THE OCCURRENCE OF RADON ON THE TOBIQUE FIRST NATION RESERVE AND ITS IMPLICATION FOR RADON OCCURRENCE ALONG THE SAINT JOHN RIVER VALLEY

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ABSTRACT

A survey of 6 large public buildings on Tobique First Nation land in northern New Brunswick, showed five of them to be above the acceptable limit of 200 Bq/m^3. As most of the 350 homes on the Reserve are located close to any one of these buildings, the concerns generated by the test results, and resulting anxiety for radon in their own homes by residents, was high. This was fueled by the historic high incidence of cancer on the Reserve. While Health Canada recommends a 90 day test, this wait was unacceptable to the Chief and Council. Consequently, a two day residential radon test was conducted for each of the 350 homes on the Reserve, as this was a relatively fast way to screen homes into three categories.

Over a period of three weeks, two E-Perms were installed in each of the 350 homes. In addition, several soil vapour monitor wells were constructed to assess the levels of radon in the soils near some of these homes. An analysis of Uranium content in soils was also undertaken. The results indicate that greater than 50 % of the homes have radon levels greater than 200 Bq/m^3, with 11.7% of these showing levels greater than 600 Bq/m^3. The paper will discuss the implications of the 2 day high density radon survey; its relationship to the 90 day test; the relationship of radon levels in homes to background levels in soil; and the implications for numerous other communities along the Saint John River Valley that potentially lie on the same sand and gravel deposits that lie beneath the reserve.

Background

The Tobique First Nation Reserve is situated in the north-west corner of the Province of New Brunswick. (*Figure 1*)

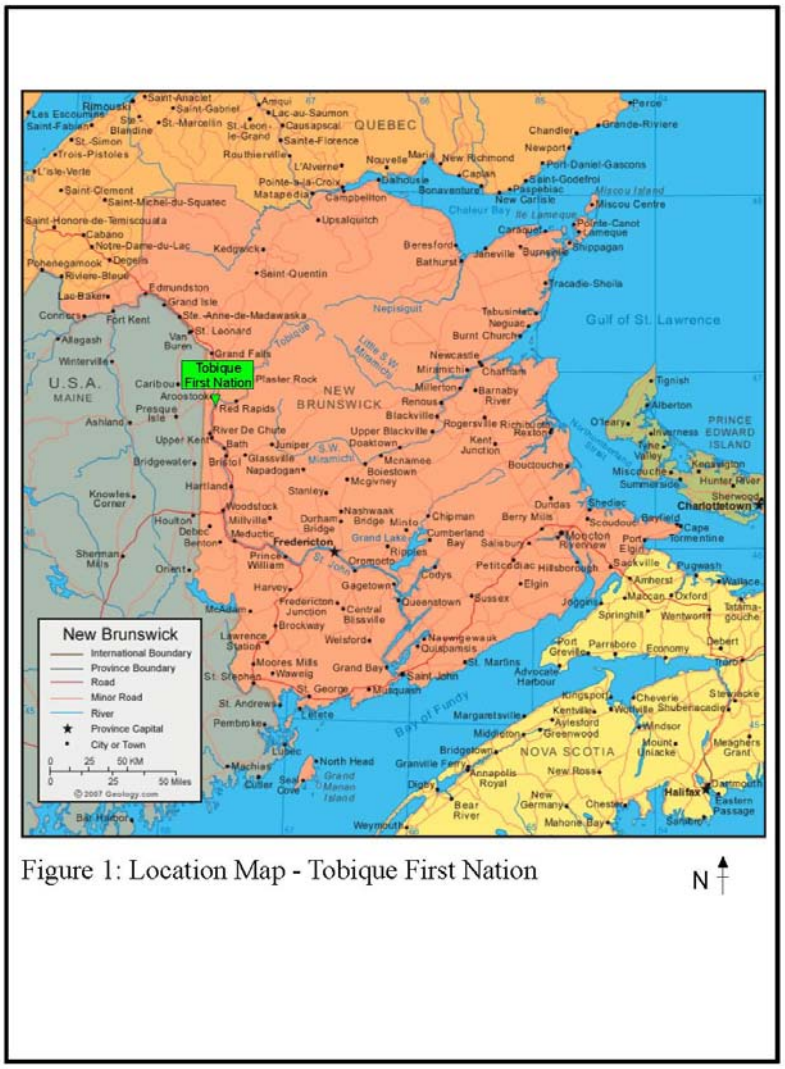

Figure 1: Location Map - Tobique First Nation

The Reserve lies in the Saint John River Valley, which forms the border for some of its length with the State of Maine. The majority of reserve housing (80%) is mainly located on a glacial floodplain consisting of flood, channel and overbank deposits of sands and gravels. (1) (*Figure 2*)

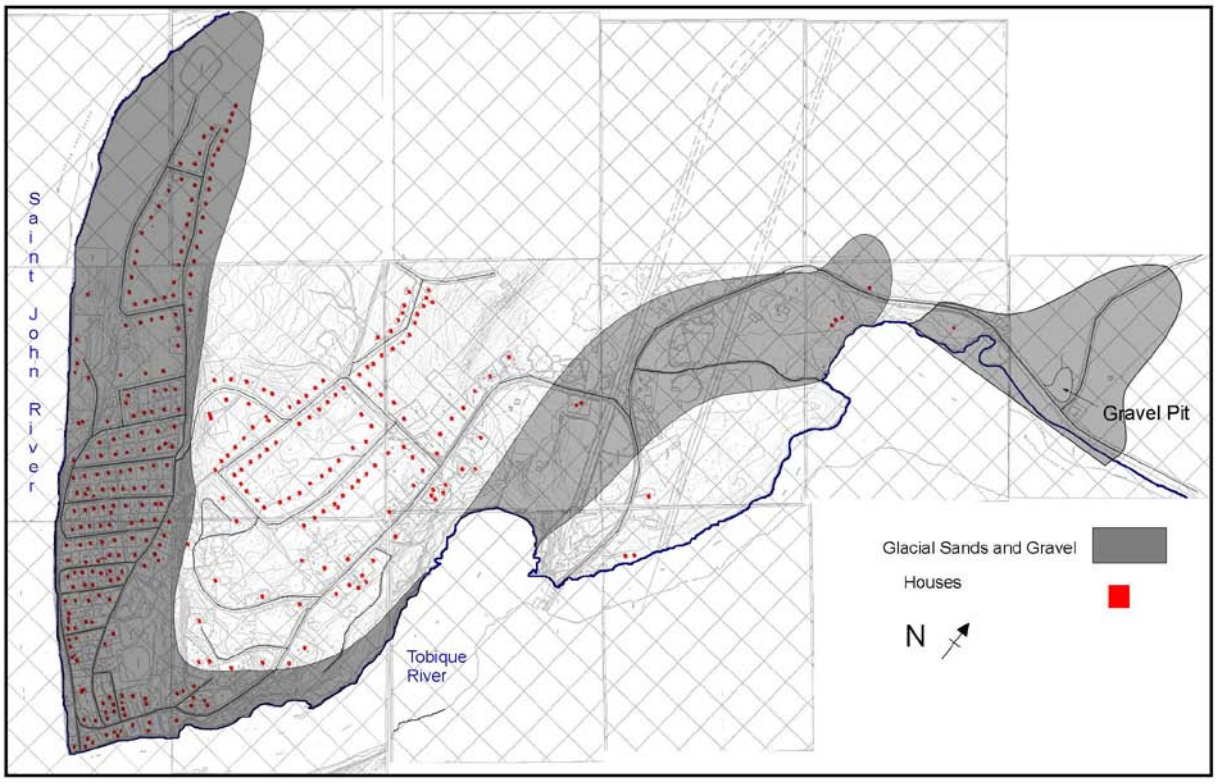

Figure 2: Surficial Geology Deposits

These granular deposits lie beneath the main part of the Reserve to depths approximating 15 m (50 ft). The water table on the glacial floodplain lies some 5 metres (16.4 ft) below ground surface. The remainder of Reserve housing lies on the gently to steeply sloping river valley slopes and are underlain by ablation tills composed of an agglomeration of poorly sorted gravel, sand, silt and clay. Thickness of these deposits varies from 1 m to 4 m (3.3 to 13 ft).

The bedrock beneath the glacial sands and gravels and which is exposed along the river valley is composed of argillaceous limestone interbedded with calcareous shales. (2)

Adjacent to this area of New Brunswick lies the State of Maine, and the County of Aroostook. Radon surveys in this county indicate that an estimated 49% of homes have radon levels greater than 4 pCi/L (148 Bq/m^3) and that the average indoor air radon level is 6.6 pCi/L (244.2 Bq/m^3) (3). No generalized information on radon occurrences in Victoria County, the adjacent county in New Brunswick, is available or published.

Investigation

In October 2010, Health Canada, as part of a national survey program, undertook 90 day radon testing using TASL alpha track detectors in the six buildings under federal responsibility, located on the Tobique First Nation Reserve. Of these six buildings, five (80%) showed radon levels above the 200 Bq/m^3 (5.4 pCi/L) guideline. In these five buildings, radon levels varied from 200 Bq/m^3 (5.4 pCi/L) to a high of 1,217 Bq/m^3 (32.9 pCi/L). These results, which were presented to the Reserve residents in February of 2011, raised considerable anxiety and a great deal of concern as the Reserve, over the years, believes that it has seen significant numbers of residents contract various types of cancer.

The high percentage of buildings in the Health Canada survey that showed high radon levels was taken, by the Reserve residents, to indicate that an equal number of Reserve homes could be equally impacted by radon. The Chief and Council wanted to react to these concerns and to lower the anxiety levels of residents. Health Canada's recommendation was to conduct 90 day tests, preferably in the winter months, before any mitigation can be recommended. In the case of the Tobique Reserve, application for funding and the normal lengthy approval would make the testing period fall in late 2011 with results available in 2012 and mitigation work, if required, in middle to late 2012. The level of anxiety on the Reserve was such that this timetable was unacceptable.

Consequently, a screening survey of all homes was proposed using a two day (48 hours min.) two unit test. The intent of this was to: allay fears; reassure the residents that something was being done; determine homes with high to very high radon levels; identify homes where 90 day tests would be needed to confirm mitigation; and, where radon levels were such, that allowing a considerable time to elapse would not expose the residents unduly to high radon levels; and to identify homes where mitigation, based on risk assessment, data and evidence, was required.

Previous Radon Surveys

Federal Building Radon Survey

The only specific data available for the Reserve was obtained by Health Canada (4). The summarized results are presented in *Table 1*.

Table 1: Federal Building Survey-Tobique Reserve – (Radon Bq/m^3)

Building #	1	2	3	3	5	6
Max	1217	520	390	277	<200	261
Min	299	411	235	211	<200	231
Average	497	455.3	285.7	233.5	<200	246

Cross Canada Survey of Radon Concentrations in Homes

A generalized data set was obtained by the federal government during a national survey (5). These results were reported by the Health Region. The health region containing the Reserve is Region 3 and is shown in bold on *Table* 2.

Table 2: Radon Levels for Health Region 3 – Tobique Reserve		
Health Region	> 200 Bq/m^3	>600 Bq/m^3
1	9.8%	2.0%
2	8.1%	0.0%
3	**17.3%**	**7.7%**
4	25.0%	3.6%
5	26.4%	5.7%
6	33.3%	18.5%
7	26.8%	3.4%

NB: Numbers reflects a 75.4% response rate to the 90 day survey. Numbers of respondents in New Brunswick were 392, the total for all regions. (ie: average of 56 respondents/region.) Region 3 covers the area of two counties.

Reserve Residential Housing

Typically, Reserve homes are 1,200 to 1,500 ft^2 in size, and consist of a single storey bungalow with a poured concrete wall basement. Typically, basements are occupied, with one and sometimes two bedrooms; laundry room; recreation room and /or storage. Most homes have an open basement sump into which the outside perimeter tile drain emptied. No sump pumps however were seen in these sumps. (**Photographs 1 and 2**)

Photograph 1- Unfinished Sump Hole

Photograph 2- Temporarily Covered Sump Hole

From one to three small round drains are present in the concrete floor of the basement. (**Photograph 3**)

Photograph 3 Unsealed Drain Holes

Basement floors normally showed both settlement and shrinkage cracks. (**Photograph 4**)

Photograph 4: Crack in Basement Floor

Vertical basement walls, where exposed and could be observed, often contained fine cracks. The homes investigated and/or assessed were a cross section of the types and structures of the homes built on the Reserve. Homes had been constructed in large groups over the years that funds were available. Consequently, four to five different housing layouts were found, which were applicable to the majority of homes. There are also four long single storey buildings containing four small apartment units.

Radon Testing

E-Perms

The tests took place in March 2011, when there was an average 0.6 m (2 ft) of snow cover; a frost layer 0.6 m (> 2 ft) thick, and, when homes were under winter heating conditions. Two E-Perms were installed in 350 homes on the Reserve. They were installed using standard placement

distances. At the end of the time period they were collected and analysed. Of the 350 E-Perm sets, we found that 4 sets had been moved during the test period by children, and some residents had moved the E-Perms to locations they spent the most time in, from the locations that they had been set. We found that 346 test sets were untouched and the results were considered applicable.

Sniffer Surveys

With the results of the E-Perm survey, a determination was made considering all data and available information that the homes with the highest radon concentrations should be considered for mitigation. In order to assess the building needs for mitigation, sniffer surveys were conducted in several typical house layouts. A Model VS472 Sniffer, manufactured by Environmental Instruments Canada Inc., was used to assess radon entry points in these basements. These surveys were conducted in early summer 2011.

Soil Surveys for Radon Gas

Given the known radon results from the Health Canada survey it was apparent that soil radon gas concentrations had to be sufficiently high to cause the results found in the buildings. During a forensic radon audit of the Wolastoqewyik Healing Lodge in early March 2011, three shallow boreholes screened over the last foot, were drilled outside the building. When monitored, using the VS472 sniffer for 5 minutes, high concentrations of radon were seen. Consequently, additional shallow boreholes (10) were constructed across the Reserve in late spring to assess the background radon gas concentration in the glacial soils.

The shallow boreholes consisted of a 3 ft (0.9 m) section of solid one inch (2.35 cm) PVC pipe attached to a 1 ft (0.31 m) section of PVC screen.

The results from these shallow boreholes were supplemented by the monitoring of six deep boreholes, drilled in February 2011, for an environmental assessment for two oil spills. The deep boreholes consisted of 10-15 ft (3.05 – 4.6 m) of solid PVC pipe and screen lengths from 15-30 ft. (4.6 – 9.14 m). All boreholes were left for a minimum of 5 days before monitoring for 5 minutes using the VS472.

While no known Uranium occurrences are present in the region, the radon levels would indicate that dispersed Uranium may be present in the glacial deposits.(6) Consequently, four soil samples were obtained from the shallow boreholes and were analysed for Uranium content.

Results

Housing Survey

The house surveys identified the presence of a number of openings, through which radon could easily enter. The total area of average size openings into a typical basement is shown in *Table 3*.

Table 3: Typical Size Basement Openings	
Sump	0.79 ft^2 (diameter 1 ft - 0.3 m)
Cold Cracks	2.08 ft^2 (0.2 inch - 0.064 m width)
Drains (2)	0.08 ft^2 (0.25 ft/0.08 m diameter)
Floor Cracks	0.6 ft^2 (0.1inch - 0.03 m width)
Wall Cracks	0.017 ft^2 (0.04 inch - 0.01m width)
Total opening available for radon entry:	3.56 ft^2 (0.331 m^2)

E-Perm Survey

The results of the E-Perm survey are shown in *Table 4* and *Figure 3*.

Table 4: E-Perm results		
Homes Tested	350	(Suspect Units = 4)
Totals (All) E-Perms	350	(Totals Homes Accepted = 346)
<200 Bq/m^3	167	166
200-600 Bq/m^3	142	159
>600 Bq/m^3	41	41
Percentage of Homes with Radon above the Guideline of 200 Bq/m^3		
>200 Bq/m^3	52.3%	50.9%
>600 Bq/m^3	11.7%	11.7%

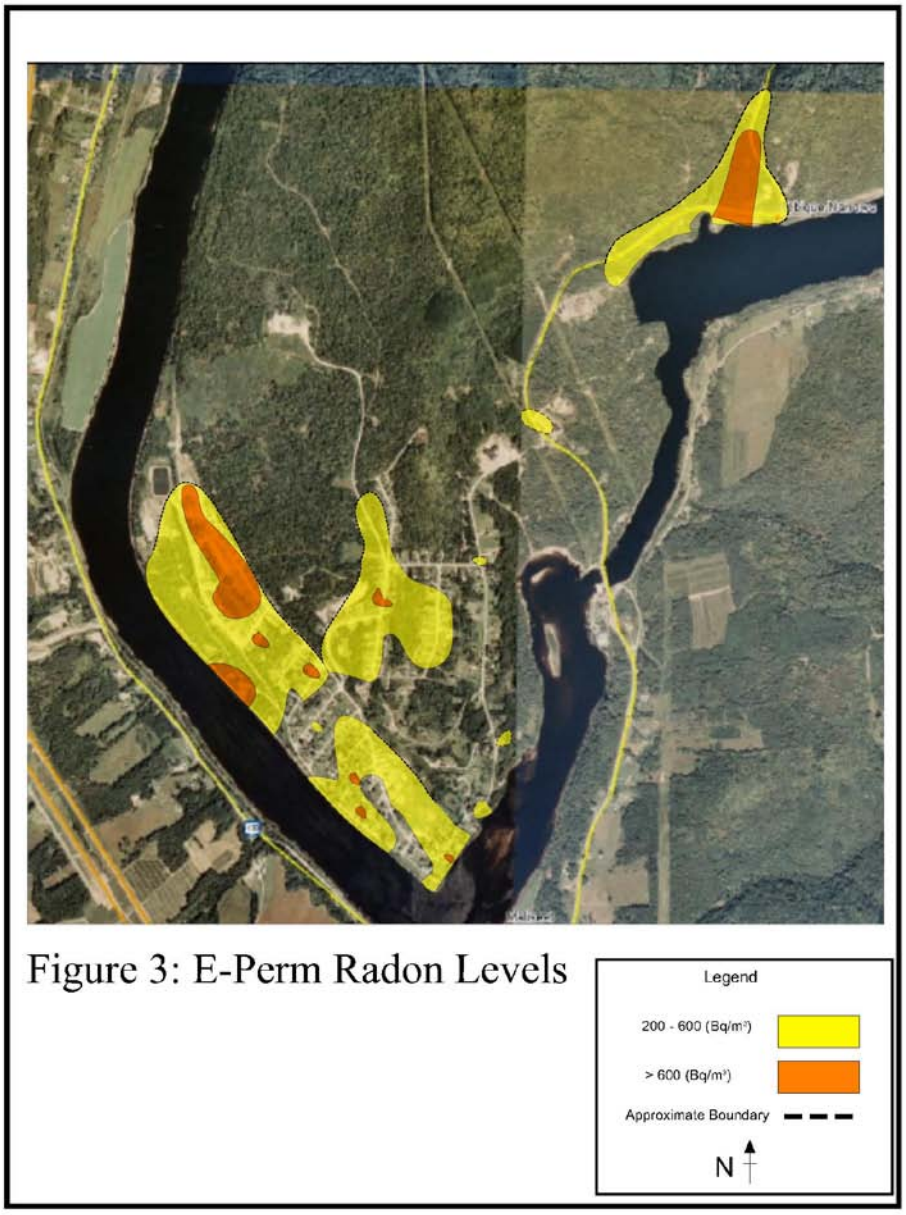

Figure 3: E-Perm Radon Levels

Sniffer Survey

The detailed sniffer survey of 5 houses where the E-Perm tests gave radon concentrations above 1,000 Bq/m^3, identified several potential radon entry openings. These are shown in *Table 5*. Openings of the similar configuration and size were identified in many other homes, which were surveyed for mitigation purposes.

Table 5: Potential Radon Entry Openings in 5 Homes, June 2011	
2 day Test Radon Levels in these homes were 3,767.7 to 1,086 Bq/m^3, (March 2011)	
Ambient Radon in Basement Air (June 2011)	1,140 to 633 Bq/m^3
Cold Cracks (1)	3,780 Bq/m^3
Sump/Drain (3)*	9,760 to 3,357 Bq/m^3
Floor cracks (2)	1,816 to 1,218 Bq/m^3
Under floor slab (14)**	4,174 to 1,125 Bq/m^3
*Number of tests	
** Holes drilled for connectivity testing	

Soil Radon Gas Survey

In total, 13 shallow boreholes have been constructed in the glacial sands and gravels of the Reserve, while 3 were completed in the ablation tills (sands, gravels, silts and clays) that lie on the valley sides. The glacial sands and gravels of the valley floor have water tables deeper than 5 m below ground surface. On the valley sides, the glacial sands and gravels show water tables greater than 15 m in depth. These glacial deposits have an estimated pore space percentage of 25% to 40%.

The three shallow boreholes drilled around the Healing Lodge in March 2011, gave radon concentrations from 1,150 to 1,387 Bq/m^3. These readings were obtained beneath a 0.6 m of frozen soil and 0.6 m to 1.0 m of snow cover. All other boreholes were monitored in June 2011. The results are shown on *Table 6* and displayed on *Figure 4*.

Table 6: Radon Levels in Soils (Bq/m^3)	
Shallow Boreholes (13)	
Glacial Sands and Gravels	310 - 2145 (ave. 920.6)
Ablation tills	293 - 1,555 (ave. 855)
Deep boreholes (6)	
Glacial Sands and Gravels	267- 1,226 (ave. 700.8)

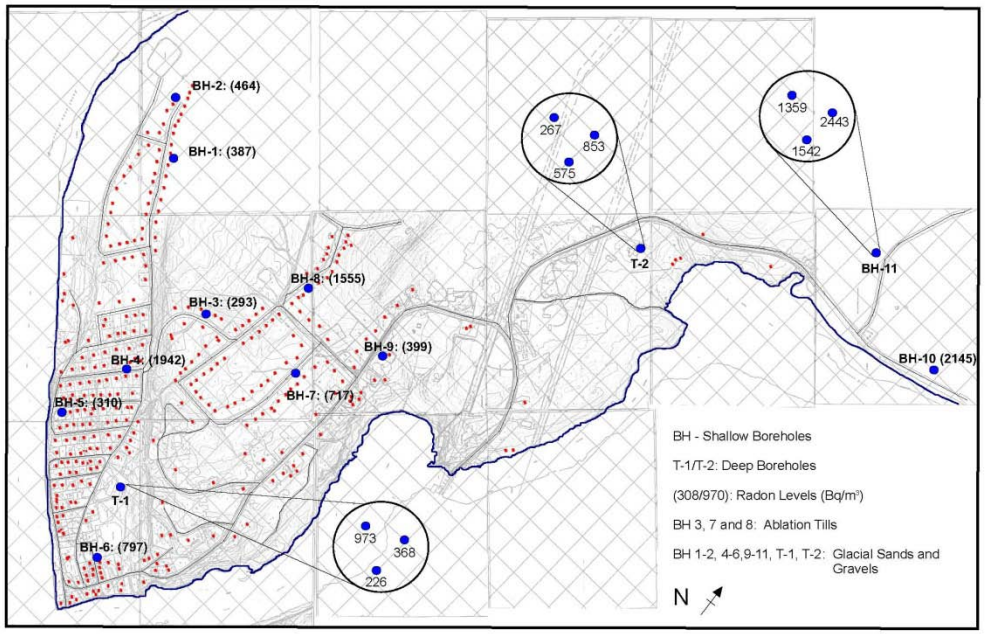

Figure 4: Radon Levels in Soils

Uranium in Soils

The soil analyses provided results of Uranium content of 0.4 to 1.2 mg/kg for the four soils samples.

Discussion

The results of the E-perm survey showed that approximately 50% of the homes on the reserve showed radon levels above 200 Bq/m^3. It is interesting to note that the percentage of homes in the County of Aroostook in the State of Maine, which lies immediately across the border from Victoria County in New Brunswick and the Reserve, has a somewhat similar percentage of homes (49%) above the US limit of 148 Bq/m^3 (4 pCi/L). This gives some indication of a potential commonality of radon occurrences across the entire area. Also, on an area basis, the results of the Cross Canada Survey by Health Region indicated that 17.3% of homes had radon levels above 200 Bq/m^3, with only 56 homes, on average, were tested per region. In the case of the Reserve 350 homes were tested. These tests were conducted on a significantly denser ratio than the Cross Canada Survey. Even given the potential difference in readings between the short term tests and the 90 day tests, the results indicate that the percentage of homes above 200 Bq/m^3 in this, and likely other health regions could be much higher than previously thought. Of the 50% of homes on Reserve above 200 Bq/m^3, 11.7% were found to have radon levels above 600 Bq/m^3, while the cross Canada Survey found 7.7% be to above 600 Bq/m^3 for this region. While

the two day E-Perm test is not comparable to a 90 day test of the Cross Canada Survey in its ability to predict long term levels or a need for mitigation, it does confirm that the high concentrations of radon present in the soils have access to the homes and can be present in the homes at high concentrations.

The results of the E-Perm tests have been plotted on and are shown on *Figure 3*.

While the use of the results to generate an occurrence map is questionable, given that several factors influence the presence of radon in homes, the exercise is still useful as the majority of homes possess similar features, structures, entry points and radon levels in soils beneath and adjacent to the homes. It is interesting to note that the main section of the Reserve, with the highest density of homes, is located on the glacial sands and gravels and also shows greatest number of homes above the guideline. This, together with results of the radon testing in the soils, presents a strong case for linking the radon occurrences in homes to these glacial deposits.

On the Figure, two areas are defined where the radon levels in homes were lower than 200 Bq/m^3. Given that homes in these areas were of similar construction and basement type, the reason for lower levels of radon may be due to the location of these homes over a fine sand layer. These fine sands are present from ground surface to a depth of as much as 2 m. Coarser sands and gravels are present under the remainder of the Reserve located on the glacial floodplain. The fine sands would be more susceptible to moisture blockage of pore space and would also have a lesser ability to allow mobilization of the radon gas.

The soil probes have provided confirmation that there is a strong source of radon present beneath the Reserve in both the glacial sands and gravels of the valley floor and the ablation till of the valley sides that is the cause of the radon presence in the homes. Given that these soils are highly porous and non-saturated and that the radon gas consequently has a high mobility potential through these soils the presence of high levels of radon is not a surprise.

Comparing the shallow and deep soil probes boreholes, we see that the average concentration in the shallow boreholes of 905.9 Bq/m^3 is similar to the average for the deep boreholes of 700.8 Bq/m^3. This would tend to indicate that the radon source and generation is relatively evenly distributed throughout the soil profile. Radon is estimated to have a mobility of 2 to 3 m. (7)(8). Given the high levels of radon found beneath the floors of the homes, the potential for mobilization of radon immediate to the basement and the distribution and generation of radon throughout the soil profile, the potential for radon presence in homes over the long term is high.

While conducting the sniffer surveys for identification of radon entry points, we covered two sumps with plastic sheets, to assess other openings without interference from the radon entering the sump and we noted a definite rise in the plastic covers of the sumps, when doors were opened on the main floors of the homes. (*Photograph 5*)

Photograph 5: Raised Plastic from Stack Effect

This demonstrated an active "stack effect' in June, a summer month. One can then reasonably assume, that these stack effects will be much greater in the winter months during active heating of the homes.

Health Canada states that short term measurements are "never acceptable to determine if the radon concentration exceeds the Health Canada guideline to assess the need for mitigation" and it "recommend that the results of a short term test be confirmed with a 'follow up' long term test made at the same location". While I accept that a recommendation for a 90 day test prior to determining a need for mitigation is an excellent recommendation in 95% of situations, there are some situations where other evidence and data may preclude such a recommendation and where the risk is high enough to recommend mitigation without the long term test. In the case of the some of the Reserve housing such a situation exists.

Consequently, I recommended that mitigation be conducted on the homes where high concentrations of radon were found. I further recommended that 90 day tests be conducted on those homes with lower radon levels. This recommendation was based upon all the data obtained from the investigation into the radon levels on the Reserve, not only on the 2 day E-Perm results. The results were considered together with the following factors in considering a recommendation for mitigation where radon was present at high levels:

- There exists beneath reserve housing a source of high levels of radon gas.
- The radon gas resides in highly porous non-saturated soils which impart ease of mobile to the gas.
- Reserve housing in general, possesses numerous openings that allow radon entry and these openings, when combined, are significant in total size.

- High levels of radon are present in houses in both winter and summer months on a short term basis.

- Stack effects are observed to be operative in houses in summer months.

This accumulated information, assessed on a risk basis, indicates that at least homes with high levels of radon should be mitigated as there are no known factors would indicate that long term radon levels would be reduced to less than guidelines of 200 Bq/m^3.

Consequences for the Saint John River Valley

The same glacial soils that are present beneath the reserve are also present throughout the entire Saint John River valley. The larger deposits of glacial sands and gravels are shown on *Figure 5*.

Figure 5: Glacial Sands and Gravel Deposit Saint John River Valley

Numerous other adjoining smaller deposits are also present especially along the smaller of the valleys of the Saint John River valley system. Are the conditions on the Tobique Reserve applicable to other housing along the Saint John River Valley?

It is estimated that between 145,000 and 150,000 people live in the Saint John River Valley. At a household average of 2.6 persons per home this would equate to the presence of 57,600 homes in the River Valley. Of these, approximately 40,000 homes are single family detached dwellings. Many of these homes were built over 50 years ago and a significant number, over 100 years ago. These homes often have basement walls composed of field stone joined by lime

mortar. In addition, these basements often have dirt floors. Many of the houses younger than 50 years will have cold joints and sumps similar to the houses on the Tobique Reserve.

Overall, one can assume that there is some degree of commonality in house building, structure and basement as was evident on the Reserve. Given that similar glacial soils, also likely high in radon, lie beneath a significant portion of these houses; and significant openings exist to allow radon entry; the risk of similar levels of radon in the homes throughout the valley, is considered to be high. Towards the lower end of the Saint John River Valley, lies the City of Fredericton. A recent study of thorium exposure in Fredericton indicated that an estimated 18% of homes have radon levels above 200 Bq/m^3.(9) Fredericton lies on a floodplain underlain by approximately 5 m of glacial sands and gravels. This study supports the conclusion that radon is a notable environmental contaminant present throughout the entire Saint John River Valley and which potentially impacts many thousands of homes located there.

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