the contamination. As per provincial guidelines, suitable disinfection should be undertaken and water retested to ensure there is no fecal contamination. Occasionally, test results are reported as *overgrowth – unable to interpret*. This is due to the presence of excessive environmental bacteria (non-coliform). Repeat testing is needed.
Fecal coliform bacteria are a subgroup of total coliform bacteria. They exist in the intestines and feces of people and animals. The presence of fecal coliform in a drinking water sample often indicates recent fecal contamination (possibly due to improperly working septic system, feces from pets and wild animals). That means there is a greater risk that pathogens are present. As per provincial guidelines, the drinking water should be boiled and corrective actions should be taken with fecal contamination. Retesting should be carried out following appropriate corrective action.

[2] Color, pH, turbidity, fluoride, antimony, arsenic, barium, boron, cadmium, chloride, chromium, copper, iron, lead, manganese, mercury, selenium, strontium, sodium, nitrite, sulphate, total dissolved solids (TDS), uranium, and zinc.

We conducted key informants' interviews of health officials, drillers, officials of the DOEC and the DOHCS. The FGD and interviews were audio recorded and transcribed. We carried out content analysis of the FGD and interview transcriptions.

Ethics Approval

Ethical clearance and approval of informed consent (for focus group discussion and interviews of key informants) was obtained from the Interdisciplinary Committee on Ethics in Human Research (ICEHR).

Results

Background information of the communities

Name of the communities visited:

York Harbour, Cormack, Little Rapids, Humber Village, Pinchgut Lake, Bay St. George's South, Bonne Bay.

Utilization of water (N=45):

Cooking (43, 94%), drinking (41, 89%), washing (45, 98%), bathing (42, 91%), gardening (30, 65%), pets (26, 57%), agriculture (1, 2%).

Demographic information of the participants of focus group discussions:

Age - 36-55 years (35%), 56-65 years (50%), above 65 years (15%)
Gender - females (70%)
Education - university degree (40%), diploma in trade (33%), high school (22%), below high school (5%)

Water quality and background of wells

Microbiological parameters

Summer samples:

23% (5/23*) of drill wells and 63% (12/19*) of dug wells water contaminated with total coliform. No drilled well water had fecal coliform. However, 10% (2 out of 20) of dug well water had fecal coliform. Depths of drill wells and dug wells range from 14 to 440ft (average 133ft) and from 3 to 42ft (average 16ft) respectively.

Fall samples:

28% (2/7*) of drill well water had total coliform and 80% (8/10*) and 10% (1/10*) of dug wells had total coliform and fecal coliform respectively.

* *Lab reports (3) showing other bacterial overgrowth or particulate matters are not included*

Comparison between summer and fall samples of the same sources: 5 samples (4 drilled wells and 1 dug well) remained coliform free in both seasons. 2 samples (1 each from drilled well and dug well) had transformed from contamination free to contaminated water (total coliform). 2 samples (1 each from drilled well and dug well) changed from total coliform positive (1 fecal coliform positive) to coliform free. 5 samples (all dug wells) remained contaminated in summer and fall and in addition 1 sample also showed fecal coliform positive in fall (Table 1).

Table 1: Comparison of biological contaminants in well water samples from the Humber River Basin communities collected in the summer and fall of 2011.

Drilled Well No.	**1**		**2**		**3**		**4**		**5**		**6**	
Season	S	F	S	F	S	F	S	F	S	F	S	F
Total Coliform Count	0	0	0	0	0	0	0	0	1	0	0	24
Fecal Coliform Count	0	0	0	0	0	0	0	0	0	0	0	0

Dug Well No.	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**	
Season	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Total Coliform Count	0	0	80	0	0	3	2	15	24	1	29	3	33	1	15	1
Fecal Coliform Count	0	0	30	0	0	0	0	0	0	0	0	0	0	1	0	0

S Summer
F Fall

	Coliform -ve in summer and fall
	Coliform +ve in summer and -ve in fall
	Coliform -ve in summer and +ve in fall
	Coliform +ve in summer and fall

** Six lab reports showing other bacterial overgrowth or particulate matters either in summer or falls or both are not included*

Physical and chemical parameters

Two water samples had high arsenic (0.025 and 0.013 mg/l, *guideline value 0.01 mg/l*) and 1 sample had high fluoride (5.35 mg/l, *guideline value 1.5 mg/l*) (all were from drill wells). All three samples were coliform free. These three chemically contaminated wells represented 7% (3/45) of the total wells. Wells that had arsenic present were both located in the same community. A past survey conducted in the same community also showed high arsenic and fluoride in ground water samples used for irrigation and livestock (DOEC, 2008b). This community was not located near any geological sources of arsenic as indicated by geological survey maps of Newfoundland and Labrador. Arsenic and fluoride in water are major health threats in some parts of the province.

Microbial Contamination

There are several other physical parameters, associated with possible microbiological contamination, such as color and turbidity. Three samples exceeded the guideline values of color (range from 32 to 135, *guideline value, 15 true color units or TCU*) and two of them had contamination of coliform (both total coliform positive and 1 fecal coliform positive). Ten samples (7 drill wells and 3 dug wells) exceeded the guideline values of turbidity (range from 1.4 to 13.7, *guideline value, 1 nephelometric turbidity units or NTU*) and five samples (3 drill wells and 2 dug wells) had contamination of total coliform. Six water samples had high iron and manganese and three of them had both the minerals. These two parameters are essentially used for aesthetic purposes only.

Effects of filters

Water samples from eight sources (out of 45) were collected twice; before and after filtration at the same time during summer. These households used various types of water filters, such as water softeners, external fridge filters, sediment filters, and carbon filters. Each filter has its own specification, such as removal of iron or chlorine or other minerals. Our analysis showed that these filters had limited capacity to provide clean and fresh water. For example, one particulate/sediment filter could not eliminate total coliform (reduced from 62 to 27). Out of three water samples with high turbidity, only one had shown reduction below guideline value. A carbon filter couldn't reduce fluoride to a safe level (reduced from 5.35 to 5.01). Out of two water samples with high manganese (aesthetic parameter), one had reduced below guideline value. All the households carefully follow the instruction given by the manufacturers and replace old cartridge on a regular basis. However, the use of filters gave the users a sense of security and satisfaction due to improvement of perceivable physical characteristics of water, such as taste, odor.

Well Maintenance

Comparatively dug wells were older than drill wells. We asked well owners about maintenance of their wells and whether it was linked with water quality. Regular maintenance means timely cleaning of wells (mostly by chlorination) or immediate cleaning if there has been any suspicion of contamination due to flood, or change of taste or odor. High turbidity, total coliform and total dissolved solids were found in those drill wells that were either not maintained or maintained occasionally. Despite regular cleaning, one dug well contained coliform (total) contamination. The deepest dug well (42ft) had high total coliform, turbidity and color due to lack of maintenance.

Description of some individual wells

a) b)

Figure 1: These two dug wells had total coliform contamination in both seasons and in addition well 'a' had fecal coliform

Figure 1 shows two wells, which were contaminated by total coliform in summer and fall. Well ‘a’ also had fecal coliform in fall. Physical and chemical parameters of well ‘a’ were within normal limit. Water samples of both sources were visibly clear and transparent and owners were happy with its taste, odor and color. Well ‘a’ was close to a river bank and surrounding land sloped towards the river. Possibly the well remained contaminated by surface run off from surrounding highland. Well ‘b’ is close to wetland; however, the source of contamination could not be ascertained during our survey. Physical and chemical parameters of well ‘b’ showed high turbidity, iron and manganese.

Figure 2: This drill well became contaminated by total coliform in fall

The well shown in Figure 2 was free from any form coliform contamination in summer, but in fall it became contaminated (total coliform). Its physical and chemical parameters were within normal limit. Apparently the well head looked secured and properly maintained; however the contamination of the fall sample indicated possible underground seepage from the surrounding land. The slope of the surrounding ground was towards the well. The owner did not monitor the well regularly.

Figure 3: Dug well – summer sample was highly contaminated by total coliform (80) and fall sample had bacterial overgrowth.

The dug well shown in Figure 3 was highly contaminated as indicated by total coliform counts measured in the summer and had bacterial overgrowth in fall. The well was covered with Styrofoam and the color of the water was brownish. Water was used for cooking, bathing and washing. In the kitchen an aerator was used before using water in cooking. The well owner did not monitor the well regularly and the last proper cleaning with *Javex*^{TM} (sodium hypochlorite) was done five years prior. A walk through survey identified a boggy marshy land nearby; however, this could not be ascertained as its link to poor quality water. Chemical analysis showed the highest color (135 TCU) and high turbidity (7.7 NTU) levels of all the wells sampled. This provides supporting evidence of surface contamination and hence high microbial level. The water also contained high iron and manganese.

Figure 4: Drill well remained free from microbial contamination in summer and fall

The drill well shown in Figure 4 had a secured well head and the surrounding area was a properly maintained, flat surface. The well was located at least 100ft from the house, but close to the shed (seen in the figure). Water was regularly (once a year) monitored by the well owner. However, physical and chemical analysis showed little elevated level of turbidity (1.8 NTU) and manganese (0.31 mg/l).

Figure 5: Only dug well in our study showing negative coliform in both summer and fall

The dug well shown in Figure 5 was properly maintained and had negative coliform samples (zero count) in both seasons. The surrounding area is flat and 50ft from the house and driveway. Physical and chemical analysis showed a slight elevated level of turbidity (1.7 NTU) and iron (0.44 mg/l).

Community perspectives on water quality

There was mixed response from participants with regard to perception of the quality of their well water. Several households did not filter water and had full faith in its quality. In general, the communities were very confident of their water sources, based on the absence of any reported outbreak and personal experience. Some wells remained untested for more than 30 years due to the absence of any major water-borne disease in the family. People believe that the location of wells in sand bank ensured purity of water as the sand acted as a filter and therefore they didn't see a need for any test. Interviews of the well owners showed that around 87% of drill well owners had full faith in their water sources, but laboratory analysis showed that 55% of them had aesthetic and contaminants parameters higher than guideline values. Around 94% dug well owners perceived that their water was not-contaminated and fit for consumption, but 67% had problems related to aesthetic and/or contaminants parameters.

People perceived water quality by change of color, odor or stains in sink, toilet bowl or clothes. For example; foul smell is associated with sulphur, brownish slime on water linked with presence of iron as observed in toilet bowl or on the bottom of dog dish if it sits for a couple of days. Some communities complained about sulphur and sodium as the main contaminants of their ground water sources. However, our reports of chemical analysis did not reflect the presence of those chemicals in the respective communities. The owners of arsenic and fluoride contaminated wells had no previous complains about their quality, and hence they were surprised by the reports and worried about their future prospects. Communities residing along the sea coast believed that the presence of a high salt content in well water resulted in the rising occurrence of hypertension. Moreover, the situation would be worse due to climate change and sea level rise. However, we could not find any conclusive evidence; as only one sample out of 15 samples from the coastal communities had a high sodium level.

People believed that agricultural activities, particularly animal farming could pollute surface water and water bodies and eventually contaminate wells. Their major concern related to well water was dairy barns, poor management of cattle manure/waste and dead animals, routine daily washing of cattle sheds, and use of medications for animals. The communities were fully aware of the lessons of the Walkerton (Ontario) tragedy of 2004 which resulted from contamination of water by animal waste. In one community, there was a report of a barn functioning without a proper drainage system, the runoffs ending up in the soil and gullies outside the barn and eventually contaminated water percolating into the ground. This prompted some of the households to install filters as a measure for minimizing any health risks. We found two total coliform positive samples from the community; however, it was beyond our scope to undergo in depth investigation to establish causal relation between animal farming and contamination. Therefore, further study is needed. Logging was also believed to pollute local water, as expressed by some community members.

Generally the quality of water is considered to be good until the month of May or June. In the summer months, probably due to runoff and melting of the snow, the water becomes undrinkable. Therefore, those wells are mostly cleaned in the spring or in the summer after the

runoffs, at least once a year. The households buy water for drinking and cooking and spend about $40 every month. In one focus group discussion, the community members mentioned more frequent cleaning of their wells. They carried out scrubbing, draining, and applying *Javex*™ (liquid chlorine – sodium hypochlorite) (also known as *shock treatment*) repeatedly, about 2 to 3 times every year. Depending on the number of households that used the well, the annual cleaning and maintenance fee was reported to be around $75 per household. Despite cleaning of wells, some households tended to avoid them due to fear of unknown health risks. In those cases where the management and mitigation strategies to restore well water quality failed, some households in the community resorted to bottled water, boiling and storing of water in jugs in the fridge, use of conditioners as well as the installation of a dual filtration system. Several households annually spent from $40 to $480 for water filtration. There were diverse opinions regarding bottled water as exhibited by the fact that some members of the community drank bottled water while others avoided it altogether. Some suspected that the bottled water contained harmful substances used in the manufacturing of the bottle or contained anti-freezing agents or some alcohol.

There were always some cases when the wells ran out of water especially during a dry summer. This mostly happened when the wells were shared by multiple families. Hence, they used tanks to store water. Some households borrowed water from friends or went to nearby springs with short pipes to collect water. Several communities considered springs as the sources of drinking water. They were also aware that road sides and driveways are the potential sources of organic chemicals from diesel and gas contaminating water sources. Some households felt that the boggy smell in the water of dug and drilled wells, occasionally accompanied by oil film on top of the water, made those wells unfit for drinking and cooking, except for washing, showering, and flushing the toilet. The alternative sources of drinking water for such households then became a community spring or bottled water purchased from local stores.

The people most vulnerable to water contamination in the area were believed to be the seniors and low income households. Such households were unlikely to be able to afford big water systems or water filtering systems and other related requirements for water safety.

While some households preferred to have a public water supply (instead of the current private wells) for assured regular monitoring by the authority concerned; others were not that keen due to high maintenance cost, fear of chlorination of water leading to the alteration of natural taste, and loss of autonomy or personal freedom. Another concern that the community had with chlorine in water treatment was its limited use in elimination of microbes such as coliform but not the chemicals in water. However, the use of chlorine and its associated smell was considered a lesser issue to handle when compared with other issues that affect water quality in the community. Communities also decried the cost of the water system, estimated to be around $3,000 (excluding other costs such as those associated with purchase of salt, filters, and testing of the quality of water for bacteria and chemical contaminants). Tests for chemicals such as lead, fluoride or arsenic were seldom carried out because of the associated high cost and non-availability of the testing facility on the island, making it even more difficult and challenging to the community. Tapping of rain water as an alternative source did not garner much support in the community due to the perceived risks that have been associated with acid rain.

The community was also concerned with the operations of the provincial government and wished to see the province assume a more proactive role. There are several communities (not studied) without proper sewage treatment facilities and their entire raw sewage was dumped in

the nearest water bodies, river, lakes or ocean. They believed that the mandate of the government should include regular monitoring of all the activities in the areas including the barns. They felt that safer waste disposal in the barns without contaminating the surrounding water sources would reduce the threat to the health of the local communities. The communities were also aware of health risks due to extensive use of nitrate fertilizer seeping into the water resources and the risk of pancreatic and stomach cancer, use of pesticides on lawns and manure on pastures and golf courses which ultimately ended up contaminating the water resources. Even though the groups understood the challenges of regular visits by the relevant health authorities to smaller communities, the health of such communities remained paramount and therefore must not be compromised. Some suggested that government should be accountable for regular monitoring of water quality of the private wells. Around 90% of households are keen to have a laboratory facility in the province with the capability to monitor water samples for basic physical and chemical parameters with public health importance, such as heavy metals, fluoride etc. Around 85% of them are willing to bear part of the cost of testing in order to sustain the lab. Some even suggested having a mobile water monitoring facility and making it accessible to the entire province.

Our study has changed the perspective of water quality among some participants. For example, when the lab declared water from one dug well unfit for consumption, due to a very high count of total and fecal coliform, the owners were taken by surprise. The well was shared by around 40 households and before testing the quality of the water was taken for granted. They occasionally cleaned the water with *Javex*™. The result prompted them to clean it properly. First, the owners raised money by individual contribution from all the users. Then they cleaned the well by removing water, followed by scraping the inner surface, treating it with *Javex*™, installing an appropriate cover and clearing the surrounding ground. In the fall, we rechecked the well and found nil report. The well owners appreciated our initiative and recognized the benefit of regular monitoring.

Well driller's perspective

According to the well drilling experts, salt in the bedrock, iron and sulphur were the main contaminants of well water. These contaminants not only overburdened the drilling process but also increased the cost of the whole operation. In some areas they experienced high level of salt in the underlying limestone rocks making it really difficult to guarantee water to the homeowners even at a depth of 500 feet. Drilling cost was related to the depth of the well and varied between $8,000-10,000 at a rate of $18 per foot and $25 for casing. The Walkerton scare of 2004 sensitized the community with regard to their health risks and prompted them to have their own drill wells. The areas which have a lot of underground water enabled more people to drill and install wells. The trend of expansion of private wells in underserved communities has been hindered by environmental consequences which must be considered to avoid drying up of the wells. One driller shared how uncontrolled expansion of private wells in the past led to shutting down at least 5 subdivisions (a row of 20 to 30 houses).

The presence of sulphur in water could be determined by the smell of rotten egg and sometimes even iron and manganese, or a mixture of both, smelled like sulphur. However, in order to identify each of the particular pollutant, the drillers suggested the use of an appropriate laboratory test. The drillers suggested the installation of a filter after detection of sulphur or to

pump water directly into an open tank for aeration to remove the bad smell before the water is supplied to the house. As contaminants might take years to pollute well water, regular tests at least once in every six months to one year were warranted. The wells should be repaired and thoroughly washed by specialists especially in the rainy seasons if water is discolored due to surface sand or mud or the presence of bacteria. The presence of sand in the water indicates inadequate casing which lets in the surface sand and mud. The well water quality can be restored by re-driving a new casing to keep sand, mud, and bacteria from the well. In order to minimize chemical pollutants such as arsenic, the drillers suggested putting more casing or cementing the well, preferably by *fondue cement* (cement that sets in about 6 hours, but begins to become solid in a much shorter time) in order to block the cracks and to harden it before boring the hole down deeper. They suggested following provincial government guidelines to seal any abandoned wells. Unfortunately, most people don't know that keeping the well-hole open is against the legislation. There were some abandoned wells left unattended for a long time near the TransCanada Highway, and eventually surface run off and even sewage drained into the underground water.

Health officials' perspectives

The big issue with the quality of well water is the fact that many homeowners are probably not well-versed in monitoring the water quality. According to a health official, such risk was not a result of ignorance or lack of knowledge or information but failing to take responsibility. The Department of Government Services underwent an elaborate approval process in collaboration with a project proponent which included the development of a water supply system.
This complete approval system included the proper construction of a septic tank system in order to protect both the individual's well water and the entire underground water resources in an area. However, there was a possibility of a person completing the process of septic system approval with Government Services without the approval of the well location. The onus rested with the homeowners to follow through. Usually, the opportunity was missed when any home owner failed to get back to Government Services for the information on the proper construction and maintenance of their well. Unfortunately, Government Services also moved on without a proper follow-up. The home owners were left on their own while the department moved on to the next on the list without caring about the previous homeowners. A number of homes were older and there might have been no regulations in place a number of years ago.

The current ground water quality monitoring system in the area has been purely voluntary due to lack of any directive from Government Services demanding a compulsory monitoring of private wells. However, owners of private wells have always been free to submit the samples of water from their wells to the department of Government Services for testing. Over the past couple of years the department of Government Services analyzed 1,000 to 1,500 samples annually. Possibly it was the same private well owners that submitted their samples for testing once or twice every year because of their awareness, while the majority of the population might not be aware of such service existed and available to them.

There were no specific incidents of contamination of well water in the western region. However, when some areas such as those around agriculture are perceived to be at risk, Department of Environment and Conservation and Department of Health and Community Services should step in to check the groundwater sources, including private wells. Such assessments are normally a follow up to complaints of risks of well water contamination which arise due to observed activities such as a farmer spreading manure on his fields, or someone

having a furnace or fuel tank or a punctured line that breaks free and results in suspected contamination of soil. There were past reports of naturally occurring arsenic, uranium, fluoride and sulphur in the groundwater of the west coast. Lead in water came from old plumbing systems. Some other studies have also found radioactive lead isotopes in the groundwater.

Generally, after detection of contamination of any sample, the local environmental health officer immediately contacts the well owner by phone in order to inform and provide advice on protective measures, such as disinfection and maintenance of the well. Often, such measures include no consumption of such water before boiling, disinfection of the well and submission of another sample for testing after the disinfection. Repeat bacterial contamination following disinfection prompts follow up advice or a visit by an inspector to assess the well to provide additional information including proper construction of the well. If management and mitigation strategies fail to restore water quality, the alternative would be to advise the well owner to look for an alternate source of water or to look for another water treatment option.

In the past 20 years, at least four major giardia outbreaks (beaver fever) have occurred in the region. There has been an average of 6-10 cases of confirmed giardia specimens submitted by physicians and the routine includes follow up to identify the possible sources of exposures. Around 60% of people in the backcountry or recreational areas were infected with giardia due to use of water from the surrounding streams or ponds. However, there has also been the possibility of contamination of well water due to surface run off. Unfortunately there is no water testing facility to identify giardia in water and cases are essentially diagnosed clinically.

One health official emphasized that the department's future collaborative efforts on the improvement of private well water quality would include public education as well as providing facilities, staff and other resources for monitoring water quality and testing water samples for contamination. However, a health official pointed out that effective collaboration with communities depended on the interest of a particular community regarding the quality of their well water. In the past, some of department's initiatives on community engagement had mixed responses. The government mandate covers public wells. However, there has been some movement to make mandatory testing of private wells if intended for public consumption such as in a school or restaurant**.**

Environment official's perspectives

Private water supplies do not have mechanisms and stipulated regulations for quality monitoring due to the nature of their ownership. Therefore, privately owned wells are used at one's own risk. Issues such as regulation, monitoring, treatment, the nature of wells, whether dug or drilled, as well as the construction and maintenance of the wells are some of the major determinants of preference of use of water for drinking in the community. In fact, untreated water from private wells is one of the major concerns. Besides, most dug wells are usually not properly constructed in comparison to drilled wells and they also tend to have poor maintenance records.

Private well owners need to be more proactive and should be responsible to monitor their water on a regular basis. Hence, the department offers appropriate reference materials which advise and encourage the owners of private wells to submit samples of their well water to the department for testing for coliform at least twice every year or season without incurring any cost. Private well owners are also advised to test their well water for inorganic contaminants even if it costs more rather than using the water at their own risk.

One of the major challenges is the inconsistency of existing policies and the regulations to include private wells in routine monitoring. This is compounded further by the fact that the clear status of wells in the province is obscured and therefore largely unknown in terms of their exact locations, distribution, and density in the whole region. Obtaining the particular status of all wells in the region might prove difficult, especially with regard to private dug wells. Private drilled wells may be easier to identify through reports of listed well drillers or the well owners.

Certainly, there is a policy that requires all owners of wells in the region to register their wells with the Department of Environment and Conservation and also to show the competency of well drillers they engage. In fact the registered drillers furnished the paper work and submit. However, this regulation only focuses on the owners who would be engaging well drillers but remains silent on those owning dug wells. Another major concern with regard to the existence of unknown wells is the fact that these wells are directly linked to public water resources through aquifers and groundwater and therefore if not properly managed, may increase susceptibility to contamination of the entire region's groundwater system. This would increase the risk of contaminating everyone's well water supply. For instance, if one decided to store fuel next to one's own private well, then leakage may end up contaminating other wells that pull water from the same aquifer.

Coordination of municipal affairs and infrastructure for public health is important due to its obvious implication on drinking water and the general health of the community. Government Services remains one of the most vital departments as it is directly concerned with the quality of groundwater resources including issues that are related to bacteriological as well as issuance of water advisories for public water supplies. The Department of Natural Resources may not have a direct link with the issues related to drinking water but it is useful to be engaged as the department has been involved with the management of protected water supply areas of which ground water is one component. Those with the responsibility of managing crown lands would be another important link when it comes to cabin construction. So given that anything can happen, any project or activity that can contaminate the water or negatively impact on the water resources in the area is taken care of through collaboration with the diverse networks of institutions in the area.

Discussion and recommendation points

- Maintenance of the water quality of private wells is extremely important because communities utilize the water for all regular household activities, such as cooking, drinking, washing, and bathing.
- As multiple departments are involved in management of water, it is believed that a coherent policy of coordination and sharing of information will benefit the community.
- Almost one fourth of the drilled wells and three to four fifth of dug wells are at risk of becoming contaminated by with bacteria. This can indicate the existence of openings (e.g. cracks) that allow potentially contaminated surface water to infiltrate ground water supplies. The implication is that contaminated ground water may contain pathogenic organisms that, if consumed, could result in illness and adverse health outcomes. As compared to drilled wells, dug wells need more attention with regard to maintenance and monitoring of water quality.
- Changes in the quality of the water from season to season support the recommendation from the provincial government that water testing should be carried out regularly throughout the

year. Chemical analysis revealed the vulnerability of some communities due to the presence of arsenic and fluoride. Hidden chemical contamination can have very significant adverse health consequence in the future. Chronic illnesses due to long-term chemical exposure can add a further burden to the province's health budget. The sources of arsenic and fluoride contamination are believed to be geological; however, more extensive well water and geological surveys of the area are needed. The arsenic affected community had a past record of contamination, which strengthens the need for an in-depth survey.

- Water filters, used inside the home, played a limited role in the removal of contaminants from well waters sampled, although they did function to improve the taste and odor of the water. In order to remove specific contaminants, identification and promotion of appropriate filters is needed. There is a need for more community outreach effort to disseminate the right information on water treatment and filters. Currently, many well owners are influenced by internet content and fall prey to misleading information.
- Some communities' refusal to participate in our study indicated a communication gap between the community and the municipal authority. There was also a lack of awareness among the communities who actively participated in the study. Greater partnership among the communities, municipalities, and the provincial authorities (health, environment, etc.) will improve the maintenance and monitoring of wells, and adherence to the government guidelines. Media and internet are playing significant roles in disseminating information to the communities. The authorities can take advantage of the same channels to convey the right message. Institutions like Memorial University can get engaged and play a lead role to bring all the stake holders together. There is a need for advocacy at the provincial level to make water testing of private wells mandatory.
- The study showed that routine maintenance alone cannot ensure potable water. Retesting is required to verify its efficacy. Apparent good physical impressions like transparent, colorless and odorless water are insufficient indicators for its purity.
- A lack of economic prospects for remote communities and lowering of household incomes due to outmigration of the younger generation are a major hindrance for promotion of a public water supply. Moreover, cultural factor, such as intolerance to the smell of artificial chlorine, further discourages the shift to public supply.
- Communities felt that accessibility to water monitoring facilities can bring significant improvement in water quality and in order to sustain this initiative, communities are ready to share a part of the expenditure.
- More stringent regulation is needed to register new wells and to control indiscriminate drilling, which has resulted in the rapid fall of water level in several places. Stricter vigilance is also required to ensure the proper sealing of abandoned wells. This will help to prevent seepage of contaminants to aquifers.
- A complete inventory is needed for all currently used drilled, dug, and abandoned wells. Moreover, the municipalities must be expected to update the status of all private wells including risk factors, such as conditions of the wells, location of septic tanks, fuel tanks, roads, water bodies, agricultural lands, animal barns, slopes etc. Similar activities need to be carried out by the concerned cabin associations, where municipalities do not exist.

Outcome of synergy session at Corner Brook

As a part of the project, we have shared the research findings with the community, academicians,

government officials and reporters in Corner Brook. The Harris Centre and Grenfell Campus of Memorial University jointly organized the synergy session on 26th June, 2012. The presentation was made by Dr Atanu Sarkar, Principal Investigator, and it was followed by a one hour discussion. The outcomes of the discussions are as follow:

- Proper waste management is mandatory to ensure good quality groundwater. Municipalities and the provincial government are the keys to play a major role to protect water resources, particularly in remote communities.
- Dairy farms and agriculture farms are the major threats to underground and surface water resources. There should be more stringent regulation on management of manures. Local water resources should be protected from manures, fertilizers and pesticides. Manures can be managed in a more environmentally friendly manner, such as production of biogas, which provides energy and kills all pathogenic microbes.
- Information dissemination on water quality and its management needs to be improved. Current access to information is not very helpful.
- Communities, municipalities and provincial government recognize the need for establishment of an accredited lab in this province for analysis of physical and chemical parameters of water.
- There is need for a complete inventory of private water resources, such as wells, springs, ponds, etc. in the whole province.
- Stronger regulation for registration of existing and future wells. Well drillers should be part of this knowledge empowerment and active stakeholders in maintenance of this registration.

References

DOEC 2001, Source to Tap - Water Supplies in Newfoundland and Labrador, Department of Environment and Conservation, 2001, St John's, NL.

DOEC 2008a. Hydrogeology of Agricultural Development Areas Newfoundland and Labrador, St John's, NL http://www.env.gov.nl.ca/env/waterres/reports/ground_water/chapter_14_humber_valley_ada.pdf

DOEC 2008b. Near Real Time Groundwater Levels and Water Quality of Farming Areas in Newfoundland and Labrador (Final Report), St John's, NL

DOEC 2010a. Groundwater Usage Statistics, St John's, NL http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/data/useage.html

DOEC 2010b, Groundwater Quality Data (till Dec 1997), St John's, NL http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/data/quality.html

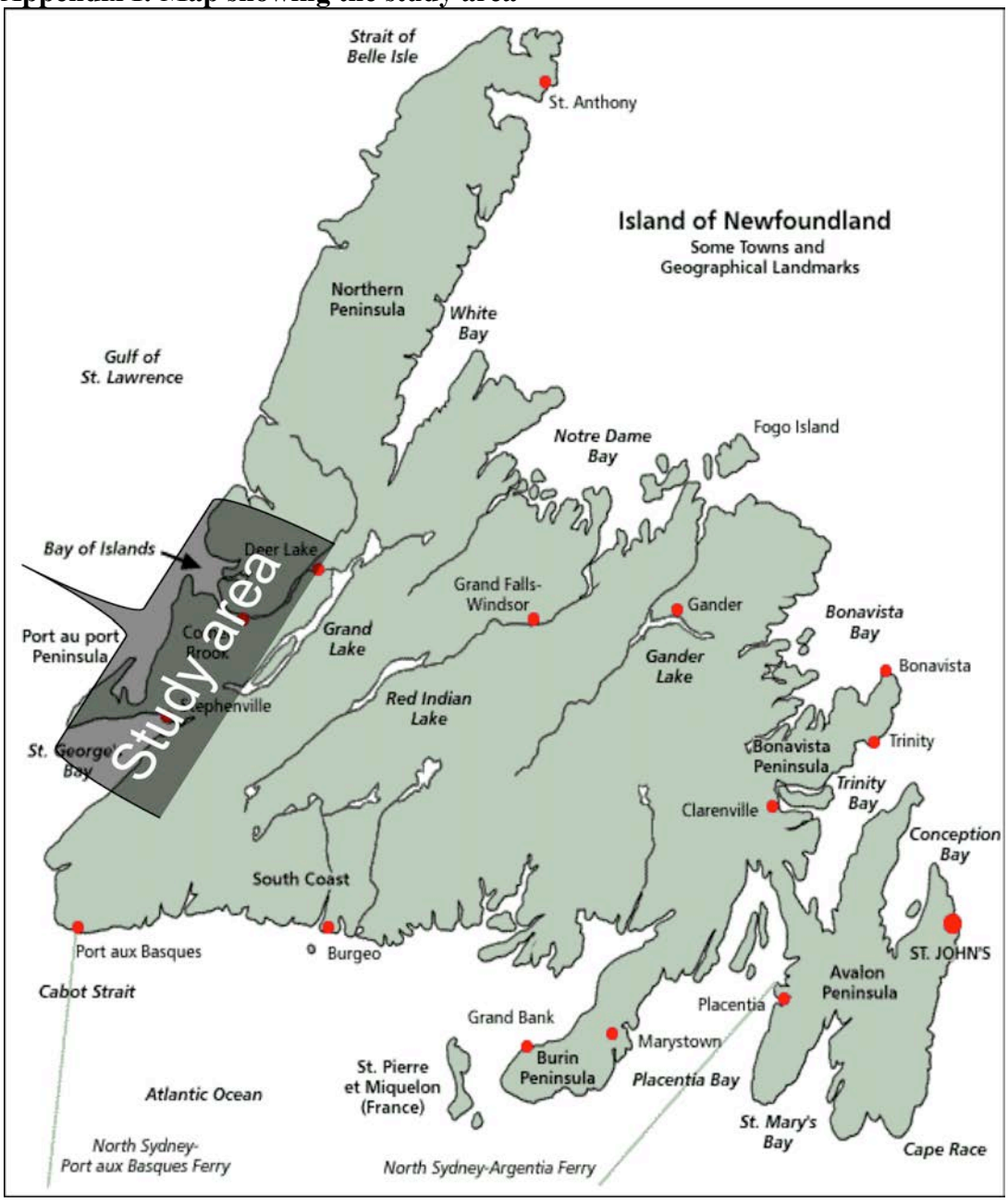
DOEC 2010c. Well Water. St John's, NL http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/well/index.html

DOEC 2010d. Newfoundland and Labrador Water Treatment Plant Inventory, St John's, NL http://www.env.gov.nl.ca/env/waterres/waste/inventory.pdf

Guzzwell GK, Geo P. 2000. A Report on the Water Quality of Dug Wells Lined With Galvanized Steel Culverts. Water Resources Management Division Department of Environment and Labour, & Support Services Division Department of Government Services and Lands

Howse D. 2003. Newfoundland and Labrador Drinking Water Survey, DOEC, St John's, NL

Appendix I: Map showing the study area



Appendix II

WELLWATER SAMPLE COLLECTION FORM

Identification of well owner:
Name:
Address:
Contact number:
Email:

Sample coding:
Microbiological testing

M										

Chemical testing

C										

Community: Cormack (CM), Humber village (HV), Little Rapids (LR), Bay St. George's South (SG), York Harbor (YH), Georges Lake (GL), Pinchgut Lake (PL), and Wiltondale-Bonne Bay Big Pond (WB)
Date: 01-31 (01, 02,……..30, 31)
Month: January till December (01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12)
Year: 2011 – 11, 2012 – 12
Sample sequence: 01-99 (Number will be the same in subsequent sampling from the same source)
Type of source (√): a) Dug well b) Drill well
Physical quality of water (brief description, including depth):

WELLWATER CONDITION FORM

Well Condition

1. Wellhead condition:
   (A vermin proof well cap, with two screened vents, should be firmly in place at all times to securely seal the wellhead).
2. Well annulus backfilled and sealed:
   (The annulus between the outside of the well casing and the drill hole should be filled with impervious clay like material).
3. Area immediately surrounding the well properly sloped:
   (The area immediately surrounding a well must be adequately graded for a minimum distance of 5 meters in all directions from the wellhead and must be graded to an elevation of at least 0.6 meters from the highest known surface water level).
4. Wellhead accessible and proper distance from ground surface or pump house floor.
   (The wellhead should be extended a minimum of 0.6 metres above finished grade by welding a section of steel casing, of standard pipe size and weight, to the existing wellhead. The weld

should be continuous to prevent the entry of pollutants in the well. For outside applications a pitless adaptor should be used to allow access to the well for the supply line. For wells finished inside a pumphouse a standard well seal may be used to seal the wellhead provided it is equipped with a screened vent and the electrical cable access is sealed).

5. Distance from a building:
   (A well should not be located inside, under or too close to a building unless provision is made in the construction of the building to allow access to the well for cleaning, treatment, repair, testing and inspection of the well. A well located inside a building must be finished above floor level, sealed, and vented in the same manner as a well finished outside).
6. Distance from possible sources of contamination:
7. Location of abandoned well near production well:
   All wells when abandoned must be sealed in accordance with the Department of Environment and Conservation Guidelines for Sealing Groundwater Wells.
8. Hand pump well construction:
9. Name of the driller
10. Year of registration
11. Description of the landscape (such as flood prone land etc)
12. Maintenance (including routine water quality monitoring)
13. Any Past report/s of water quality test
14. Use of well water **(√):**

cooking	drinking	pets	washing	bathing	garden	agriculture	other (mention)

15. Household treatment of well water **(√):**

no treatment/direct intake	boiling	chlorination	filter (type)	other (mention)

16. Past history of contamination, if yes, nature of contamination:
17. Actions taken to clean the well
18. Proposal for the larger initiative to promote sustainable water resource management and health in the province (tentative).

THE LESLIE HARRIS CENTRE OF REGIONAL POLICY AND DEVELOPMENT
1st Floor Spencer Hall, St. John's, NL Canada A1C 5S7
Tel: 709 864 6170 Fax: 709 864 3734 www.mun.ca/harriscentre

THE HARRIS CENTRE
Memorial University