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Environmental Radioactivity in Canada 1988

Radiological Monitoring Annual Report

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Environmental Health Directorate
Health Protection Branch

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Acknowledgement

This report describes the activities and measurements carried out by the Environmental Radiation Hazards Division of the Bureau of Radiation and Medical Devices during 1988. It was prepared by R.G. McGregor, with contributions from P.E. Cobbold, R.S. Eaton, B. Hauck, H. Marshall, J.M. Quinn and B.L. Tracy. The radiochemical analyses were carried out by W.G. Awrey, L. Burns, M. Iamello, J. Lahey, A.Y. Lin and W.B. Walker. The work was done under the direction of D.P. Meyerhof, Chief, Environmental Radiation Hazards Division. E.G. Létourneau, Director, Bureau of Radiation and Medical Devices, is thanked for his support of the program.

The co-operation of Environment Canada, Agriculture Canada, the Department of National Defence, Field Operations Directorate of the Department of National Health and Welfare, provincial departments, municipalities and private individuals in obtaining the samples is gratefully acknowledged.

Abstract

The radiological surveillance program of the Department of National Health and Welfare is conducted for the purpose of determining levels of environmental radioactivity in Canada and assessing the resulting population exposures. Following major changes to the CAMECO Port Hope operations to reduce uranium emissions, a study was initiated to measure uranium levels in air in the community. Studies continued on lung cancer and domestic exposure to radon, and current levels of cesium-137 in caribou, a major source of food in northern communities. The movement of tritium in the Ottawa and St. Lawrence rivers was studied following an accidental release into the Ottawa River. Monitoring continued of fallout contamination from Chernobyl in imported foods. All measurements recorded during 1988 were below the limits recommended by the International Commission on Radiological Protection.

This report is prepared as a summary of work in progress and as a means of publishing the results of ongoing programs in a format that, it is hoped, will be useful to those who receive it. Comments, suggestions and questions concerning this material are appreciated. Thanks are hereby extended to those who have taken the time to contact the Division, and an invitation is extended to everyone to send their ideas to:

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1. Introduction

The Environmental Radiation Hazards Division of the Bureau of Radiation and Medical Devices investigates the potential health effects to the Canadian population from natural and man-made sources of environmental radioactivity.

During 1988 a project was initiated to measure uranium levels in air at Port Hope, Ontario, following major changes to the CAMECO (formerly Eldorado Resources Ltd.) operations, which are expected to result in reduced emissions to air. This program will continue until September 1989. Additional special studies were conducted in the following areas:

- Continuation of the case-control study of lung cancer and domestic exposure to radon.
- Continuation of the study of current levels of cesium-137 in caribou, a major source of food in many northern communities.
- Emergency planning under the Federal Nuclear Emergency Response Plan for the reentry of the Soviet satellite Cosmos 1900.
- Determination of tritium in water of the Ottawa and St. Lawrence Rivers following a release from the Chalk River Nuclear Facility.
- Determination of radioactivity contamination of foods and consumer products following radioactivity releases from processing equipment sources.

Studies on the potential impact of radioactive emissions from nuclear reactors in Canada and residual fallout from atmospheric nuclear weapons tests were maintained.

Based on his Canadian experience with nuclear emergencies, Dr. Roger Eaton of the Division acted as a consultant to the International Atomic Energy Agency for four weeks to assist with the Agency's development of its nuclear emergency plans.

Radioactivity levels in imported foods resulting from contamination by fallout from the Chernobyl reactor accident were measured in samples from 14 countries. The program for export certification for levels of certain radioisotopes in Canadian foods continued.

In this report, results are presented in tabular form and are expressed in SI units. Radioactivity measurements are in becquerels (Bq): one becquerel is approximately equivalent to 27 picocuries. Absorbed doses are in grays (Gy): one gray is equal to 100 rads. Dose equivalents are in sieverts (Sv): one sievert equals 100 rems.

2. Special Projects

2.1 Radon Studies

A 700-pair case-control epidemiology study has been under way in the city of Winnipeg since 1986 in an attempt to discover any effect of radon on lung cancer at domestic environmental levels. During 1988, staff of the Manitoba Cancer Treatment and Research Foundation continued with interviews. Radon levels were measured by means of alpha-track dosemeters in houses currently occupied by the cases and controls. Through the interview questionnaire, the addresses of previously occupied houses are being determined. For those addresses still in existence in the Winnipeg area, the average annual radon concentration is being measured using the alpha track dosemeter in order to try to establish radon exposure over the last twenty years. To date, 500 pairs of cases and controls have been interviewed and 2,300 radon dosemeter results for six-month exposure periods have been analysed.

Development of methodology for radon measurement by alpha-track damage counting in CR-39 plastic continued, with the introduction of a microcomputer-based image analysis technique. The software adopted allows for greater flexibility, with the choice of several combinations of microscope illumination, magnification and grey level threshold. This system, being used for the Winnipeg case-control study, has increased the capacity for analysis to 200 plastic foils per day.

2.2 Radiocesium in Northern Canada

At the end of 1986, the Bureau began a program to measure the current levels of cesium-137 in caribou, a major source of food in many communities in northern Canada. Lichens are the primary source of radionuclides in grazing caribou, since, being slow-growing, non-deciduous, and rootless, the lichens retain radioactivity accumulated from atmospheric fallout. Reindeer pastures in Lapland were heavily contaminated by fallout from the Chernobyl nuclear reactor fire, and there was some concern that the grazing lands of Canadian caribou might have been similarly affected. Samples of caribou meat were taken from the major herds in the fall of 1986 and spring of 1987; additional samples were taken east of Hudson Bay in 1988. About a quarter of the cesium-137 currently present in Canadian caribou had its origin in the Chernobyl nuclear reactor; the bulk of the current activity was deposited as fallout from atmospheric weapons tests in the early 1960s and has been retained in the lichens, falling away with an effective half-life in the biosphere of 7-8 years. The current levels of activity are given in Table 1 and Figure 1.

These low levels are not expected to present a hazard to consumers of caribou meat. However, there was no information on the levels of cesium-137 in populations relying on the caribou, the amounts transferred from the meat, or the radiation doses received. There were also questions as to whether the accepted models for cesium uptake and retention, based on temperate-zone populations with a modern western diet, are applicable to the diet and living conditions in northern Canada. Further, there were some uncertainties about the amount of caribou eaten, and whether other dietary items might be contributing to radiocesium uptake. For these reasons, a program of whole-body monitoring of human subjects is planned for early 1989. During 1988, discussions were held with federal and Northwest Territories government officials, community leaders and native interest groups. As a result, two communities – Baker Lake and Rae-Edzo in the Northwest Territories – have been selected for the program. Dietary information will be obtained along with whole-body monitoring data.

2.3 Cosmos 1900

In May, 1988, it became evident that another Soviet satellite, (Cosmos 1900), carrying a nuclear power source might reenter the atmosphere and disperse its radioactive core material.

While the probability that this reentry would occur over Canada was only 3%, the potential for significant risk to health existed and a comprehensive plan was required. As a consequence, extensive planning began in June. Meetings of a coordinating group, a technical advisory group, a public information group and an operating group were held regularly until early October. As the summer progressed, the USSR acknowledged that it was unable to command the satellite to transfer itself from a near-earth orbit to a long-term storage orbit. However, there was an automatic system on board that could be activated by one of a number of possible events. Such an event occurred early on October 1 and the reactor part of the satellite was successfully placed into a 700-km-high orbit. Reentry of this core material is not expected for several hundred years, by which time most of the fission products will have decayed to the level of radioactivity present in the reactor core before the reactor was made operational.

This planning provided an excellent exercise of the Federal Nuclear Emergency Response Plan (FNERP). The experience identified some of the deficiencies in it and the Public Information Plan that has been developed, and has led to some changes. This redrafting was initiated late in the year.

2.4 Nuclear Power Sources in Outer Space

For ten years, Dr. Eaton of the Bureau has been providing technical advice to the Department of External Affairs for meetings for the United Nations Committee on the Peaceful Use of Outer Space on matters related to nuclear power sources. This advice resulted from Canada's experience in the recovery of Cosmos 954 in 1978 and its lead role at the United Nations on this subject.

Through its Scientific and Technical and Legal Subcommittees, this committee is endeavouring to establish legal principles for the safe use of such power sources; a number of principles have already been settled.

Although consensus was reached on one additional principle in 1988, the criteria for the safe use of such satellites remain a problem. However, improved co-operation from the Soviet Union augured well for the negotiations in 1989.

2.5 Uranium Emissions in Port Hope

In 1981 and 1982, this Division undertook a study of air-borne uranium concentrations at various locations in Port Hope, Ontario. The studies began after emission control equipment problems at Eldorado Resources Limited (now part of CAMECO) led to enhanced levels of uranium dust in the town. The results showed that average uranium concentrations were a factor of 50 below allowable limits for members of the public[1]. Major changes to Eldorado Resources Limited operations at Port Hope in 1983 were expected to result in reduced uranium emissions to the atmosphere.

After discussions with the Atomic Energy Control Board, a project was undertaken to measure the uranium levels in air at various locations in the community. In June 1988, six high-volume air-sampling stations were installed at the locations shown in Figure 2. A seventh station was established at the Harmony Creek pumping station in Oshawa, 40 km west of Port Hope, to serve as a control. Air filters are changed weekly at these sampling stations and are returned to the laboratory for uranium analysis. An Anderson cascade impactor is being used on a rotating basis at each of the stations to determine the size distribution of the uranium particles. Thermoluminescent dosimeters (TLDs) were placed at each of the air-sampling stations, and at various points around the fence of the CAMECO refinery and the waste storage area on Dorset Street East. These are read quarterly to obtain average gamma radiation doses.

The monitoring program will continue until September 1989. The results of the study will be presented in the next annual report.

2.6 Consumer Products

In February, some devices used to reduce static electricity in commercial packaging production lines were found to be defective under tests *in situ* by the Atomic Energy Control Board. The device is a small tubular fitting attached onto compressed-air lines; the inside wall is covered with ceramic microspheres impregnated with polonium-210. In time, the glue suffers radiation damage, and individual spheres may become dislodged. Of the units in use by the Canadian food, beverage, drug and cosmetics industries, two failed Atomic Energy Control Board tests. Recent output from the two production lines, bottled mouthwash and frozen concentrated fruit juice, was tested for the presence of the microspheres.

The mouthwash was filtered and the flat filter paper was presented to an alpha-particle detector. Since each microsphere would appear as a point source of about 1000 Bq of polonium-210, they would have been very easy to detect. None appeared. The thick fruit-juice concentrate was centrifuged to recover any microspheres present. A layer of chloroform, denser than the fruit juice but lighter than the microspheres, kept the fruit juice from reburying the particles; the chloroform was dumped from the centrifuge tubes into filter funnels and the filter papers were presented to the alpha-particle detector. Again, no activity was detected.

In June it was found that the sealed radiation sources of a commercial sterilizer in the state of Georgia had been leaking cesium-137. The only product received in Canada present during the period of possible contamination was one shipment of saline solution for contact lenses. No cesium-137 was found in the solution, nor on the packages.

3. Environmental Monitoring Programs

Since 1958, the Bureau of Radiation and Medical Devices has maintained a network of 27 environmental monitoring stations at airport weather offices across Canada (Figure 3), with the cooperation of the Atmospheric Environment Service of Environment Canada, in addition to one station at the Bureau proper. The station at Hay River, Northwest Territories, was discontinued in the spring of 1988.

Further environmental radioactivity measurements are made in the vicinity of seven nuclear reactor sites:

- the Whiteshell Nuclear Research Establishment (AECL-WNRE), Pinawa, Manitoba (three monitoring sites);
- the Bruce Nuclear Power Development, Tiverton, Ontario, with eight 750 MW(e) units in service, (four at Bruce A and four at Bruce B) (seven monitoring sites);
- the Pickering Nuclear Generating Station, Pickering, Ontario, with seven 500 MW(e) units in service (three at Pickering A and four at Pickering B), and one undergoing retubing (Pickering A) (six monitoring sites; site #2 was discontinued at end of first quarter);
- the Darlington Nuclear Generating Station, Newcastle, Ontario, with four 880 MW(e) units under construction (six monitoring sites);
- the Chalk River Nuclear Laboratories (AECL-CRNL), Chalk River, Ontario (five monitoring sites);
- the Gentilly Nuclear Site, Gentilly, Quebec, 600 MW(e) (nine monitoring sites); and
- the Point Lepreau Nuclear Generating Station, Point Lepreau, New Brunswick, 600 MW(e) (nine monitoring sites).

The locations for the monitoring equipment are shown in Figures 4 to 10.

Routine monitoring is also carried out for radioactivity in air particulates near the McMaster University Research Reactor, Hamilton, Ontario, and in air particulates and sea water during visits of nuclear vessels to Nova Scotia and British Columbia.

3.1 External Radiation Exposure

Measurements of external gamma radiation dose rates are carried out quarterly at the 28 environmental network stations and 32 monitoring sites around the five nuclear power stations (Bruce, Pickering, Darlington, Gentilly, and Point Lepreau). The measurements are performed quarterly, using CaF_2:Mn bulb thermoluminescent dosemeters. The TLDs are attached to the weather housing of the air sampling equipment of the network stations and to the housings of the atmospheric water vapour collection units around the power stations. Four additional sites were added around Gentilly during the year.

Average quarterly dose rates for 1988, together with the yearly cumulative doses, are presented in Tables 2 and 3. Occasionally, TLDs are lost in transit or through vandalism. No quarterly value is reported in such cases; in determining the cumulative value, the average value for the remaining quarters is assumed. The values in Table 2 from the environmental stations give an indication of the range of normal background dose rates across Canada. The values from the reactor environs in Table 3 fall within the same range. This indicates that these doses are attributable to normal background radiation.

3.2 Air

3.2.1 Tritium in Water Vapour

Atmospheric water vapour is collected monthly, for tritium determination, from the vicinity of the Bruce, Pickering, Darlington, Gentilly, and Point Lepreau generating stations. Air is drawn through molecular sieves to collect the water vapour, which is then recovered in the laboratory for the determination of tritium by liquid scintillation counting. The flow rate of air through the sieves is reduced during the summer, from 0.2 $m^3\ d^{-1}$ to 0.06 $m^3\ d^{-1}$, to prevent the sieves from becoming saturated by the higher humidity. The tritium activity in air around these nuclear reactors is given in Table 4; the values are similar to those found in previous years. The activities near Gentilly and Point Lepreau were very close to background. The observations at the Darlington site represent pre-operational background for the first six months of the year. The activity was not increased above background after the tritium extraction plant began operations in July.

3.2.2 Gross Beta Radioactivity

At each station in the environmental monitoring network, a continuous high-volume air sampler draws air through a glass-fibre filter at the rate of about 900 m^3 d^{-1}. The gross beta activity on each filter is measured to determine the gross beta activity in airborne particulates. Filters are normally returned to the Bureau weekly; in areas of heavy pollution the filters are changed more often, as they become clogged. An additional air sampler is operated near the McMaster University Research Reactor in Hamilton, Ontario. Table 5 summarizes the results of these determinations, giving the monthly and annual average specific activity measured at each station and the average for the entire country. The values show no clear trends (Figure 11), and are similar to those measured in previous years; they represent principally background activity from natural sources.

3.3 Precipitation

Precipitation, wet and dry together, is collected in open cylinders with polyethylene liners at all stations of the environmental monitoring network. Samples are returned monthly and composited for analysis quarterly. These total quarterly gross beta activities are given in Table 6. As for the airborne activities, these represent principally activity from natural sources.

3.4 Submarine Visits

Nuclear submarines occasionally visit Shearwater, Nova Scotia. During these visits the filters collecting airborne particulates are changed daily at the Shearwater monitoring station, and gross beta activity is measured in the usual way. Samples of seawater are also taken before, during, and after these visits and scanned by gamma-ray spectrometry. Nuclear submarines also visit Esquimalt and Nanoose Bay, British Columbia, where water and bottom samples are monitored by the Radiation Protection Service of the Ministry of Health of British Columbia. No activity attributable to these vessels was found in 1988.

3.5 Drinking Water

3.5.1 Fission and Activation Products

Untreated water is collected from the intake sites of waterworks on the Winnipeg River, Lake Huron, Lake Ontario, and the Ottawa and St. Lawrence Rivers (Figures 4 to 10) to monitor the effects of any release of fission products from the Whiteshell Nuclear Research Establishment, Ontario Hydro or Hydro-Québec nuclear generating stations, or the Chalk River Nuclear Laboratories. Water is collected daily, and analyses for strontium-89, strontium-90 and cesium-137 are made quarterly on composite samples. The concentrations of strontium-90 and cesium-137, given in Tables 7 and 8, remained within normal ranges in 1988; strontium-89 was not detected, implying an activity of less than 1 mBq L^{-1}.

3.5.2 Tritium Release to the Ottawa River

During December 1988 and January 1989 a special monitoring program was carried out on Ottawa River water. The program was initiated following the release of a significant quantity of heavy water containing radioactive tritium into the river at the Chalk River Nuclear Laboratories (CRNL) on December 8, 1988.

Description of the Incident

At about 6 a.m., on Thursday, December 8, 1988, a broken seal on a heavy-water pump at the NRU reactor at CRNL caused a spill of contaminated heavy water into an enclosed room. That afternoon about 40 terabecquerels of tritium were released to the air (1 terabecquerel = 10^{12} or 1 million million becquerels; 1 becquerel = 1 disintegration-per-second = 27 picocuries). This dispersed quickly over western Quebec and at no time constituted a public health hazard. In addition, up to 500 litres of heavy water escaped into the Ottawa River on the morning of December 8. This did not become apparent until December 14, six days later. Subsequent measurement by CRNL showed that a total of 400 terabecquerels (10,000 curies) of tritium had been released into the river.

On December 15 the Department of National Health and Welfare (NHW) began daily collections in its sampling network of drinking water stations on the Ottawa River (Figure 12). Under normal conditions, quarterly composites of untreated water from these stations are analysed for strontium-90 and cesium-137. Two of the sites, Rolphton and Deep River, are upstream from CRNL and hence elevated levels of tritium were neither expected nor observed there. The other three stations, Petawawa, Pembroke, and Ottawa, are downstream. In addition, daily sampling of water was initiated at Rockland and Hawkesbury, which are downstream from Ottawa. In early January, Chomedey (City of Laval) and La Salle (City of Montreal) were added to the temporary sampling network. Samples were also taken at Grondines, one of the regular sampling stations on the St. Lawrence River.

All of the stations took samples of untreated water; at Ottawa, both treated and untreated samples were taken. The samples were returned daily by courier to the NHW laboratory at the Bureau of Radiation and Medical Devices in Ottawa. Tritium concentrations in the water were determined by liquid scintillation counting.

Results

The concentration of tritium is shown in Figure 13 as a function of both time and distance downstream. The results of all the measurements made by NHW are given in Table 9. By the time sampling had begun on December 15, seven days after the event, peak tritium concentrations had already reached Petawawa and, probably, Pembroke. The peak reached communities further downstream in the following times:

Ottawa – 22 days, Rockland – 25 days, Hawkesbury – 28 days, and Chomedey – 31 days. Chomedey is on Rivière des Prairies, the continuation of the Ottawa River, where it passes north of the Island of Montreal. Tritium was just detectable at La Salle, a short distance downstream from the confluence of the Ottawa and the St. Lawrence. These results suggest that most of the water pumped at La Salle originated in the St. Lawrence River. This, of course, may vary with season. The tritium was detected at Grondines in the later part of the month.

The transport times estimated above are appropriate only for winter conditions. Measurements made during a controlled release from Rolphton in the summer of 1981 showed transport times twice those observed for this release[1].

Treated and untreated samples from the Ottawa pumping station showed no significant differences. This is as expected, since the tritium occurs as part of the water molecule and should not be distinguishable by physical or chemical treatment processes.

The data collected have confirmed that there was no health risk from the release. All of the concentrations measured are less than two per cent of the Maximum Acceptable Concentration of 40,000 Bq L^{-1} specified in the Guidelines for Canadian Drinking Water Quality[4]. From the results in Table 9 the dose to an average Ottawa resident has been estimated to be 0.2 microsieverts (Sv). By comparison, the average dose from background sources is 2 mSv (2000 Sv) per year. International recommendations are that the dose from a nuclear facility to any individual in the general public not exceed 1 mSv per year[5]. The measurements have provided information on transport and dilution processes in the Ottawa River, useful for emergency planning.

3.5.3 Natural Radioactivity

Studies of population exposures to natural radioactivity continued with the radiochemical analyses of drinking water for radium-226 and total uranium. Samples were collected from Regina, Elliot Lake and Port Hope monthly. The samples from Port Hope and for the first, third and fourth quarters from Elliot Lake were composited into quarterly samples for analysis. The concentrations of radium-226, (Table 10), for Port Hope and Regina were less than 5 mBq L^{-1}. For the town of Elliot Lake, which is located at the centre of uranium mining activities in Ontario, radium-226 concentrations ranged from 8 to 18 mBq L^{-1}. The concentration of total uranium for Elliot Lake and Port Hope were less than 2.0 mBq L^{-1}, while the range of levels for Regina is 0.8 to 3.7 mBq L^{-1}. All concentrations measured in 1988 were less than the Maximum Acceptable Concentrations of 1000 mBq L^{-1} for radium-226 and 100 g L^{-1} for total uranium as recommended in the Guidelines for Canadian Drinking Water Quality, 1987[4].

3.6 Milk

Samples of whole milk are collected monthly from commercial outlets in 18 cities (Figure 3); cesium-137 is determined monthly and strontium-90 is determined quarterly in composite samples. The results of these analyses, for 1988, are given in Tables 12 and 13. The levels of cesium-137 in milk have been dropping since the cessation of atmospheric weapons testing in 1962 (see Figure 14), but were elevated slightly after the Chernobyl nuclear reactor fire in the spring of 1986. The levels have again fallen to, or below, values found before the accident in most parts of the country. The levels of strontium-90 activity in milk were barely affected by the Chernobyl fallout and have continued to fall.

Monthly samples of raw milk are also taken in the vicinity of the Whiteshell Nuclear Research Establishment and the Bruce Nuclear Power Development and analysed for iodine-131 and cesium-137. Cesium-137 levels were the same as elsewhere in the country, indicating that global fallout is the major source of cesium-137 in milk at these locations. No iodine-131 activity was detected.

3.7 Food Monitoring

3.7.1 Imports

As part of our examination of the levels of radioactivity in food imported into Canada, which may have been contaminated as a result of fallout from Chernobyl, 76 samples were measured from 14 different countries. As the year progressed, the number of food samples was reduced as certain types showed very low residual contamination. However, dried spices and filberts originating in Greece and Turkey remained a concern, and monitoring of these items continued. Thirty samples of oregano were measured; one was refused entry into Canada when the radioactive cesium content was found to exceed the screening limits. All the filbert samples were cleared. The results of analyses of imported foods for 1988 are given in Table 14.

3.7.2 Export Certification

A number of countries, including Egypt, Greece, Japan, Morocco, Peru, Thailand and Venezuela, require radiation certificates for certain radioisotopes in imported foods. Analysis of the radioisotope content of the Canadian food product for export (with the exception of milk and milk products) is the responsibility of the exporting firm and is performed under contract to the firm by commercial analytical laboratories. A copy of the analysis report, together with product identification, quantity, shipment date, and other information required by the purchasing country are supplied to the Bureau of Radiation and Medical Devices, where, upon review, a certificate is issued to the exporting firm.

About 50 certificates were issued during 1988 for foods and other items, including apples, various kinds of beans, honey, butter, powdered skim milk, tobacco, and bull semen. None of these exceeded the limits set by the importing country.

3.8 Quality Assurance

Laboratory quality control programs for analyses continued through participation in interlaboratory comparison programs sponsored by the Environmental Protection Agency and the Department of Energy in the United States. The performance of the Division is summarized in Table 15.

4. Reports and Presentations

1. Crete, M.; Lefebvre, M.A.; Cooper, M.B.; Marshall, H.; Benedetti, J.L.; Carriere, P.E.; Nault, R. *Contaminants in Caribou Tissues from Northern Quebec*. In: Fifth International Reindeer/Caribou Symposium, Arvidsjaur, Sweden, August 1988.

2. Eaton, R.S. *Radon, Is it Really Dangerous? Technical and Social Aspects*. Emergency Preparedness Digest 15(2): 12-17, 1988.

3. Eaton, R.S. *Pollution In and From Space. The Use of Nuclear Power Sources in Outer Space*. In: Proceedings of International Coloquium on Environmental Aspects of Activities in Outer Space – State of the Law and Measures of Protection, Cologne, West Germany, May 17-19, 1988, University of Cologne (in press).

4. Eaton, R.S. *Radon and Its Decay Products in Indoor Air* (Book Review). Science 241: 990, 1988.

5. Eaton, R.S.; McGregor, R.G.; Walker, W.R.; Létourneau, E.G. *A Comparison of Radon Long Term Integrating Measurements with Results Obtained from Grab Samples*. Presented at the Canadian Radiation Protection Association Annual Conference, Montebello, Quebec, May 10-13, 1988.

6. Iamello, M. *Determination of Ra-228 in Water by Liquid Scintillation Counting*. Presented at the 4th Workshop on Analytical Chemistry Related to Canada's Nuclear Industry, Kimberley, Ontario, May 15-18, 1988.

7. Marshall, H.; Cooper, M.B.; Tracy, B.L. *Radioactive Cesium in Caribou in Northern Canada*. Presented at the Canadian Radiation Protection Association Annual Conference, Montebello, Quebec, May 10-13, 1988.

8. Meyerhof, D.P. *Proposed Revision to the Guidelines for Radiological Characteristics of Drinking Water*. Presented at the Canadian Radiation Protection Association Annual Conference, Montebello, Quebec, May 10-13, 1988.

9. Tracy, B.L. *Assessment of Contamination at a Former Nuclear Weapons Test Site, Maralinga, Australia*. Presented at the Canadian Radiation Protection Association Annual Conference, Montebello, Quebec, May 10-13, 1988.

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2. Department of National Health and Welfare. *Environmental Radioactivity in Canada 1987*. 88-EHD-145, Communications Directorate, Jeanne Mance Building, Ottawa K1A 0K9.

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4. Department of National Health and Welfare. *Guidelines for Canadian Drinking Water Quality*. Canadian Government Publishing Centre, Hull, Quebec K1A 0S9.

5. International Commission on Radiological Protection. *Recommendations of the International Commission on Radiological Protection*. ICRP Publication 26, Pergamon, Oxford, 1977.

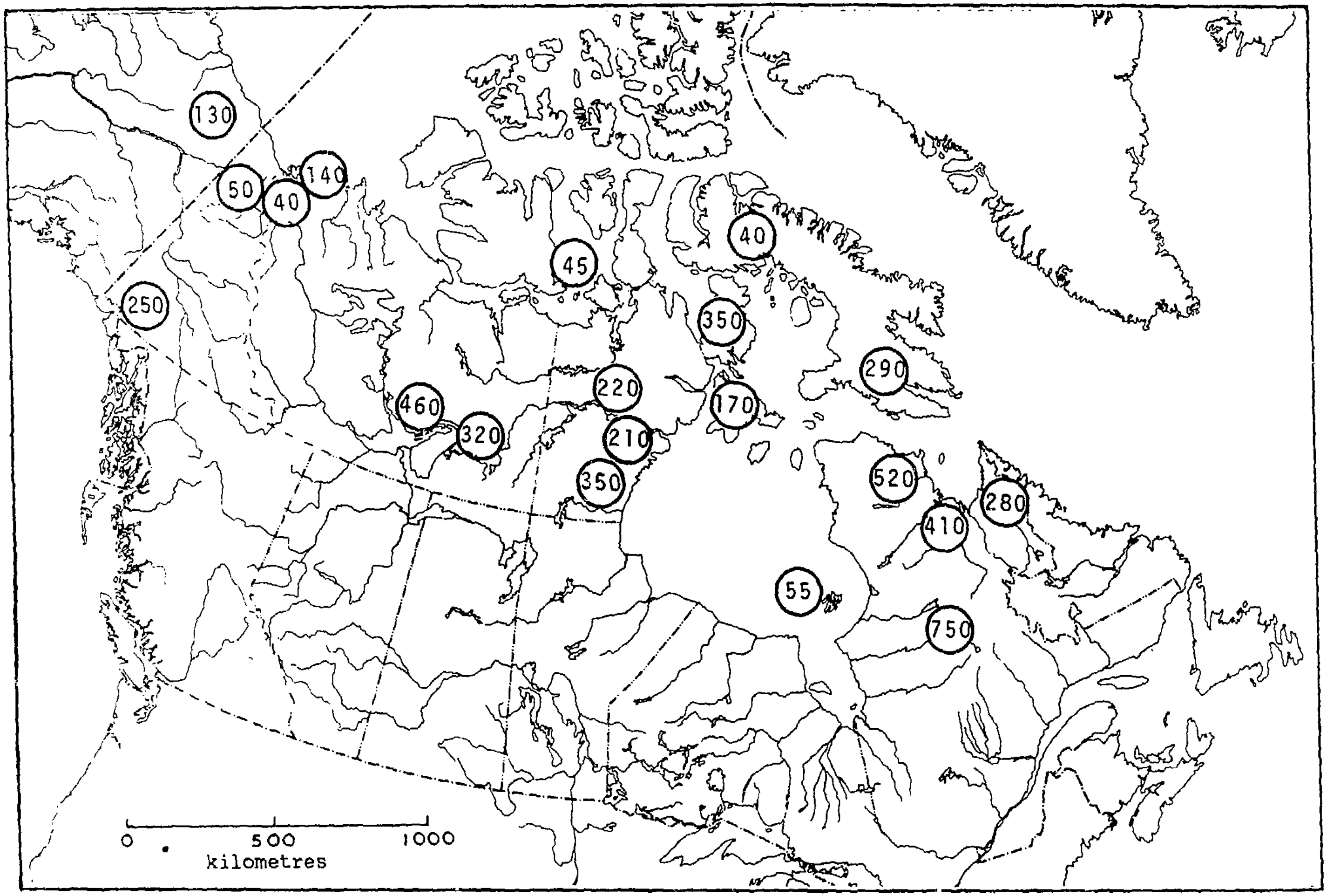

Figure 1. Cesium-137 Concentrations in Caribou Muscle Tissue, Becquerels per Kilogram

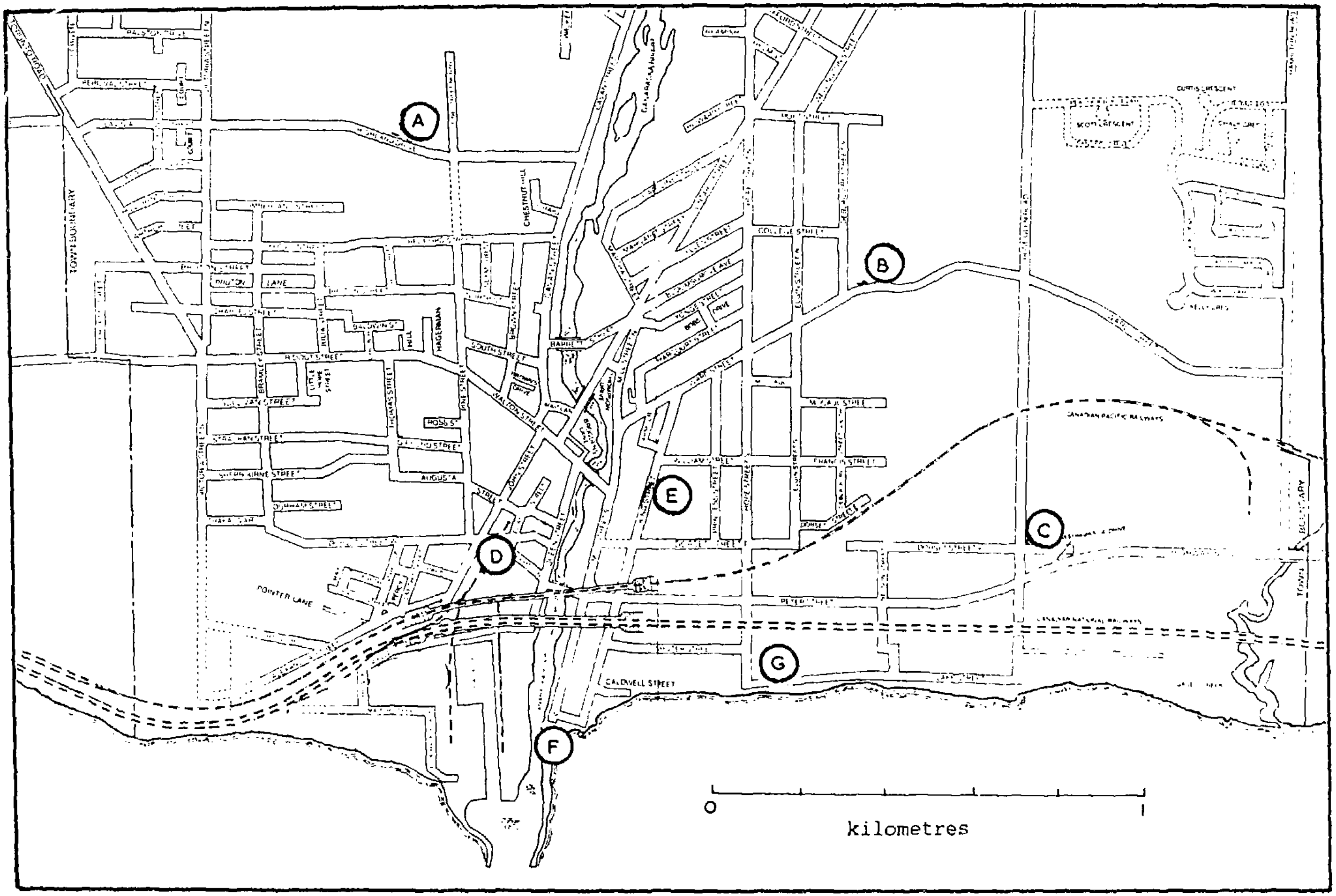

Figure 2. Air Sampling Locations in Port Hope

Figure 3. Canadian Sampling Network

Key to Figure 3

Sampling Station	Drinking	Air	Precipitation	Milk	TLD
Calgary	-	x	x	x	x
Churchill	-	x	x	-	x
Coral Harbour	-	x	x	-	x
Digby	-	x	x	-	x
Edmonton	-	x	x	x	x
Elliot Lake	x	-	-	-	-
Fredericton	-	x	x	-	x
Goose Bay	-	x	x	-	x
Greenwood	-	x	x	-	x
Halifax	-	x	x	x	x
Hay River	-	x	x	-	x
Inuvik	-	x	x	-	x
McMaster	-	x	-	-	-
Moncton	-	-	-	x	-
Montreal	-	x	x	x	x
Moosonee	-	x	x	-	x
Ottawa	-	x	x	x	x
Port Hope	x	-	-	-	-
Quebec	-	x	x	x	x
Regina	x	x	x	x	x
Resolute	-	x	x	-	x
Saskatoon	-	x	x	x	x
Sault Ste. Marie	-	x	x	x	x
St. John's	-	x	x	x	x
Summerside	-	x	x	-	x
Sussex	-	-	-	x	-
Thunder Bay	-	x	x	x	x
Toronto	-	x	x	x	x
Truro	-	-	-	x	-
Vancouver	-	x	x	x	x
Whitehorse	-	x	x	-	x
Windsor	-	x	x	x	x
Winnipeg	-	x	x	x	x
Yellowknife	-	x	x	-	x

"x" indicates that a given type of sampling is carried out at a given station.

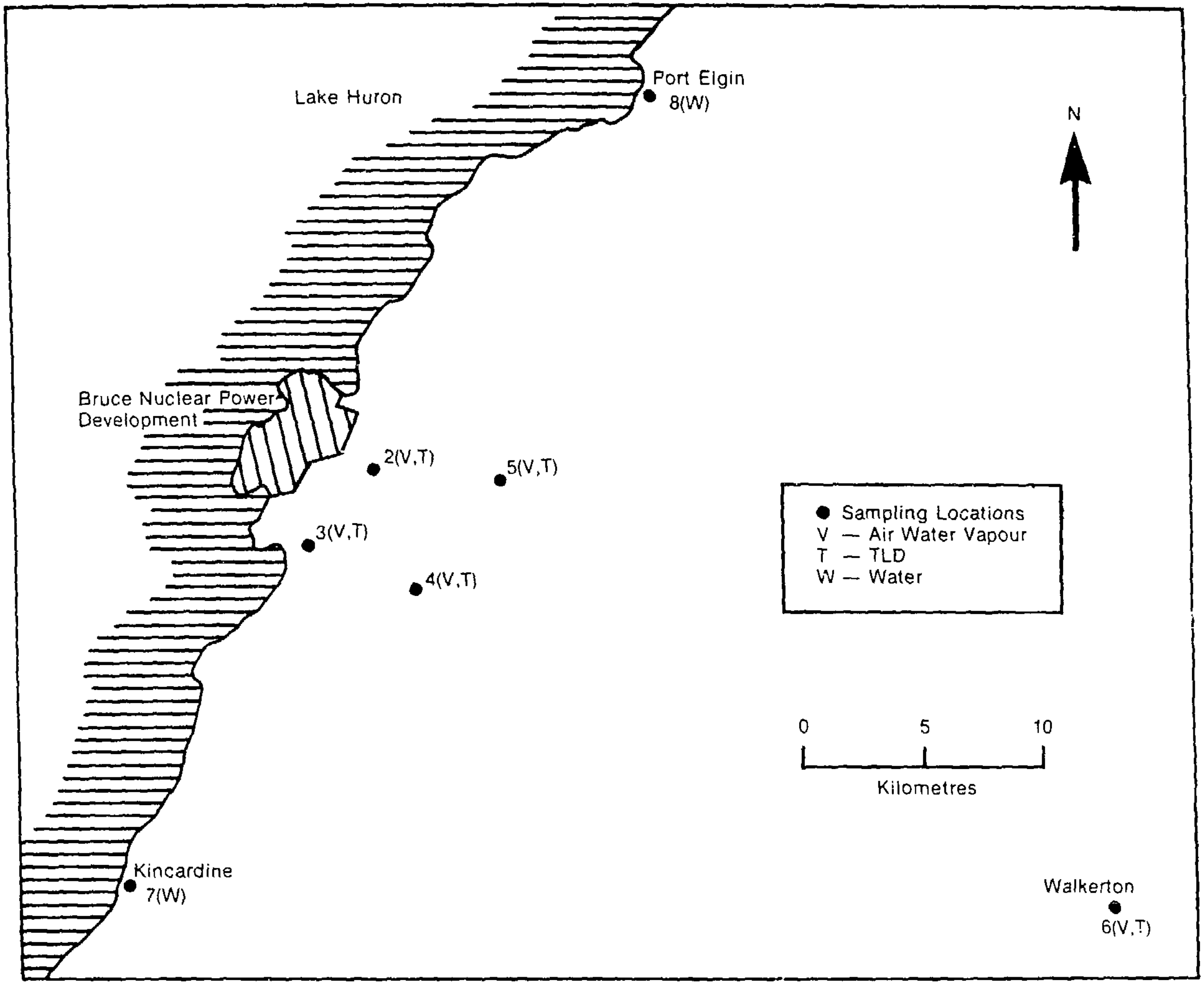

Figure 4. Sampling Locations in the Vicinity of the Bruce Nuclear Power Development

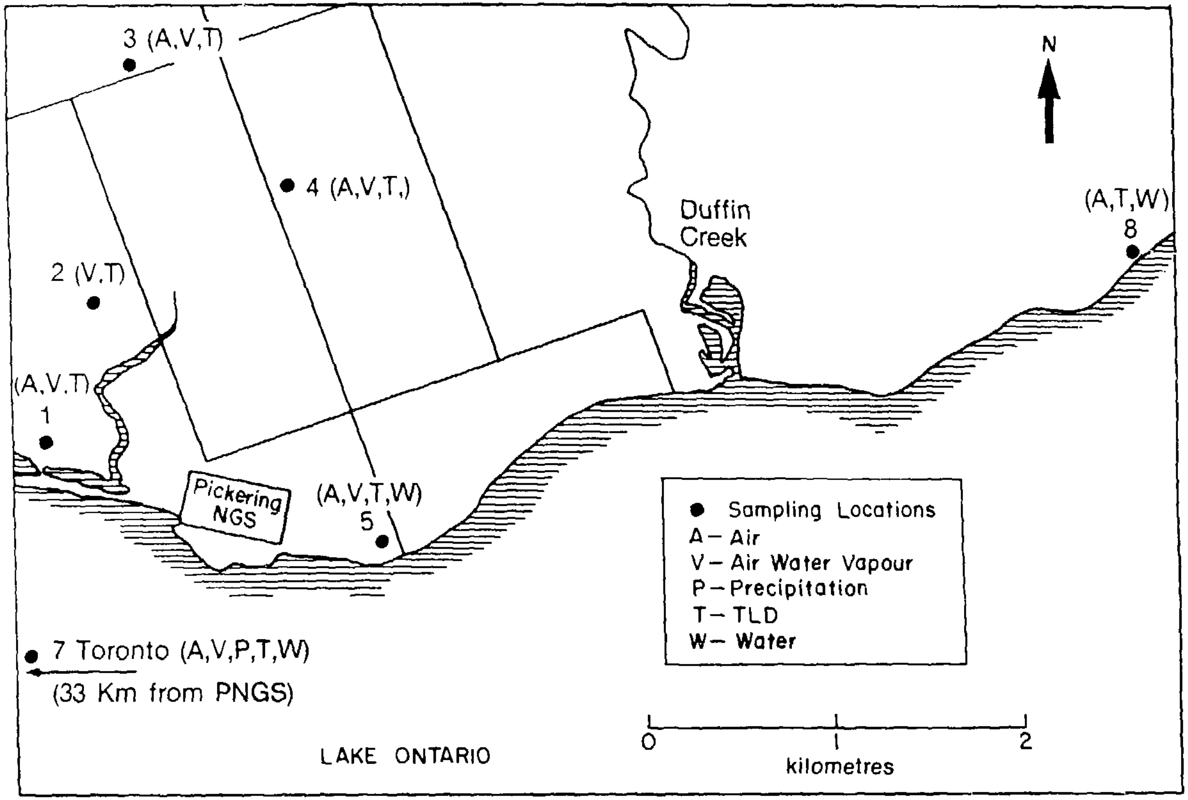

Figure 5. Sampling Locations in the Vicinity of the Pickering Nuclear Generating Station

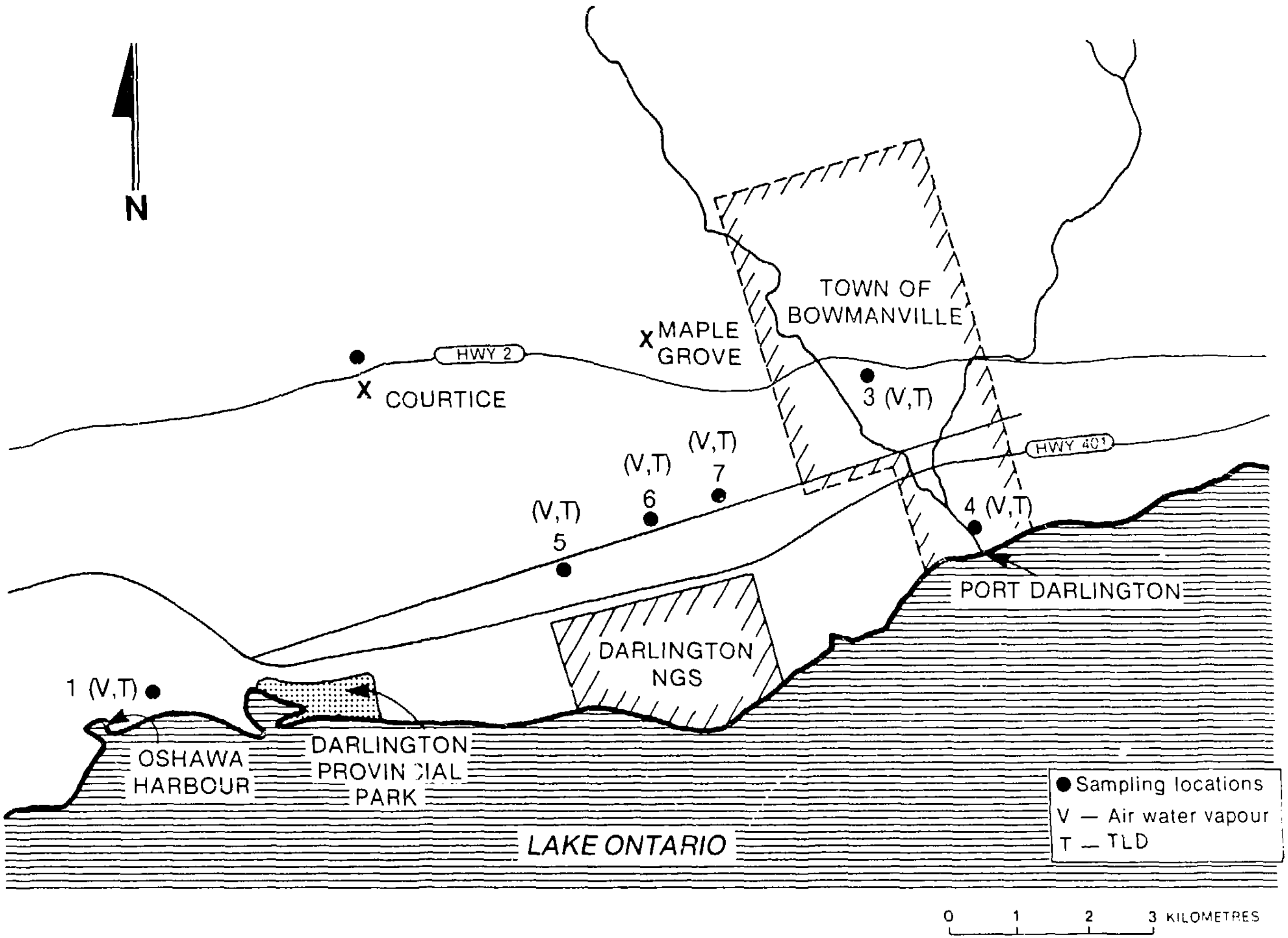

Figure 6. Sampling Locations in the Vicinity of the Darlington Nuclear Generating Station

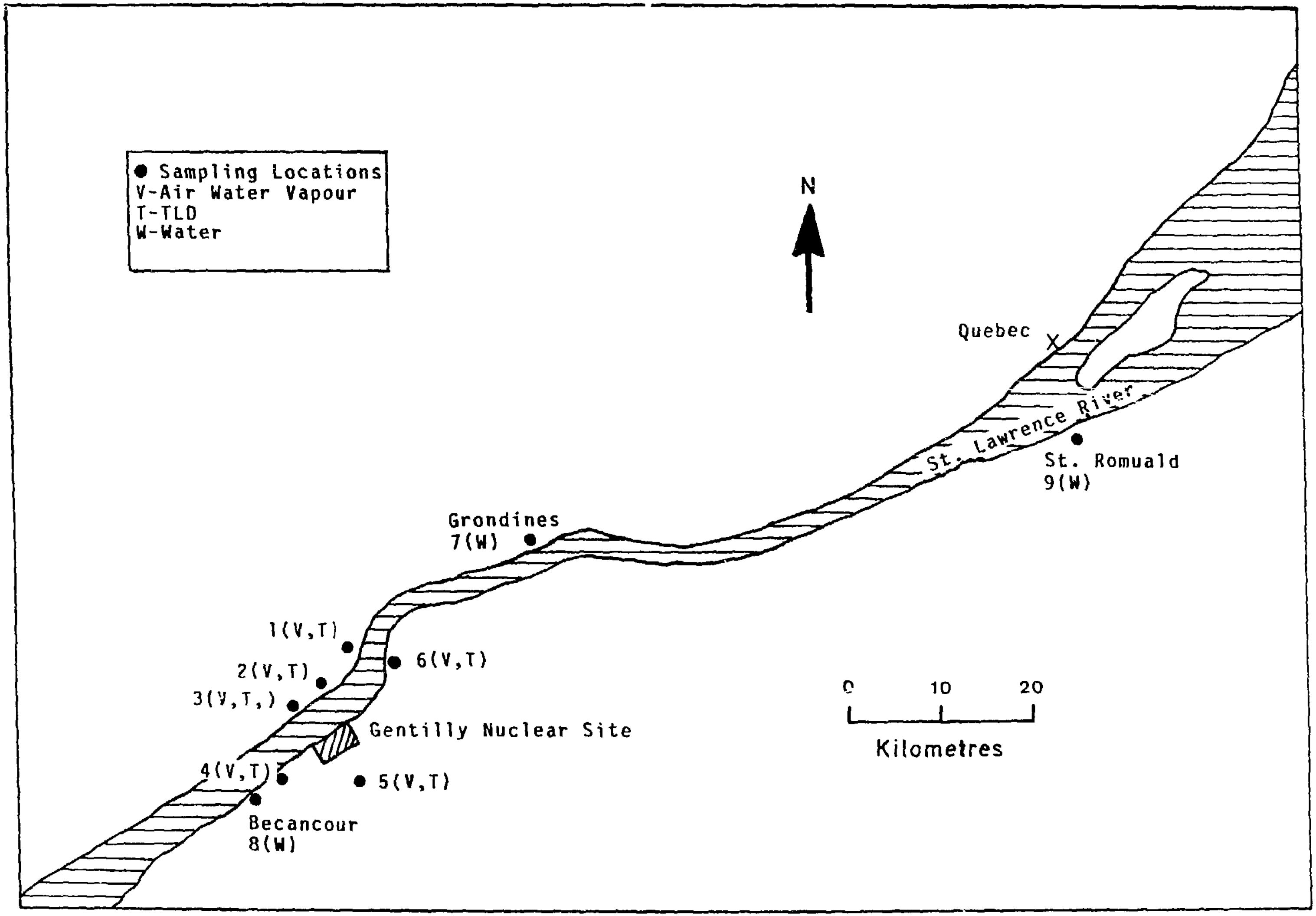

Figure 7. Sampling Locations in the Vicinity of the Gentilly Nuclear Site

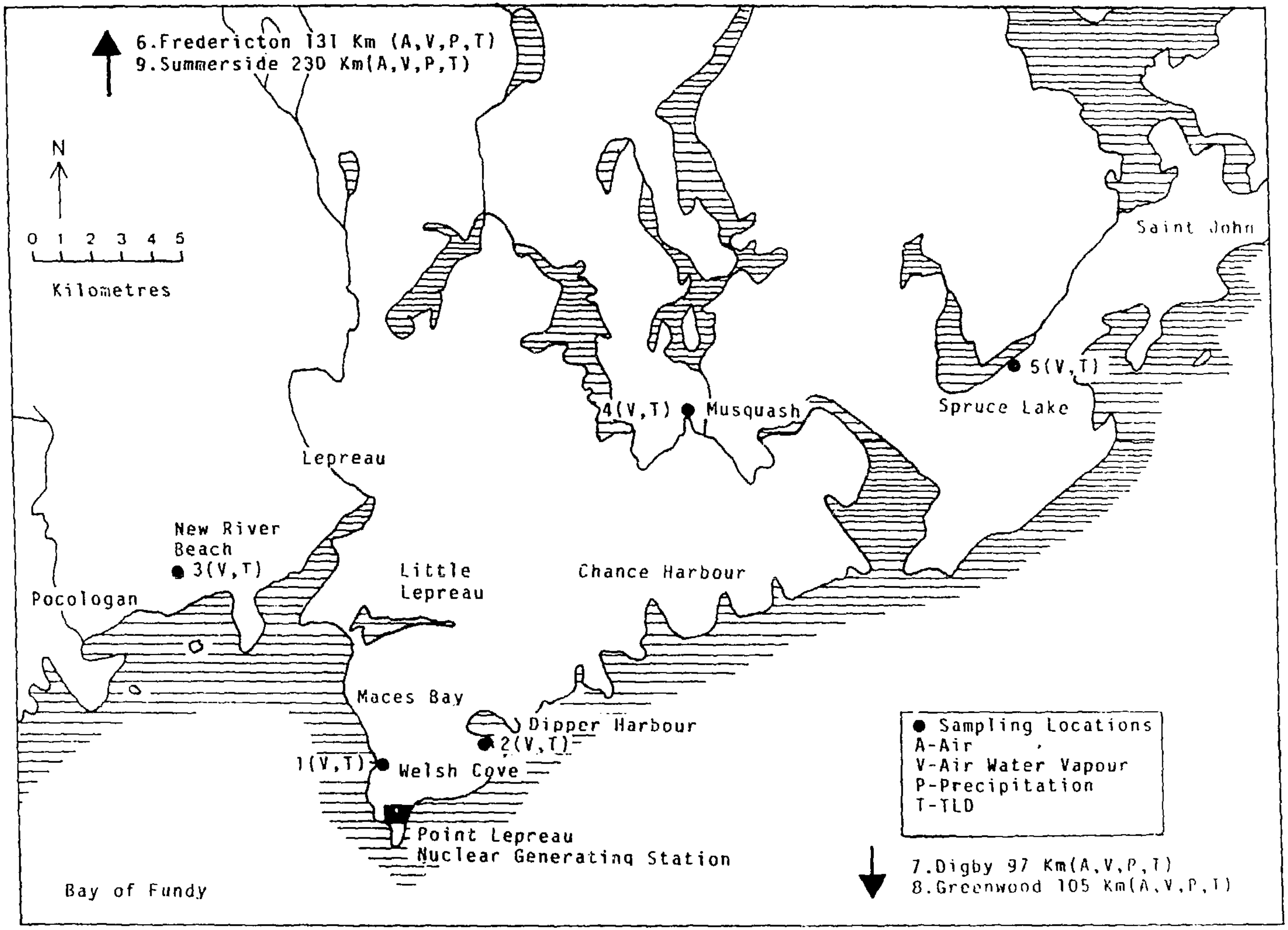

Figure 8. Sampling Locations in the Vicinity of the Point Lepreau Nuclear Generating Station

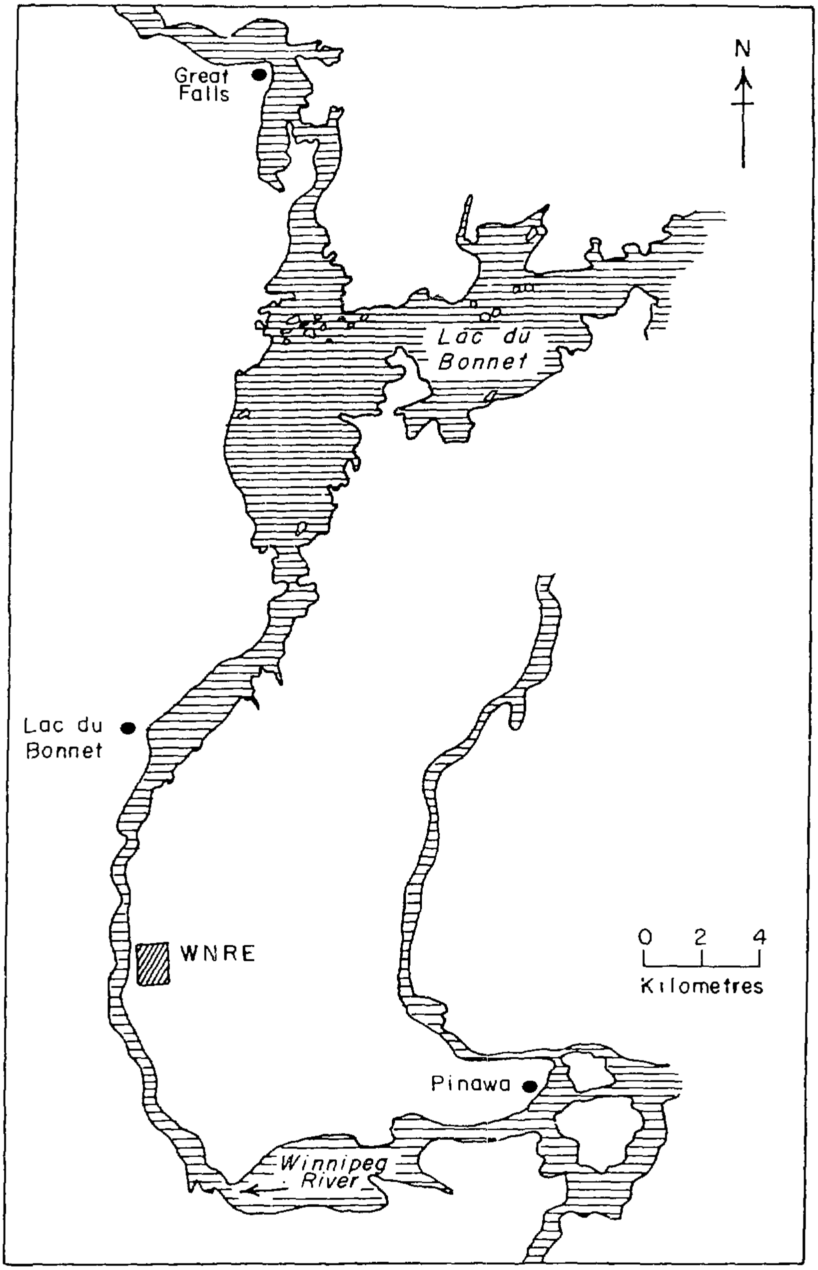

Figure 9. Sampling Locations on the Winnipeg River

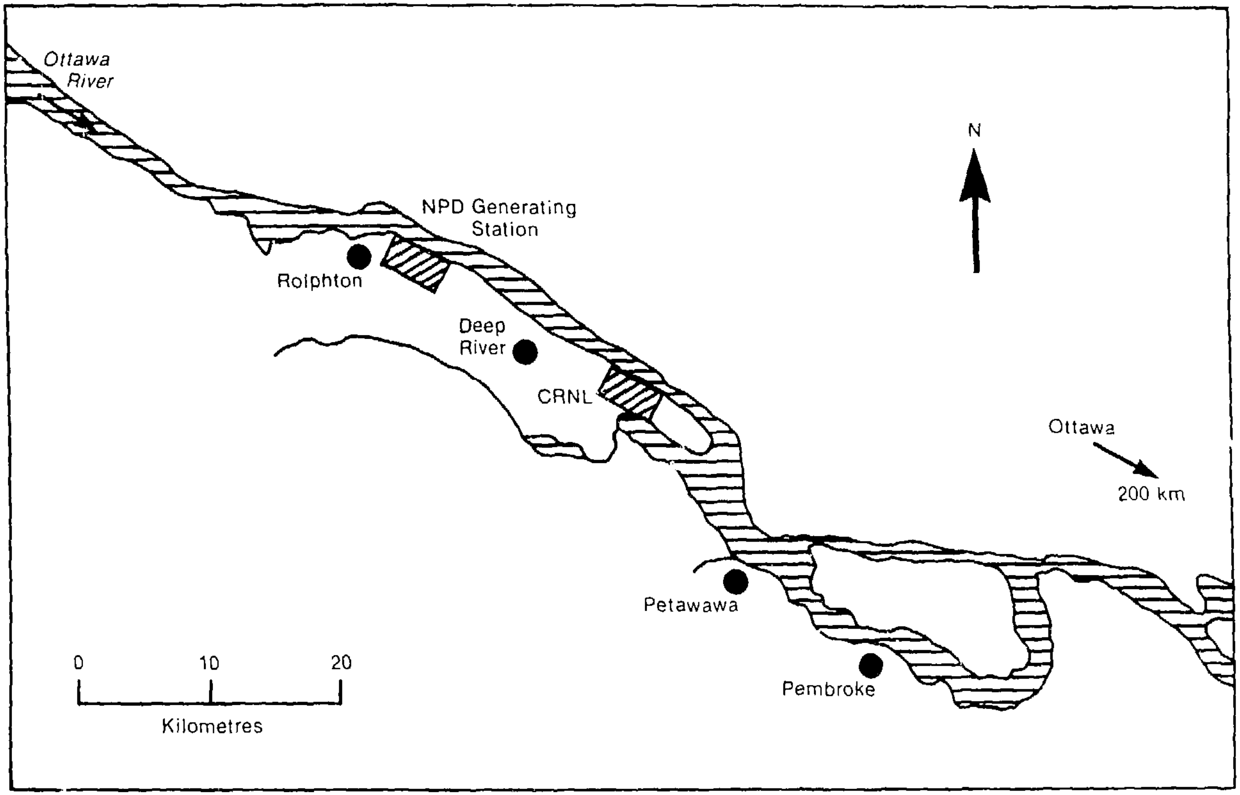

Figure 10. Sampling Locations on the Ottawa River

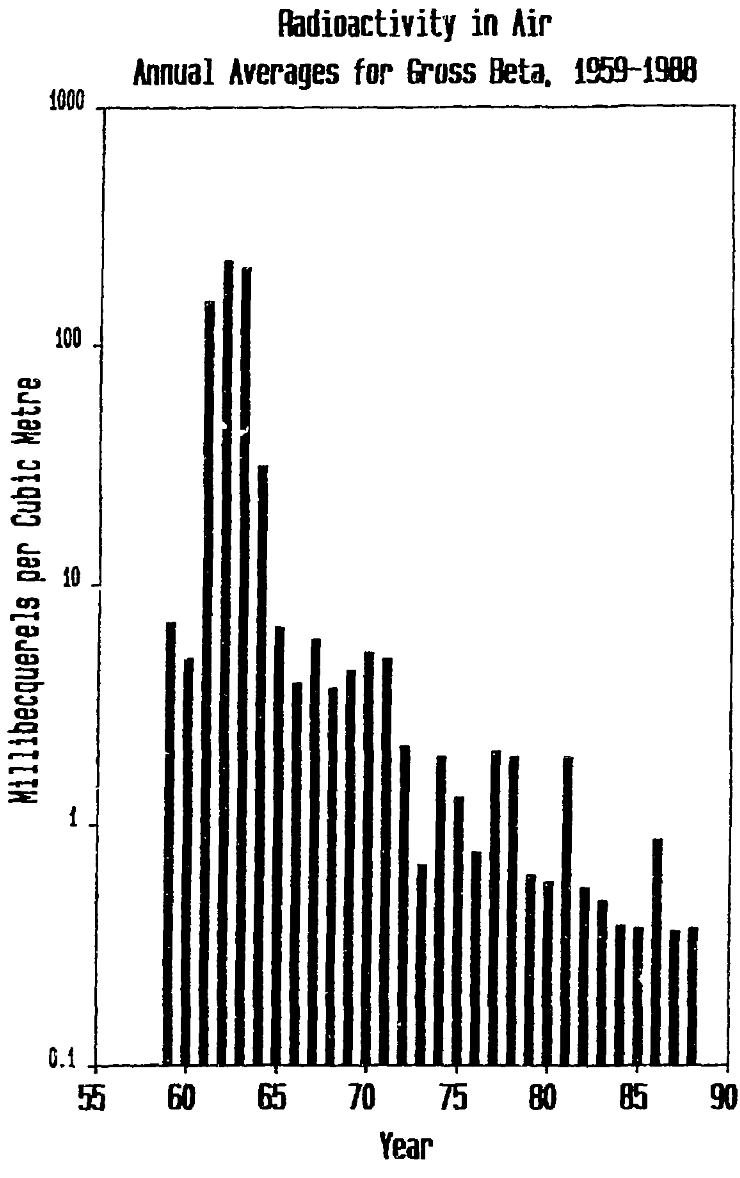

Figure 11. Fallout Trends in Gross Beta Radioactivity in Surface Air

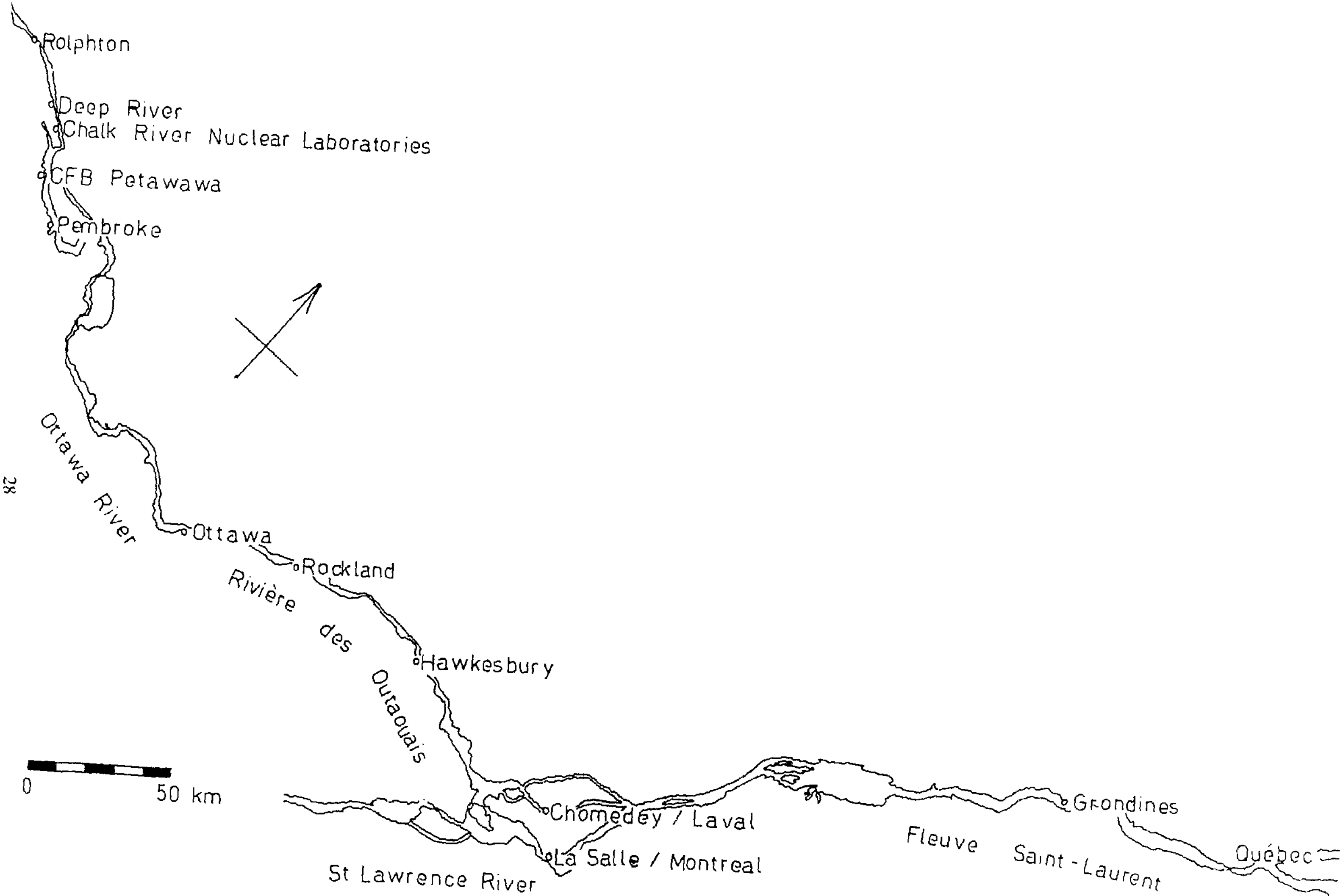

Figure 12. Tritium Sampling Locations on the Ottawa and St. Lawrence Rivers

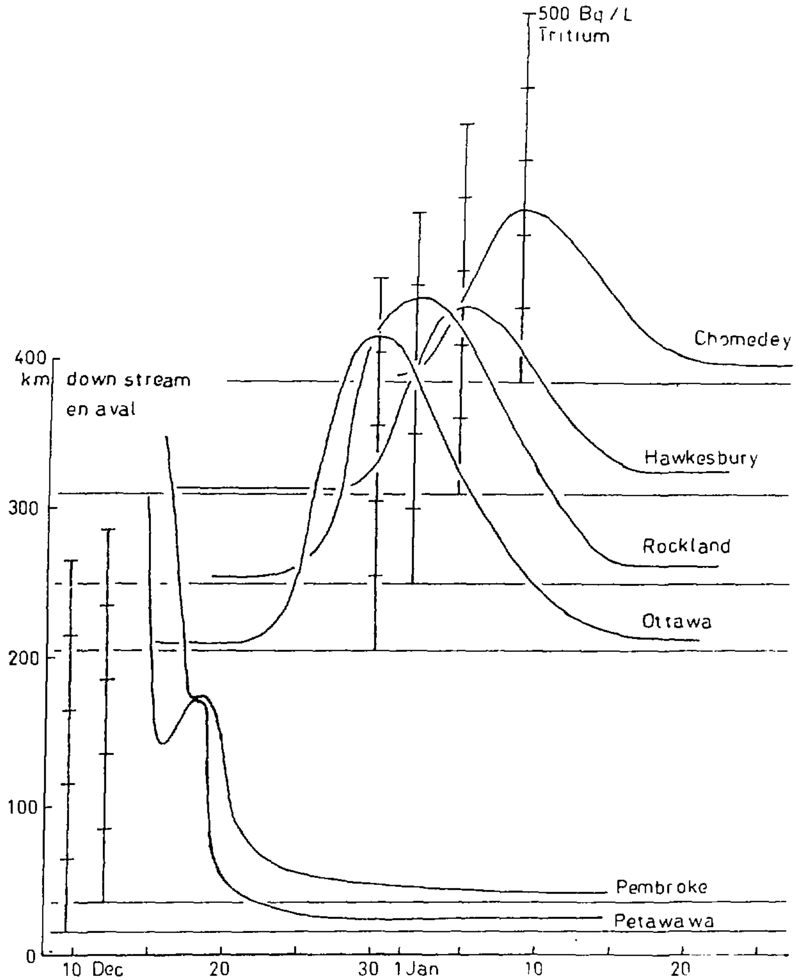

Figure 13. Tritium Concentrations in Untreated Water of the Ottawa River, December 1988 – January 1989

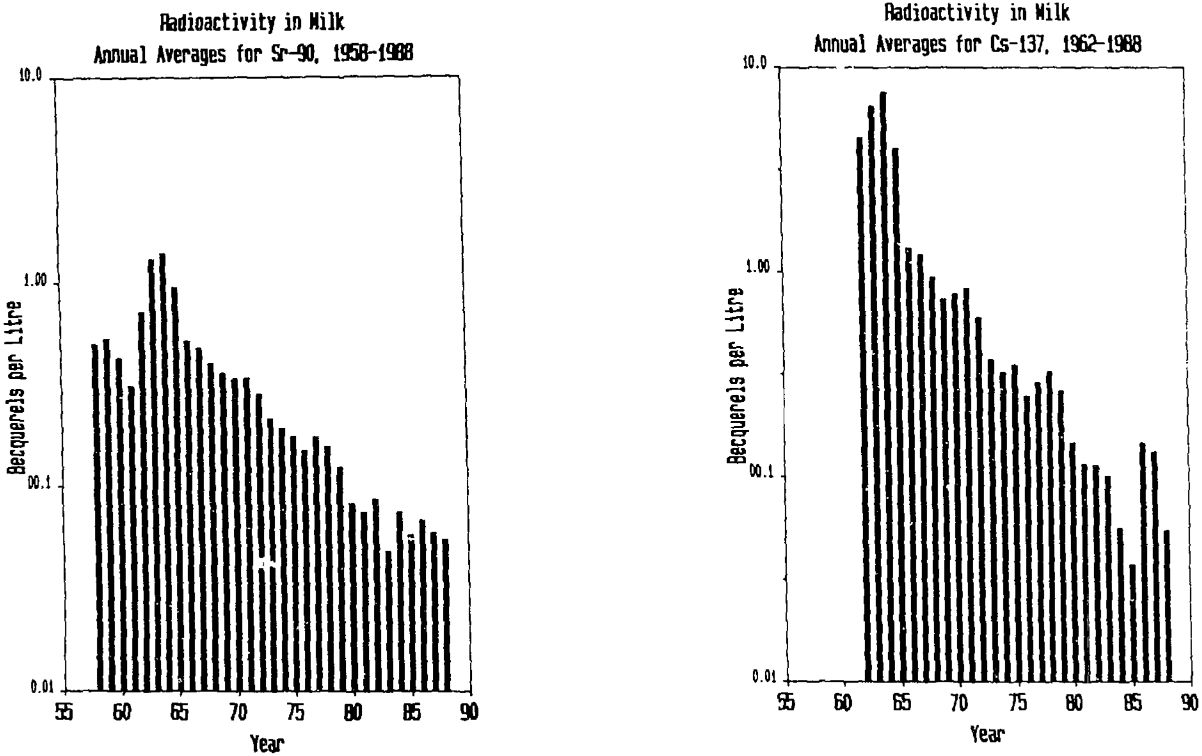

Figure 14. Fallout Trends in Milk 1958-1988

Table 1. Radiocesium Concentrations in Caribou Muscle Tissue, 1986-88

Herd	Location	Mean Cesium-137 Activity (Bq/kg wet tissue)
Barren Ground Caribou		
Western Arctic		
Bathurst	Yellowknife	460
Bluenose	Inuvik	140
Porcupine	Mackenzie Delta	40
	Eagle Plains	50
	Arctic Village	130
Eastern Arctic and the Islands		
Baffin	Pond Inlet	40
	Iqaluit	290
Beverly	Tent Lake	320
Kaminuriak	Baker Lake	220
	Rankin Inlet	210
	Eskimo Point	350
Melville	Repulse Bay	350
Victoria Island	Cambridge Bay	45
Southampton Island	Coral Harbour	170
Belcher	Sanikiluaq	55
Woodland Caribou		
several herds	**Yukon**	250
Quebec and Labrador		
George River	Caniapiscau	750
	George River	280
	Kuujjuak	410
	Riv. aux Feuilles	520

Table 2. External Radiation Dose Measurements at Environmental Stations for 1988

	Dose Rate (microgray per hour)				
Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Cumulative Dose (*milligray*)
Calgary	0.08±0.02	0.06±0.02	0.08±0.02	0.09±0.03	0.68±0.10
Churchill	0.06±0.02	0.05±0.02	0.07±0.02	0.07±0.02	0.55±0.09
Coral Harbour	0.05±0.02	0.05±0.02	0.06±0.02	0.06±0.02	0.48±0.09
Digby	-	0.12±0.02	0.11±0.03	0.11±0.03	0.99±0.14
Edmonton	0.06±0.02	0.09±0.03	0.08±0.02	0.09±0.03	0.77±0.11
Fredericton	0.06±0.02	0.08±0.02	0.07±0.02	0.09±0.03	0.66±0.10
Goose Bay	0.07±0.02	0.05±0.02	0.09±0.03	0.09±0.02	0.66±0.10
CFB Greenwood	0.08±0.02	0.09±0.03	0.07±0.02	0.09±0.02	0.72±0.10
Halifax	0.08±0.02	0.08±0.02	0.07±0.02	0.09±0.02	0.70±0.09
Hay River	0.08±0.02	-	-	-	0.70±0.09
Inuvik	0.70±0.02	0.07±0.02	0.08±0.03	0.07±0.02	0.64±0.10
Montreal	0.06±0.02	0.70±0.02	0.06±0.02	0.08±0.02	0.59±0.09
Moosonee	0.06±0.02	0.06±0.02	0.05±0.02	0.07±0.02	0.53±0.09
Ottawa	0.07±0.02	0.07±0.02	0.08±0.02	0.09±0.02	0.68±0.09
Quebec City	0.05±0.01	0.06±0.02	0.07±0.02	0.08±0.02	0.57±0.08
Regina	0.09±0.03	0.10±0.03	0.08±0.02	0.10±0.02	0.81±0.11
Resolute	0.06±0.02	0.04±0.01	0.04±0.02	0.05±0.01	0.42±0.07
Saskatoon	0.10±0.03	0.08±0.03	0.08±0.02	0.09±0.02	0.77±0.11
Sault Ste. Marie	0.07±0.03	0.07±0.02	0.06±0.02	0.07±0.02	0.59±0.10
St. John's	0.11±0.03	0.08±0.02	0.09±0.03	0.11±0.02	0.85±0.11
CFB Summerside	0.08±0.02	0.07±0.02	0.07±0.02	0.09±0.02	0.68±0.09
Thunder Bay	0.08±0.02	0.08±0.02	0.07±0.02	0.08±0.02	0.68±0.09
Toronto	0.06±0.01	0.07±0.02	0.07±0.02	0.04±0.01	0.53±0.07
Vancouver	0.07±0.02	0.06±0.02	0.07±0.02	0.08±0.02	0.61±0.09
Whitehorse	0.11±0.03	0.09±0.03	0.10±0.03	0.13±0.02	0.94±0.12
Windsor	0.08±0.03	0.06±0.02	0.06±0.03	0.08±0.02	0.61±0.11
Winnipeg	0.05±0.02	0.06±0.02	0.07±0.03	0.08±0.02	0.57±0.10
Yellowknife	0.07±0.02	0.07±0.02	0.10±0.03	0.11±0.02	0.77±0.10

- No Sample

Table 3. External Radiation Dose Measurements in the Vicinity of Nuclear Reactors for 1988

Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Cumulative Dose (milligray)
	Dose Rate (microgray per hour)				
Bruce					
2 - 3.5 km ESE	0.06±0.01	0.07±0.02	0.07±0.02	0.10±0.03	0.66±0.09
3 - 4.0 km S	0.06±0.01	0.05±0.02	0.06±0.02	0.06±0.03	0.50±0.09
4 - 8.0 km SE	0.06±0.01	0.06±0.02	0.07±0.02	0.08±0.03	0.60±0.09
5 - 8.0 km ESE	0.08±0.02	0.08±0.03	0.07±0.02	0.09±0.03	0.70±0.11
6 - 40.0 km SE	0.09±0.02	0.09±0.03	0.09±0.03	0.10±0.03	0.81±0.12
Pickering					
1 - 1.0 km NNW	0.05±0.01	0.06±0.02	0.08±0.02	0.09±0.02	0.61±0.08
2 - 1.5 km NE	0.06±0.01	-	-	-	0.53±0.04
3 - 2.0 km NNW	0.05±0.01	0.05±0.01	0.07±0.02	0.07±0.02	0.53±0.07
4 - 1.5 km NE	0.07±0.01	0.12±0.02	0.07±0.02	0.09±0.03	0.77±0.09
5 - 1.0 km E	0.06±0.01	0.07±0.02	0.07±0.02	0.07±0.03	0.59±0.09
7 - 33.0 km SW	0.06±0.01	0.07±0.02	0.07±0.02	0.04±0.02	0.53±0.07
8 - 5.0 km ENE	0.05±0.01	0.05±0.02	0.06±0.02	0.07±0.03	0.50±0.09
Darlington					
1 - 8.0 km W	0.06±0.01	0.09±0.01	0.07±0.02	0.08±0.03	0.66±0.08
3 - 5.8 km NE	0.05±0.02	0.06±0.01	0.09±0.03	0.08±0.02	0.61±0.09
4 - 5.3 km ENE	0.06±0.02	0.07±0.01	0.05±0.02	0.09±0.03	0.59±0.09
5 - 2.4 km NNW	0.06±0.01	0.07±0.01	0.07±0.02	0.09±0.03	0.64±0.08
6 - 2.0 km N	0.06±0.01	0.06±0.01	0.05±0.02	0.09±0.03	0.57±0.08
7 - 2.6 km NNE	0.10±0.02	0.06±0.01	0.10±0.03	0.15±0.04	0.90±0.12
Gentilly					
1 - 11.5 km NNE	0.06±0.02	0.06±0.02	0.08±0.02	0.08±0.03	0.61±0.10
2 - 6.5 km NNE	0.05±0.03	0.05±0.02	0.06±0.02	0.07±0.03	0.50±0.11
3 - 5.0 km NNW	0.05±0.03	0.05±0.02	0.08±0.02	0.07±0.03	0.55±0.11
4 - 7.0 km SW	0.06±0.02	0.06±0.02	0.05±0.02	0.06±0.03	0.50±0.11
5 - 6.5 km ENE	0.06±0.03	0.06±0.02	0.07±0.02	0.08±0.03	0.59±0.11
6 - 13.5 km NE	0.06±0.03	0.06±0.01	0.06±0.02	0.07±0.03	0.55±0.11
Pt. Lepreau					
1 - 2.6 km NNW	0.06±0.02	0.08±0.01	0.05±0.02	0.09±0.03	0.61±0.09
2 - 4.8 km NNE	0.04±0.02	0.07±0.01	0.04±0.02	0.09±0.03	0.53±0.09
3 - 9.7 km NW	0.07±0.02	0.10±0.02	0.05±0.02	0.07±0.03	0.64±0.10
4 - 19.3 km NNE	0.06±0.03	0.08±0.01	0.06±0.02	0.08±0.03	0.61±0.11
5 - 29.0 km NE	0.11±0.03	0.13±0.02	0.08±0.02	0.13±0.03	0.97±0.11
6 - 131 km N	0.06±0.02	0.08±0.02	0.07±0.02	0.09±0.03	0.66±0.10
7 - 97 km SE	-	0.12±0.02	0.11±0.03	0.11±0.03	0.99±0.14
8 - 105 km ESE	0.08±0.02	0.09±0.03	0.07±0.02	0.09±0.02	0.72±0.10
9 - 230 km NE	0.08±0.02	0.07±0.02	0.07±0.02	0.09±0.02	0.68±0.09

- No Sample

Table 4. Tritium Activity in Atmospheric Water Vapour for 1988
(Becquerels per cubic metre air)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bruce													
2 - 3.5 km ESE	5.04	2.07	2.07	3.76	7.35	7.17	3.29	1.26	1.25	4.06	4.33	3.89	3.80
3 - 4.0 km S	1.79	1.79	3.72	8.93	6.85	4.78	1.03	1.92	6.65	2.56	.84	2.44	3.61
4 - 8.0 km SE	.45	1.31	1.65	1.53	1.53	2.95	2.23	.91	.27	.27	.27	1.08	1.20
5 - 8.0 km ESE	.99	1.08	1.66	1.27	1.27	.59	1.31	.27	.33	.33	.33	1.66	.92
6 - 40.0 km SE	.12	.16	.60		*	*	.14	.17	.18	*	.11	.11	.14
Pickering													
1 - 1.0 km NW	1.13	5.10	2.86	4.19	5.35	2.87	2.80	6.20	10.00	8.45	10.90	4.54	5.37
2 - 1.5 km NW	2.56	1.84	4.82	7.44	13.10	-	-	-	-	-	-	-	5.95
3 - 2.0 km NNW	9.25	1.67	3.79	3.47	15.00	4.93	4.85	3.70	4.19	5.91	6.47	14.10	6.44
4 - 1.8 km NNE	29.80	7.92	7.96	3.29	22.80	16.20	15.60	9.16	12.70	6.43	4.74	6.53	11.93
5 - 1.0 km E	27.40	17.00	11.00	11.80	29.00	60.70	27.10	64.10	19.50	7.16	4.74	29.60	25.76
7 - 33.0 km SW	.15	.30	.33	.27	.52	*	*	.11	.26	.15	.39	.23	.23
Darlington													
1 - 8.0 km W	1.12	.34	.12	.29	.60	.26	.37	.43	.35	.50	.55	1.46	.53
3 - 5.8 km NE	.24	.44	.23	.14	.37	*	.20	*	.18	.25	.21	.79	.27
4 - 5.3 km ENE	.71	.54	.15	.19	.17	.27	.17	.16	.23	.50	.42	2.32	.49
5 - 2.4 km NNW	.89	.35	.56	.13	.16	.18	.22	.22	.42	.48	.26	.84	.39
6 - 2.0 km N	.76	.61	.23	.21	.37	*	.35	.43	.31	.51	.36	1.57	.48
7 - 2.6 km NNE	.64	.45	.17	.20	.26	.15	.21	.12	.12	.26	.24	1.41	.35
Gentilly													
1 - 11.5 km NNE	.13	.80	.32	*	.19	*	*	.24	.21	.26	*	.40	.25
2 - 6.5 km NNE	.23	.25	.10	*	.91	*	*	*	.11	.20	*	.41	.24
3 - 5.0 km NNW	.09	.17	.05	*	.44	*	*	.15	.22	.26	.13	.16	.17
4 - 7.0 km SW	.44	.34	.75	.29	*	*	.11	.29	.23	.22	.23	.19	.28
5 - 6.5 km ENE	.19	.33	.12	.54	.78	*	*	.26	.16	.18	.18	.24	.26
6 - 13.5 km NE	.15	.07	.15	.26	1.51	*	*	*	*	.14	.18	.38	.25
Pt. Lepreau													
1 - 2.6 km NNW	.61	.19	*	.19	.14	.15	.26	.43	1.58	.53	.16	.21	.38
2 - 4.8 km NNE	.72	.86	.57	.30	.62	.22	.36	.85	2.16	.17	.22	.27	.61
3 - 9.7 km NW	.27	.26	.14	*	*	*	*	.13	-	.28	*	.22	.17
4 - 19.3 km NNE	.19	.16	.25	*	*	*	*	*	.30	*	*	.16	.14
5 - 29.0 km NE	*	.10	.23	*	*	*	*	*	*	*	*	.17	.08
6 - 131 km N	*	*	.33	*	*	*	.15	*	.16	*	*	.25	.11
7 - 97 km SE	-	-	-	*	*	*	*	*	*	*	*	*	.04
8 - 105 km ESE	*	*	*	*	*	*	*	*	.14	*	*	.16	.09
9 - 230 km NE	*	*	-	.05	*	*	*	*	*	*	*	*	.05

*Less than 0.1 Bq m^{-3}
- No Sample

Table 5. Gross Beta Activity in the Canadian Air Monitoring Network for 1988 (Millibecquerels per cubic metre)

Sampling Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Calgary	.22	.33	.24	.31	.35	.35	.37	.35	.42	.68	.28	.48	.37
Churchill	.62	.78	.44	.39	.16	.13	.15	.19	.16	.32	.73	.94	.42
Coral Harbour	.43	.53	.34	.22	.09	.07	.04	.05	.15	.17	.37	.72	.26
Digby	.00	.00	.00	.25	.26	.25	.31	.22	.31	.32	.34	.68	.25
Edmonton	.73	.52	.31	.33	.30	.26	.27	.29	.27	.57	.54	.78	.43
Fredericton	.52	.47	.27	.24	.26	.27	.38	.25	.36	.34	.31	.52	.35
Goose Bay	.49	.50	.20	.19	.16	.10	.19	.20	.18	.22	.21	.75	.28
Greenwood	.37	.39	.31	.24	.23	.35	.23	.35	.27	.42	.32	.51	.33
Halifax	.32	.47	.34	.16	.20	.29	.32	.37	.21	.28	.29	.56	.32
Inuvik	.26	.75	.82	.65	.23	.20	.20	.15	.27	.36	.86	.92	.47
McMaster	.86	.75	.51	.52	.58	.46	.65	.60	.50	.36	.65	.83	.61
Montreal	.45	.55	.39	.27	.27	.29	.58	.38	.42	.36	.34	.69	.42
Moosonee	.46	.77	.44	.35	.24	.22	.31	.30	.31	.24	.35	.58	.38
Ottawa - Airport	.43	.38	.30	.23	.32	.44	.47	.39	.42	.30	.35	.54	.38
Ottawa -BRMD	.28	.42	.31	.19	.27	.29	.52	.40	.46	.29	.39	.57	.37
Quebec	.29	.35.	.31	.13	.20	.26	.29	.27	.35	.21	.29	.53	.29
Regina	.62	.37	.13	.27	.19	.19	.17	.19	.20	.28	.56	.71	.32
Resolute	.63	.61	.42	.49	.10	.07	.11	.06	.04	.24	.69	.99	.37
Saskatoon	1.01	.60	.31	.29	.19	.24	.19	.27	.26	.37	.76	.90	.45
Sault Ste. Marie	.72	.63	.34	.29	.38	.32	.43	.32	.43	.33	.51	.72	.45
St. John's	.32	.34	.25	.14	.18	.15	.18	.17	.18	.31	.15	.31	.22
Summerside	.50	.51	.24	.14	.19	.28	.43	.26	.26	.49	.31	.50	.34
Thunder Bay	1.06	.78	.48	.37	.48	.43	.56	.50	.44	.47	.68	1.12	.61
Toronto	.51	.47	.22	.23	.19	.18	.32	.30	.24	.23	.00	.00	.24
Vancouver	.16	.15	.11	.24	.22	.15	.14	.21	.26	.36	.15	.26	.20
Whitehorse	.42	.45	.16	.21	.15	.13	.10	.10	.12	.16	.40	.39	.23
Windsor	.51	.43	.31	.22	.18	.21	.64	.66	.52	.40	.45	.83	.45
Winnipeg	.86	.54	.27	.19	.31	.30	.22	.39	.47	.52	.83	1.07	.50
Yellowknife	.66	.58	.54	.44	.18	.11	.22	.21	.18	.36	.75	1.11	.44
Average+	.50	.51	.34	.31	.19	.16	.20	.19	.21	.30	.49	.74	.37

+Geographical-Area Weighted

BRMD - Bureau of Radiation and Medical Devices

Table 6. *Gross* Beta Activity in the Canadian Precipitation *Monitoring* Network for 1988, (Combined Wet and Dry *Deposition*)

(Becquerels per square metre)

Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Total Annual Deposition	Annual Rainfall mm Water
Calgary	16	44	71	18	148	380
Churchill	15	39	38	26	118	420
Coral Harbour	21	24	39	39	122	231
Digby	21	42	47	40	150	1223
Edmonton	27	66	76	20	189	623
Fredericton	52	52	44	34	131	941
Goose Bay	53	43	37	55	188	839
Greenwood	70	43	70	89	272	1129
Halifax	36	46	33	69	183	1400
Inuvik	21	27	10	18	77	226
Montreal	31	69	95	36	231	751
Moosonee	29	40	105	47	221	796
Ottawa (Airport)	33	58	7	31	129	869
Ottawa (BRMD)	30	47	5	27	109	869
Quebec	27	60	18	46	150	1048
Regina	16	73	57	19	166	300
Resolute	23	27	57	19	127	165
Saskatoon	28	36	45	31	139	299
Sault Ste. Marie	43	70	89	106	308	916
St. John's	45	7	7	40	100	1508
Summerside	59	44	63	43	209	958
Thunder Bay	28	55	25	49	157	695
Toronto	71	74	96	167	407	748
Vancouver	33	11	25	30	99	1224
Whitehorse	24	33	44	24	126	359
Windsor	40	58	46	62	206	649
Winnipeg	29	93	62	38	222	329
Yellowknife	19	63	45	28	156	353
National Average+	25	41	44	32	139	

+Geographical Area-Weighted

BRMD - Bureau of Radiation and Medical Devices

Table 7. Strontium-90 in Untreated Water for 1988
(Millibecquerels per litre)

Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Average
Winnipeg River					
Pinawa	*	14	2	-	5
Lac du Bonne	31	*	4	*	9
Great Falls	*	4	16	*	7
Lake Huron					
Port Elgin	18	*	6	*	8
Kincardine	20	13	7	8	12
Lake Ontario					
Toronto	12	*	10	*	8
Ajax	*	5	*	*	2
Oshawa	8	3	11	13	9
Ottawa River					
Rolphton	8	9	7	-	8
Deep River	*	2	*	11	3
Petawawa	22	3	*	*	6
Pembroke	*	9	9	*	5
Ottawa	*	*	13	12	7
St. Lawrence River					
Bécancour	6	*	8	12	7
Grondines	3	*	*	*	1
St. Romuald	4	*	*	*	2

*Less than 1 $mBq\ L^{-1}$

- No sample

Table 8. Cesium-137 in Water for 1988
(Millibecquerels per litre)

Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Average
Winnipeg River					
Pinawa	*	*	*	*	*
Lac du Bonnet	*	*	2	*	*
Great Falls	2	*	2	1	2
Lake Huron					
Port Elgin	*	*	*	*	*
Kincardine	*	*	*	*	*
Lake Ontario					
Toronto	*	*	*	*	*
Ajax	*	*	*	*	*
Oshawa	*	*	*	*	*
Ottawa River					
Rolphton	1	1	1	*	*
Deep River	1	2	1	1	1
Petawawa	3	1	2	3	2
Pembroke	2	2	3	2	2
Ottawa	4	3	3	3	3
St. Lawrence River					
Bécancour	*	*	*	*	*
Grondines	*	*	*	*	*
St. Romuald	*	3	*	*	*

*Less than 1 mBq L^{-1}

Table 9. Tritium in Water of the Ottawa and St. Lawrence Rivers, December 1988-January 1989
(Becquerels per litre)

Rolphton	Deep River		Petawawa C.F.B.	Pembroke	Ottawa raw	Ottawa treated	Rockland	Hawkesbury	Chomedey (Laval)	La Salle (Montreal)	Grondines
	≤19	15 Dec	567	-	≤31		-	-			
≤19	≤19	16	255	619	≤19		-	≤19			
	≤19	17	277	453	≤19		-	≤19			
≤19	≤19	18 Dec	310	265	≤19		-	25			
≤19	≤19	19	304	277	≤19		≤19	≤19			
	≤19	20	62	220	19		≤19	≤23			
≤19	≤19	21	65	89	≤19		≤23	≤23			
		22	42	61	20		≤23	-			
		23	34	86	19		≤24	≤24			
		24	28	60	74		-	≤24			
		25	38	45	92	-	-	-	-		
		26	-	33	240	-	-	≤22	-		
		27	23	29	310	-	-	≤24	-		
		28	-	35	374	-	190	24	-		
		29	≤23	-	421	-	272	≤24	-		
		30	-	40	416	430	335	58	-		
		31	≤23	-	410	438	360	71	≤24		
		1 Jan	-	30	394	388	-	166	-	-	
		2	-	-	340	330	-	159	≤24	-	
		3	32	23	302	304	394	227	59	-	
	28	4	24	-	253	257	351	254	100	<11	
≤22		5	-	26	221	231	326	249	111	14	
≤22		6	-	26	177	197	298	231	157	13	
		7	27	≤23	160	155	-	245	218	-	
		8 Jan	-	≤23	129	124	-	201	232	22	
≤22		9	-	≤23	101	87	178	212	243	35	
≤22	≤22	10	-	23	70	86	148	149	214	21	
≤24	≤24	11	≤23	≤22	78	79	120	112	211	20	
≤24		12	-	31	47	78	62	97	181	25	
≤24		13	-	≤24	39	44	81	85	165	25	
		14	-	≤24	42	42	-	52	140	25	

Table 9. Continued
(Becquerels per litre)

Rolphton	Deep River		Petawawa C.F.B.	Pembroke	Ottawa raw	Ottawa treated	Rockland	Hawkesbury	Chomedey (Laval)	La Salle (Montreal)	Grondines
		15 Jan	≤23	-	37	34	-	33	102	12	≤11
		16	-	-	≤24	36	≤24	46	75	21	-
		17	-	-	≤24	≤24	≤24	27	75	33	≤11
		18	-	27	≤24	≤24	26	26	29	15	≤11
		19	-	-	≤24	≤24	34	38	48	17	27
		20	-	-	14	-	-	-	28	16	28
		21	-	-	≤23	-	-	44	39	17	17
		22 Jan					≤23	-	44	15	19
		23					-	26	≤24	≤11	19
		24					-	-	33	15	18
	≤11	25					-	-	≤24	12	14
		26					-	-	14		20
		27					-	-	35	≤11	28
		28					-	-	≤24	12	11
		29 Jan							-	≤11	23
		30							-	13	≤11
		31									≤11
		1 Feb									-
		2									≤11
		3									16
		4									≤11
		5 Feb									-
		6									≤11
		7									≤11
		8									≤11
		9									-
		10									≤11
		11									-
		12 Feb									≤11
		13									-
		14									≤11

Table 10. Radium-226 in Drinking Water for 1988
(Millibequerels per litre)

	First Quarter			Second Quarter			Third Quarter			Fourth Quarter		
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ontario												
Elliot Lake Treated	<---- 8.0 ---->			17	18	15	<---- 8.0 ---->			<---- 15 ---->		
Port Hope	<---- * ---->			<---- * ---->			<---- * ---->			<---- * ---->		
Saskatchewan												
Regina	*	*	*	*	*	-	*	*	*	*	*	*

*Less than 5 mBq L^{-1}

- No sample

Table 11. Uranium in Drinking Water for 1988
(Micrograms per litre)

	First Quarter			Second Quarter			Third Quarter			Fourth Quarter		
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ontario												
Elliot Lake Treated	<---- 1.6 ---->			1.1	0.6	1.8	<---- 1.0 ---->			<---- 0.8 ---->		
Port Hope	<---- 1.1 ---->			<---- 1.1 ---->			<---- 0.9 ---->			<---- 0.7 ---->		
Saskatchewan												
Regina	2.7	1.5	3.2	2.6	3.7	-	2.7	2.0	0.8	1.8	1.6	2.1

- No sample

Table 12. Cesium-137 in the Canadian Milk Monitoring Network for 1988 (Millibecquerels per cubic metre)

Sampling Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Calgary	*	39	*	*	*	37	*	*	*	*	*	*	31
Edmonton	68	43	79	111	69	74	65	107	64	106	82	57	77
Halifax	52	69	30	69	66	58	69	51	56	61	100	90	64
Moncton	88	35	56	58	38		*	50	41	59	38	59	49
Montreal	72	67	36	42	55	54	43	41	*	30	37	40	46
Ottawa	50	82	52	53	41	44	61	44	30	32	33	40	47
Quebec	68	81	102	65	87	36	85	79	81	102	56	57	75
Regina	*	49	*	*	36	49	47	*	33	*	*	40	36
Saskatoon	49	43	41	*	*	*	46	*	*	*	45	*	36
Sault Ste Marie	115	41	108	122	128	71	121	145	93	91	76	87	100
St. John's	54	79	74	42	70	66	88	78	188	74	139	68	85
Sussex	107	36	72	58	48	*	103	62	*	54	56	47	59
Thunder Bay	68	60	79	*	53	77	69	97	61	84	53	32	64
Toronto	*	56	57	74	32	*	*	*	33	*	*	33	39
Truro	*	39	38	59	56	59	40	64	61	56	72	74	54
Vancouver	152	169	135	174	119	89	80	103	136	44	77	69	112
Windsor	*	50	30	*	30	*	*	*	*	*	*	30	32
Winnipeg	103	57	66	73	64	88	54	47	55	46	62	67	65
Bruce	*	*	*	-	*	*	35	*	-	-	*	35	31
Whiteshell	41	35	-	77	111	36	66	-	61	69	-	-	62
Average+	65	71	61	72	56	51	49	52	50	42	46	45	55

+Population - Weighted

*Less than 30 mBq L^{-1}

- No sample

Table 13. Strontium-90 in the Canadian Milk Monitoring Network for 1988 (Millibecquerels per litre)

Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Average
Calgary	41	47	56	50	49
Edmonton	58	60	69	53	60
Halifax	61	88	88	73	78
Moncton	75	72	101	81	82
Montreal	47	63	61	57	57
Ottawa	75	65	66	57	66
Quebec	70	83	77	72	76
Regina	61	68	62	49	60
Saskatoon	74	69	68	71	71
Sault Ste. Marie	110	101	103	80	99
St. John's	94	107	119	92	103
Sussex	79	80	111	91	90
Thunder Bay	77	82	68	68	74
Toronto	39	46	40	41	42
Truro	64	70	83	67	71
Vancouver	45	50	66	68	57
Windsor	38	43	37	41	40
Winnipeg	57	59	59	52	57
National Average+	50	58	58	54	55

+Population - Weighted

Table 14. Radionuclide Analyses of Imported Foodstuffs
(Becquerels per kilogram)

Sample Name	Country	Sample Date	Ru-106	Cs-137	Cs-134	K-40
White Wine	Austria	88/06/03	*	0.70	*	24
White Wine	Austria	88/06/03	*	*	*	31
Feta Cheese	Bulgaria	88/01/11	*	6.0	2.1	24
Feta Cheese	Bulgaria	88/01/27	*	2.1	0.85	21
Reindeer Meat	Finland	88/10/03	*	713	117	138
Vodka	Finland	88/06/03	*	*	*	*
Pasta	Greece	88/08/31	*	420	110	55
Pasta	Greece	88/08/31	*	42	10	89
Oregano	Greece	88/01/11	100	640	200	480
Wild Oregano	Greece	88/02/03	*	34	8.6	480
Red Wine	Greece	88/06/03	*	1.7	0.52	39
Red Wine	Greece	88/06/03	*	3.2	1.0	37
Red Wine	Hungary	88/06/03	*	*	*	32
Red Wine	Italy	88/06/03	*	1.1	*	19
Trevis	Morocco	88/03/14	*	*	*	140
Endive	Morocco	88/03/14	*	*	*	50
Red Peppers	Morocco	88/03/14	*	*	*	71
Tomatoes	Morocco	88/03/14	*	*	*	0.68
Coriander	Morocco	88/02/11	*	1.8	*	520
Vodka	Poland	88/06/03	*	*	*	*
Beer	Poland	88/06/03	*	*	*	10
Red Wine	Romania	88/06/03	*	*	*	29
Chives	Taiwan	88/01/15	*	*	*	660
Raisins	Turkey	88/01/05	*	3.6	1.6	340
Filberts	Turkey	88/01/05	*	56	16	200
Filberts	Turkey	88/01/22	*	7.7	1.9	210
Filberts	Turkey	88/02/16	*	7.0	1.9	190
Filberts	Turkey	88/02/25	*	170	49	160
Mash	Turkey	88/03/14	*	*	*	190
Filberts	Turkey	88/03/15	*	63	17	230
Filberts	Turkey	88/03/28	*	87	24	200
Filberts	Turkey	88/04/18	*	65	19	230
Filberts (Crushed)	Turkey	88/11/03	*	160	40	190
Filberts	Turkey	88/11/22	*	4.9	1.5	220

Table 14. Continued
(Becquerels per kilogram)

Sample Name	Country	Sample Date	Ru-106	Cs-137	Cs-134	K-40
Bay Leaves	Turkey	88/01/04	*	41	11	240
Anise	Turkey	88/01/05	*	*	*	640
Cumin	Turkey	88/01/05	*	*	*	640
Oregano	Turkey	88/01/05	370	1900	580	580
Bay Leaves	Turkey	88/01/08	200	260	76	150
Bay Leaves	Turkey	88/01/21	*	41	8.5	140
Oregano	Turkey	88/02/01	240	1100	330	450
Zatar Mix	Turkey	88/02/10	47	260	74	170
Ground Summack	Turkey	88/02/10	*	*	*	87
Bay Leaves	Turkey	88/02/17	*	86	27	150
Oregano	Turkey	88/02/29	120	900	260	530
Oregano	Turkey	88/03/07	4.0	76	21	670
Oregano	Turkey	88/03/11	470	3000	870	460
Oregano	Turkey	88/03/28	260	1400	400	490
Oregano	Turkey	88/04/12	52	480	140	550
Oregano	Turkey	88/04/15	350	1800	500	560
Oregano	Turkey	88/04/19	180	1100	320	500
Oregano	Turkey	88/04/20	69	600	170	450
Oregano	Turkey	88/05/13	28	190	51	440
Oregano	Turkey	88/06/07	190	1300	350	420
Oregano	Turkey	88/06/16	200	460	130	540
Oregano	Turkey	88/06/21	160	1100	310	410
Oregano	Turkey	88/06/20	130	1400	370	490
Oregano	Turkey	88/06/30	130	1200	310	450
Oregano	Turkey	88/07/08	230	1300	360	510
Oregano	Turkey	88/08/04	120	810	210	440
Oregano	Turkey	88/08/15	100	790	200	430
Oregano	Turkey	88/09/06	160	1600	410	460
Oregano	Turkey	88/09/28	220	1300	310	460
Oregano	Turkey	88/11/07	140	1400	310	490
Oregano	Turkey	88/11/07	18	150	33	620
Oregano	Turkey	88/11/08	54	620	150	410
Oregano	Turkey	88/11/08	55	700	150	440
Oregano	Turkey	88/11/08	74	630	150	510
Oregano	Turkey	88/12/13	220	1800	430	530
Oregano	Turkey	88/12/13	*	27	4.6	530
Vodka	U.S.S.R.	88/06/03	*	*	*	*
White Wine	W. Germ.	88/06/03	*	*	*	19
Jam	Yugoslavia	88/03/16	*	9.4	2.0	22
Sage	Yugoslavia	88/02/01	*	14	3.1	360
Red Wine	Yugoslavia	88/06/03	*	0.41	*	25
Red Wine	Yugoslavia	88/06/03	*	2.3	0.71	25
*Less than :			0.14	0.18	0.13	7

Table 15. Performance in Interlaboratory Comparisons

Medium	Analysis	ERHD Value*	Known Value**
Air Filter	Gross α	1.18	0.74±0.18
	Gross β	2.00	1.85±0.18
	Cs-137	0.70	0.59±0.18
Air Filter	Gross α	0.32	0.30±0.18
	Gross β	1.07	1.07±0.18
	Cs-137	0.49	0.44±0.18
Water	Gross α	0.16	0.15±0.18
	Gross β	0.31	0.30±0.18
Water	Gross α	0.22	0.22±0.18
	Gross β	0.44	0.48±0.18
Water	Gross α	0.37	0.41±0.18
	Gross β	0.42	0.41±0.18
Water	Gross α	0.35	0.55±0.18
	Gross β	0.17	0.15±0.18
Water	Gross α	0.28	0.30±0.18
	Gross β	0.36	0.37±0.18
Water	Tritium	119	123±14
Water	Tritium	214	206±20
Water	Tritium	86	86±13
Water	Sr-89	1.18	1.11±0.18
	Sr-90	0.48	0.56±0.06
Water	Sr-89	0.60	0.74±0.18
	Sr-90	0.72	0.74±0.06
Water	Ra-226	0.17	0.18±0.03
	Ra-228	0.21	0.20±0.03
Water	Ra-226	0.28	0.28±0.04
	Ra-228	0.30	0.28±0.04
Water	Ra-226	0.37	0.37±0.06
	Ra-228	0.46	0.46±0.07
Water	Ra-226	0.29	0.31±0.05
	Ra-228	0.15	0.20±0.03
Water	Uranium	0.11	0.11±0.22
Water	Uranium	0.23	0.22±0.22
Water	Co-60	2.54	2.55±0.18
	Zn-65	3.44	3.48±0.35
	Ru-106	3.84	3.89±0.39
	Cs-134	2.31	2.37±0.18
	Cs-137	3.45	3.48±0.18
Water	Cr-51	12.40	11.17±1.1
	Co-60	0.53	0.56±0.18
	Zn-65	3.80	3.74±0.37
	Ru-106	6.50	7.22±0.74
	Cs-134	0.65	0.74±0.18
	Cs-137	0.97	0.93±0.18
Water	Cr-51	9.22	9.29±0.95
	Co-60	0.88	0.93±0.18
	Zn-65	5.16	5.59±0.55
	Ru-106	5.21	5.63±0.55
	Cs-134	0.86	0.93±0.18
	Cs-137	0.53	0.56±0.18
Water	I-131	2.80	2.81±0.30
Milk	Sr-89	1.68	1.48±0.18
	Sr-90	1.85	2.22±0.11
	I-131	3.55	3.48±0.33
	Cs-137	1.80	1.89±0.18
	K	1517	1600±80
Air Sample	Rn-222	211±11	222±4

*All units are Bq L^{-1} except air filters (Bq perfilter, Rn-222 (Bq m^{-3}) and potassium (mg L^{-1})

**Uncertainty value at one standard deviation