SU-2

POINT LEPREAU NUCLEAR GENERATING STATION

Annual Compliance Report

ENVIRONMENTAL PROTECTION - 2017
ACR-07000-2017
Rev. 0

Format is the responsibility of the Document Owner

Document Approval

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Revision Record

The following is the latest revision record for this document.

Rev. #	Date	Changes Since Last Revision	Author(s)	Reviewer(s)
0	2018-03-20	New issue.	J. McCulley	G. Barton A. Murray B. Curry K. Duguay

Classification Statement

Proprietary usage

Executive Summary

This report describes the 2017 results of the environmental monitoring program for the Point Lepreau Nuclear Generating Station (PLNGS).

In 2017, 1287 samples were analysed to monitor environmental radiation around Point Lepreau and across the province in general. There were 269 other samples, including 182 Quality Assurance (QA) samples.

The analyses indicate that radiation dose from PLNGS releases continues to be well below the public dose limit (1000 microsieverts per annum), and also well below the design and operating target for PLNGS (50 microsieverts per annum).

Source of Dose to the Representative Person	*Individual Dose ($\mu Sv \cdot a^{-1}$)*
PLNGS airborne releases	0.71
PLNGS liquid releases	0.02

Reports are issued to other regulators for non-radioactive hazardous releases. These reports are described in this report in *Section 8*.

Alignment to the Canadian Standards Association (CSA) standards *N288.4-10, Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills* and *N288.5-11, Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills* was progressed in 2017. The following were completed or updated in 2017:

- *PRR-00660-SU-2 Provide Environmental Services*
- *SI-01365-P101 Developing and Maintaining the Environmental Management System*
- *SI-01365-P108 Developing and Implementing the Environmental Monitoring Program*
- *IR-07600-01 Environmental Monitoring Program*
- *IR-07600-03 Environmental Monitoring Plan*
- *PRR-00660-OP-3 Control Effluents*
- *SI-01365-P107 Establishing and Implementing the Effluent Monitoring Program*
- *SDP-01368-P077 Monitor and Control Effluents*

Canadian Nuclear Laboratories (CNL) continued their work to assist the station to close the gaps and implement the standards for PLNGS. The newly aligned program was implemented January 1, 2018.

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1 Introduction

This document describes the results of the Radiation Environmental Monitoring Program (REMP) and summarizes the reports for non-radioactive hazardous releases for the year 2017, as required by *Section 3.5* of CNSC *REGDOC 3.1.1, Reporting Requirements for Nuclear Power Plants*.

The REMP for 2017 was described in *IR-03541-HF02, Radiation Environmental Monitoring Program (REMP).* The requirement for the REMP is stated in *STD-03400-04, Radiation Protection Directives,* and *SR-79100, Solid Radioactive Waste Management Facility 2007 Safety Report*. The underlying reason for the program is the large inventory of radionuclides that are present onsite. The program operates in conjunction with *SDP-01368-P077, Monitor and Control Effluents,* a program which monitors and controls effluents at their source. The Derived Release Limits (DRLs) are calculated in *RD-01364-L1, Derived Release Limits for Radionuclides in Airborne and Liquid Effluents*.

As part of its overall Management System, PLNGS has an Environmental Management System (EMS) (*SI-01365-P101, Developing and Maintaining the Environmental Management System (EMS))* in place that is registered to National Standards of Canada, *CAN/CSA-ISO 14004-2004-04 Environmental Management Systems – General Guidelines on Principles, Systems and Support Techniques* (2nd Edition). All activities and products that could impact the environment have been identified and logged in a database. From this database, a list of significant environmental aspects (SEAs) was developed and it forms the foundation for the EMS. Management programs are in place for each of the SEAs to ensure compliance with the standards. The SEAs include radiological and non-radiological releases to water and air, waste management and accident management. Environmental assessment and improvement programs have been developed for the SEAs to ensure continual improvement.

All activities that support PLNGS are controlled by the PLNGS Management System. The environmental radiation monitoring program falls under the primary process *PRR-00660-SU-2, Provide Environmental Services*. All sub-processes related to routine environmental radiation monitoring come under SU-02.

All radionuclide analyses in 2017 were performed in the Fredericton Health Physics Laboratory at 420 York Street, Fredericton, NB.

The basis of the REMP complies with National Standards of Canada, *CAN/CSA-N288.4-M90 (R2008) Guidelines for Radiological Monitoring of the Environment)*. Since this standard was replaced in 2010 with CSA standard *N288.4-10 Environmental monitoring programs at Class I nuclear facilities*, the REMP was modified to comply with the 2010 standard in 2017.

The Radiation Environmental Monitoring Program for PLNGS fulfils several objectives. These are to:

1) permit the estimation of dose to the Representative Person and populations from the radioactive releases from PLNGS and its Solid Radioactive Waste

Management Facility (SRWMF). This estimation of dose is achieved through the analyses of environmental and effluent samples.

2) provide data to confirm compliance of PLNGS and the SRWMF with release guidelines and regulations and to provide public assurance of compliance. These provisions are achieved through the publication of the annual report on the NB Power website.

3) establish and maintain the capability for environmental monitoring so that an effective response can be made to emergency conditions. This response is assured by maintaining the resources to step up the monitoring program during increased releases that are only likely during an accident. The ability to interpret the data and make recommendations is also maintained.

4) maintain a database to facilitate the detection of trends. The database is maintained by storing all results on a computer system that has the capability of reporting and graphing any desired subsets of the data.

5) verify or refine environmental models used in the calculation of Derived Release Limits (DRLs). Verification is achieved by comparing the theoretical dispersion factor with one calculated empirically. In addition, other exposure routes to the public are continually evaluated.

6) determine the fate of released radioactive materials to show whether any pathway to humans has been overlooked. The deposition of radioactive material is determined through the collection and analysis of sample media outside of the established program. In addition, any results that are not consistent with effluent results are investigated.

The capability of the radiation monitoring laboratory is assessed through the QA program and through the daily analytical checks. These checks demonstrate the accuracy and consistency of analyses.

The following sections will briefly describe the program. Details are provided on PLNGS releases, results of analyses, dose estimates, and the quality assurance program.

2 PLNGS Radioactive Release Data

Releases from PLNGS continue to be at low levels as indicated in Table 2.01. By the time these releases reach the edge of the exclusion zone, they are diluted below the detection limits of most of the analytical procedures.

Table 2.01: Radionuclides Detected in Effluents

Nuclide	*Gaseous Effluent DRL ($Bq{\cdot}a^{-1}$)*	*Release (Bq)*	*DRL (%)**	*Liquid Effluent DRL ($Bq{\cdot}a^{-1}$)*	*Release (Bq)*	*DRL (%)*
H-3	2.8E+17	1.5E+14	5.2E-02*	4.6E+19	1.2E+14	2.6E-04
C-14	6.8E+15	3.1E+11	4.6E-03	3.3E+14	1.8E+09	5.5E-04
Na-24	-----------	-----------	-----------	2.2E+15	1.7E+06	7.8E-08
Ar-41	2.6E+17	3.4E+13	1.3E-02	-----------	-----------	-----------
Cr-51	-----------	-----------	-----------		1.5E+07	9.4E-08
Mn-54	-----------	-----------	-----------	8.1E+13	6.6E+05	8.2E-07
Fe-59	-----------	-----------	-----------	3.1E+12	3.0E+06	9.8E-05
Co-60	-----------	-----------	-----------	3.9E+13	1.7E+08	4.6 E-04
Zn-65	-----------	-----------	-----------	9.7E+12	1.5E+06	1.6E-05
As-76	-----------	-----------	-----------	1.3E+15	2.9E+05	2.2E-08
Kr-85m	2.3E+18	1.1E+11	4.8E-06	-----------	-----------	-----------
Kr-87	4.1E+17	1.3E+11	3.1E-05	-----------	-----------	-----------
Kr-88	1.2E+17	5.4E+11	4.5E-04	-----------	-----------	-----------
Sr-90	2.7E+12	1.2E+04	4.4E-07	6.0E+15	4.6E+05	7.7E-09
Zr-95	-----------	-----------	-----------	8.6E+13	3.9E+07	4.5E-05
Nb-95	-----------	-----------	-----------	8.6E+14	9.4E+07	1.1E-05
Ag-110m	-----------	-----------	-----------	2.6E+13	4.8E+06	1.8E-05
Sn-113	-----------	-----------	-----------	4.1E+12	1.0E+06	2.5E-05
Sb-122	-----------	-----------	-----------	9.4E+14	6.9E+06	7.4E-07
Sb-124	-----------	-----------	-----------	5.2E+14	3.8E+08	7.4E-05
Sb-125	-----------	-----------	-----------	1.4E+15	4.3E+07	3.3E-06
I-131	-----------	-----------	-----------	7.1E+13	2.3E+05	3.2E-07
Xe-131m	4.3E+19	1.7E+10	3.9E-08	-----------	-----------	-----------
Xe-133	1.2E+19	7.2E+12	6.3E-05	-----------	-----------	-----------
Xe-133m	1.3E+19	1.2E+11	9.3E-07	-----------	-----------	-----------
Xe-135	1.4 E+18	7.7 E+11	5.3 E-05	-----------	-----------	-----------
Xe-135m	8.6 E+17	1.9 E+11	2.1E-05	-----------	-----------	-----------
Cs-137	-----------	-----------	-----------	4.6E+14	6.1E+05	1.3E-07
Xe-138	2.9E+17	5.4E+11	1.8E-04	-----------	-----------	-----------
Gd-153	-----------	--------	-----------	4.2E+15	4.6E+07	1.1E-06
Gd-159	-----------	--------	-----------	7.2E+15	3.7E+06	5.2E-08
Tb-160	-----------	-----------	-----------	6.4E+14	7.9E+07	1.2E-05
Alpha	-----------	-----------	-----------	-----------	7.9E+06	-----------
Beta	-----------	-----------	-----------	-----------	7.8E+07	-----------
Total			7.1E-02	Total		1.6E-03

* To calculate % DRL for releases from some locations and during outages, an adjustment is made to compensate for different flow rates and/or points of release.

3 Sample Media, Locations and Frequencies (REMP)

The data contained in this report are for samples collected from January 1 to December 31, 2017, with some overlap for air, precipitation and thermo luminescent dosimeter (TLD) samples. During this time, the media analysed and their frequency of collection were as indicated in Table 3.01. Sample collection usually takes place at least once each week throughout the year. The number of each sample type collected in 2017 and the major radionuclide measurements performed on that sample type are listed in Table 3.02.

The miscellaneous sample group includes those samples that are above and beyond the listed categories or are not routinely collected.

The major sample locations are listed in Table 3.03 (details in *Appendix C*) and shown in Figures 3.01 to 3.05. Each "Indicator" site has a three or four-character identification code (e.g., F01, I10A). An Indicator site is one within the possible influence of PLNGS releases. A "Reference" site is outside the influence of PLNGS releases and is identified by the letter R at the end of the location code (e.g., A13R).

Sample locations for mobile seafood species (lobster, fish, etc.) collected in the Lepreau area are specified as accurately as reasonably possible. The location of capture, however, may bear little relationship to where the animal has been in the recent past. The availability of such samples is not generally predictable and is outside of the control of the laboratory.

Table 3.01: Schedule of Sample Collection and Analysis

Sample Medium	*Typical Frequency*
Atmospheric Sampling	
Airborne Particulates	Monthly (integrated sample)
Airborne Iodines	Monthly (integrated sample)
Water Vapour	Monthly (integrated sample)
Carbon Dioxide	Monthly (integrated sample)
Ambient Gamma Measurements (TLDs)	Quarterly (integrated sample)
Gaseous Effluent Monitor (GEM) Particulates	Weekly (integrated sample)
Terrestrial Sampling	
Ambient Gamma Measurements (TLDs)	Quarterly (integrated sample)
Milk - commercial dairy - dairy farms	Monthly Quarterly
Well Water	Semi-annually
Pond, Puddle and Surface Water	Quarterly
Berries	Weekly in Season
Garden Vegetables	Weekly in Season
Vegetation	Monthly
Soil	Quarterly
Monitoring Well Water (Near Plant)	Annually
Precipitation	Monthly (integrated sample)
Marine Sampling	
Seawater	Quarterly
Clams	Quarterly When Available
Fish	Quarterly When Available
Lobster	Quarterly When Available
Periwinkles	Monthly When Available
Aquaculture Salmon	Quarterly When Available
Crabs	Quarterly When Available
Dulse	Monthly When Available
Other Sea Plants	Quarterly
Sediment	Quarterly
Ambient Gamma Measurements of Intertidal Zone (Ion Chamber)	Quarterly
Liquid Effluent Monitor (LEM) Composite Water	Monthly Composite (integrated sample)

Table 3.01: Schedule of Sample Collection and Analysis, Continued

Sample Medium	***Typical Frequency***
Solid Radioactive Waste Management Facility	
Bore Hole Water	Three Times Per Year
Parshall Flume Water	Weekly
Ambient Gamma Measurements (TLDs)	Quarterly (integrated sample)
Hemlock Knoll Regional Sanitary Landfill	
Ambient Gamma Measurements (TLDs)	Quarterly (integrated sample)

Table 3.02: Sample Information

Sample Medium	Number of Samples	Radionuclide Measurements
Atmospheric Sampling		
Airborne Particulates	96	gamma emitters & gross alpha/beta
Airborne Iodines	96	Iodine-131
Water Vapour	96	Tritium
Carbon Dioxide	34	Carbon-14
Ambient Gamma Measurements (TLDs)*	103*	gamma exposure
GEM Particulates	50	Strontium-89,90 & gamma emitters
Terrestrial Sampling		
Ambient Gamma Measurements (TLDs)*	103*	gamma exposure
Milk - commercial dairy - dairy farms	11 10	gamma emitters & tritium
Well Water	17	gamma emitters, gross alpha/beta & tritium
Pond, Puddle and Surface Water	24	gamma emitters & tritium
Berries	3	gamma emitters
Garden Vegetables	22	gamma emitters
Vegetation	14	gamma emitters
Soil	35	gamma emitters
Monitoring Well Water (Near Plant)	11	gamma emitters & tritium
Precipitation	39	gamma emitters & tritium
Marine Sampling		
Seawater	16	gamma emitters & tritium
Clams	8	gamma emitters
Fish	5	gamma emitters
Lobster	6	gamma emitters
Periwinkles	13	gamma emitters
Aquaculture Salmon	5	gamma emitters
Crabs	0	gamma emitters
Dulse	6	gamma emitters
Other Sea Plants	12	gamma emitters
Sediment	40	gamma emitters
Ambient Gamma Measurements of Intertidal Zone (Ion Chamber)	40	gamma exposure
LEM Composite Water	12	Strontium-89,90, gamma emitters, gross alpha/beta

*The same TLD measures gamma dose from radionuclides in the air and on the ground.

Table 3.02: Sample Information, Continued

Sample Medium	*Number of Samples*	*Radionuclide Measurements*
Solid Radioactive Waste Management Facility		
Bore Hole Water	103	gamma emitters & tritium
Parshall Flume Water	162	gamma emitters & tritium
Ambient Gamma (TLDs)	181	gamma exposure
Hemlock Knoll Regional Sanitary Landfill		
Ambient Gamma (TLDs)	16	gamma exposure
Other		
Miscellaneous	76	as required
Quality Assurance	162	as scheduled

Table 3.03: General Location Codes

Code	***Location***
A	West of Pennfield Ridge
B	Pennfield to New River Beach (inclusive)
C	Lepreau and Lepreau Harbour
D	Little Lepreau and Little Lepreau Basin
E	Maces Bay
F	Welch Cove
G	Pt. Lepreau lighthouse and surrounding area
H	Duck Cove
I	PLNGS site – northeast quadrant
J	PLNGS site – southeast quadrant
K	PLNGS site – southwest quadrant
L	PLNGS site – northwest quadrant
M	PLNGS
N	Dipper Harbour
P	East of Dipper Harbour East to Musquash
Q	Lorneville
S	Saint John and surrounding area
T	Taymouth
X	Fredericton and surrounding area
Y	Hemlock Knoll Regional Sanitary Landfill

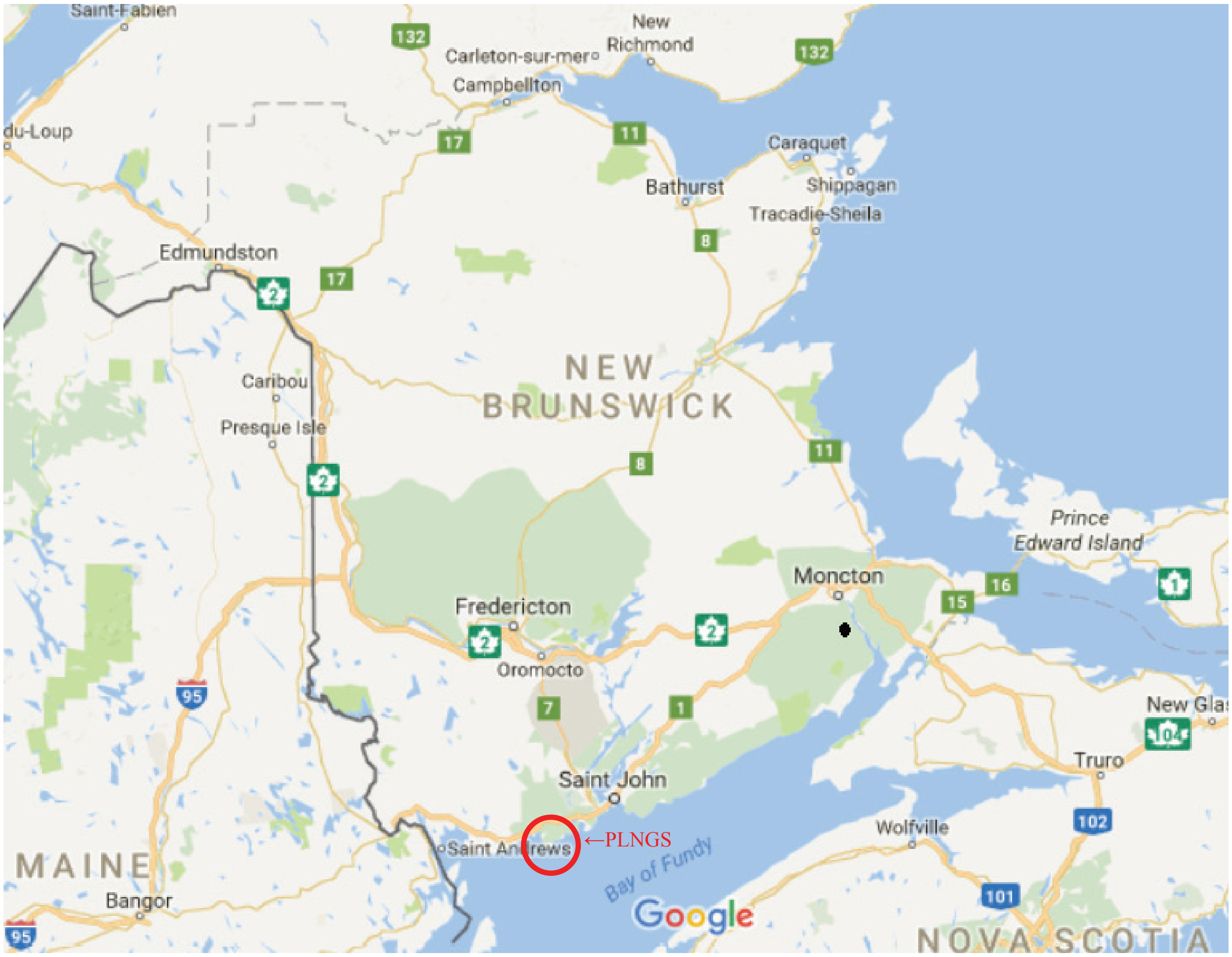


Figure 3.01: Location of PLNGS within the Province of New Brunswick

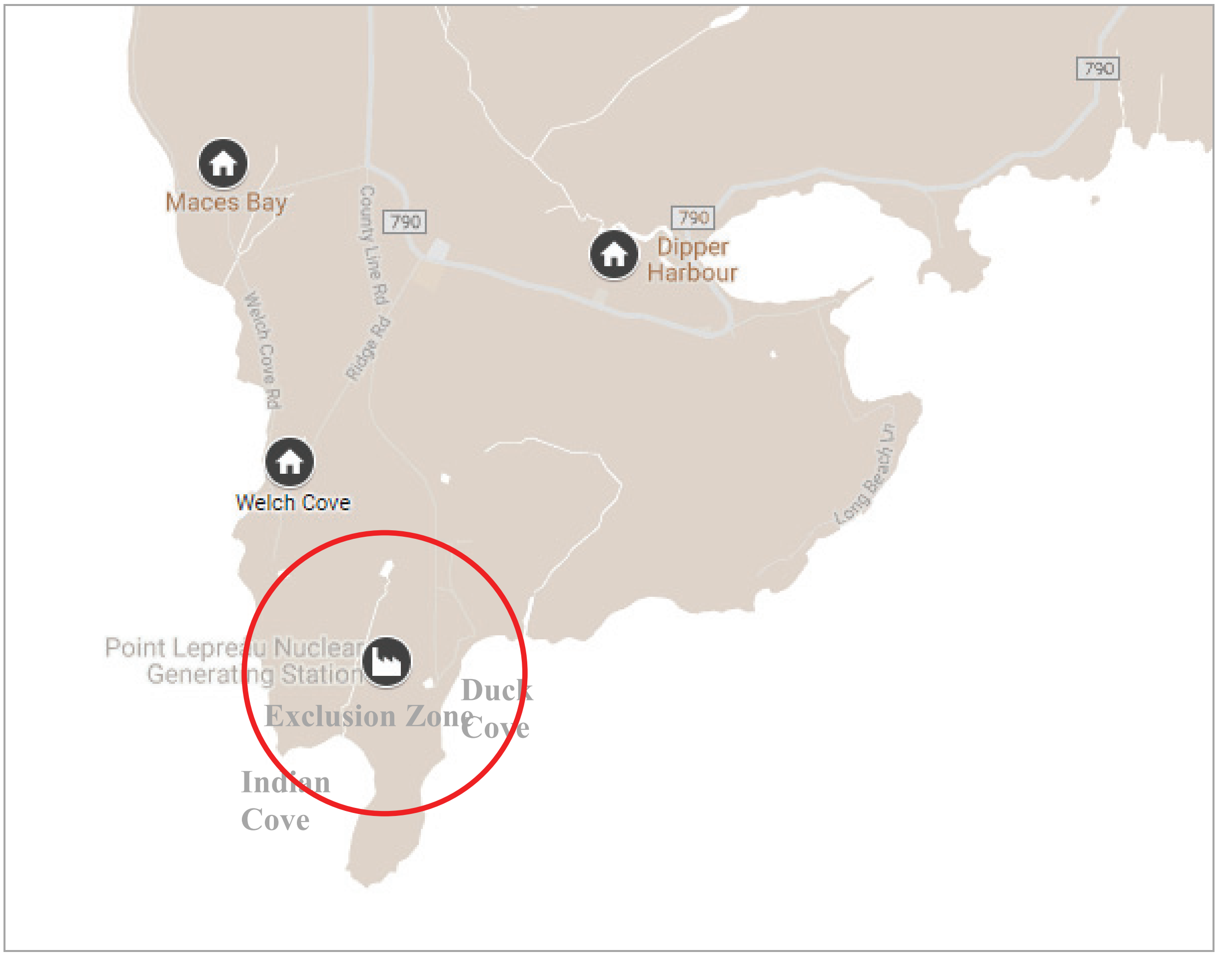


Figure 3.02: PLNGS and Immediately Surrounding Area

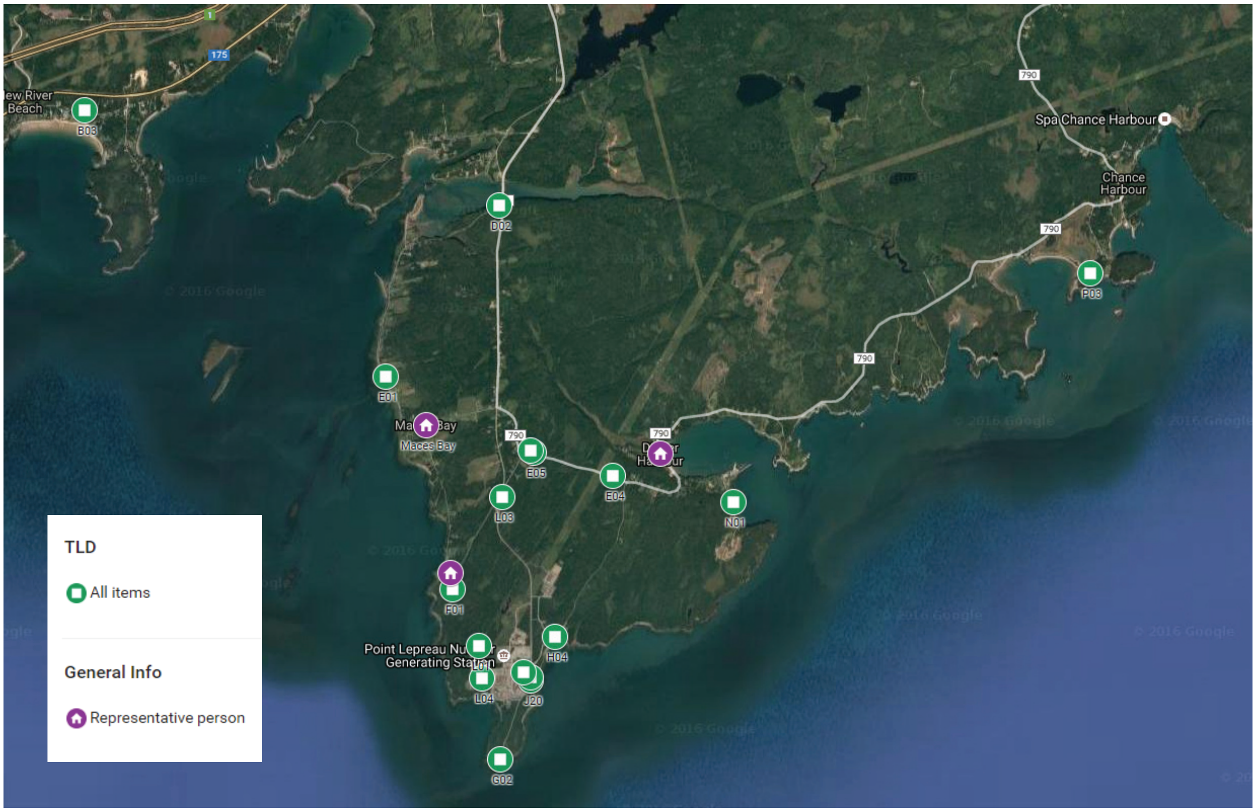


Figure 3.03: TLD Monitoring Sites at and around PLNGS

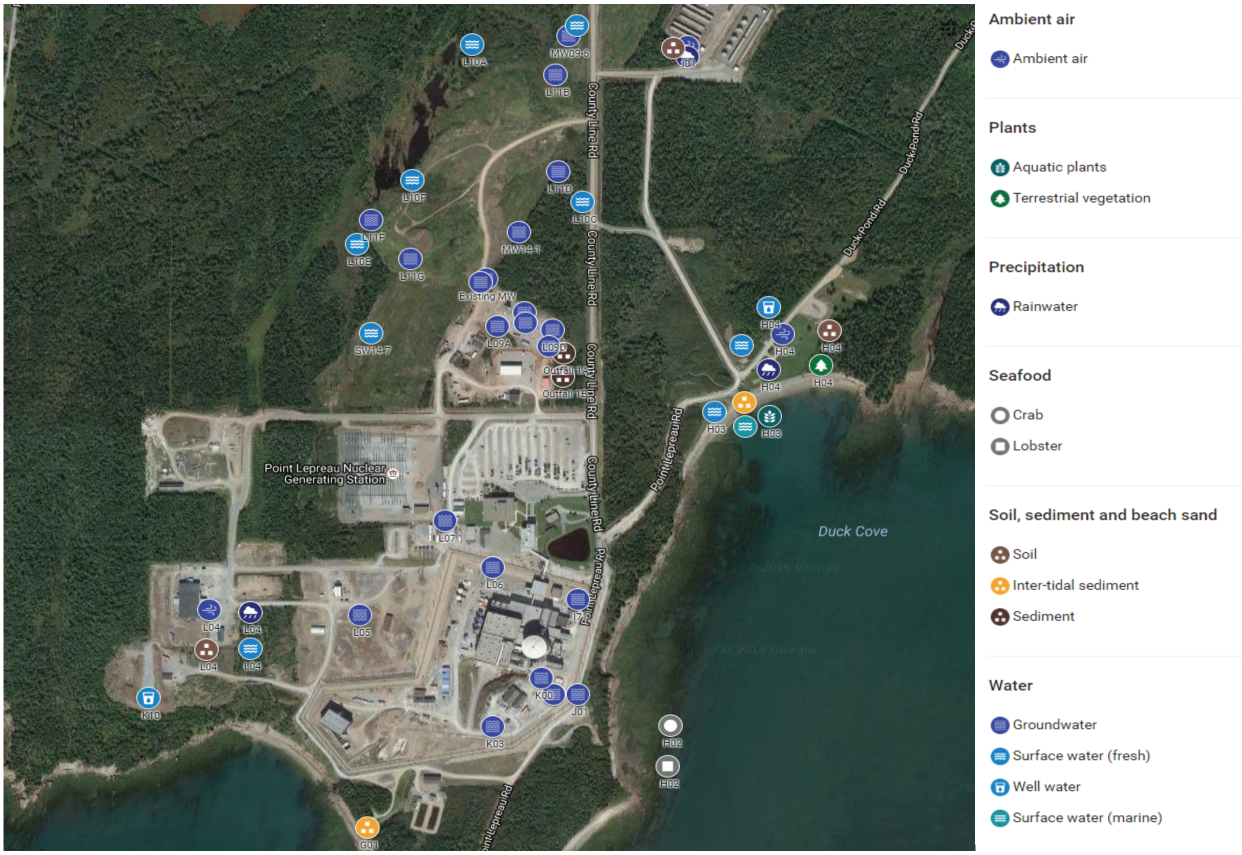


Figure 3.04: Environmental Monitoring on the PLNGS Site

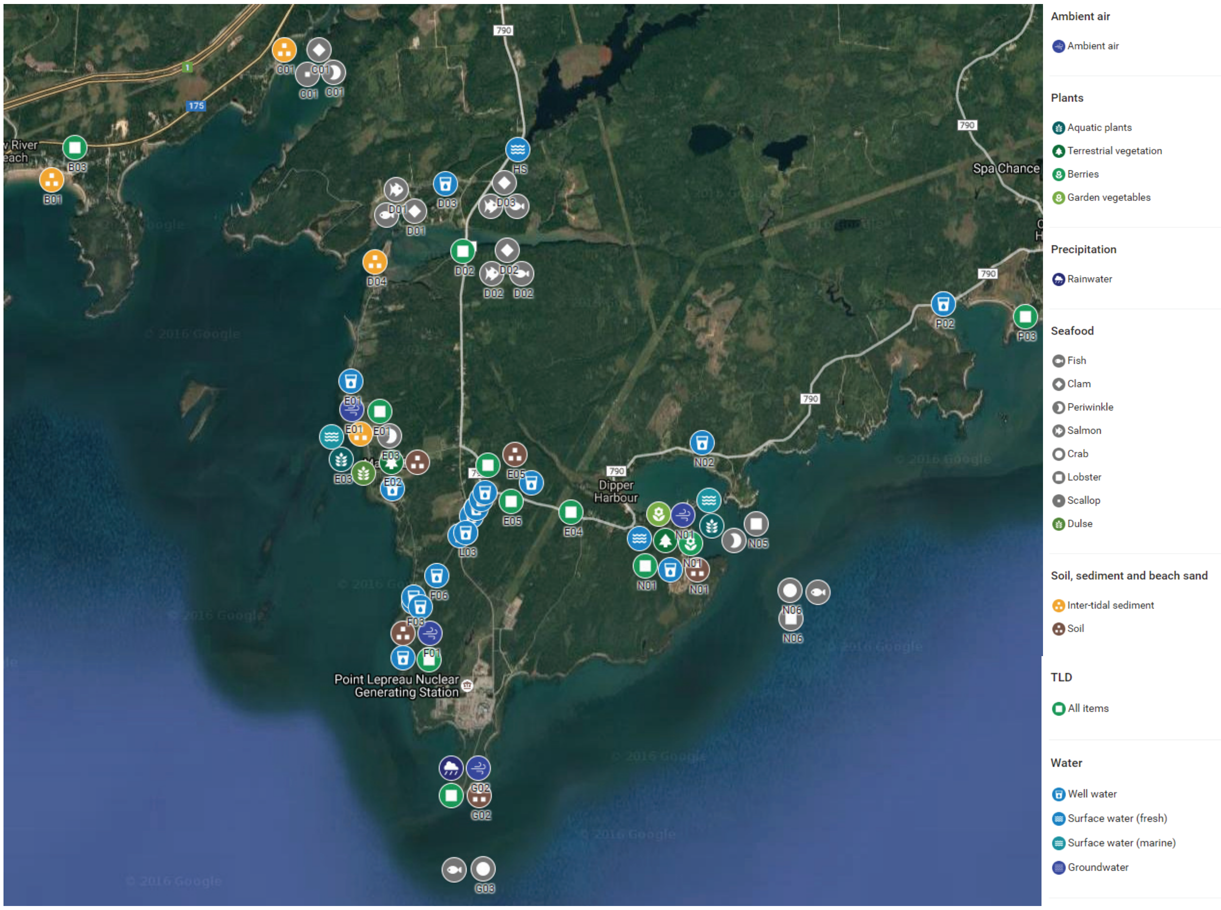


Figure 3.05: Environmental Monitoring on the Lepreau Peninsula

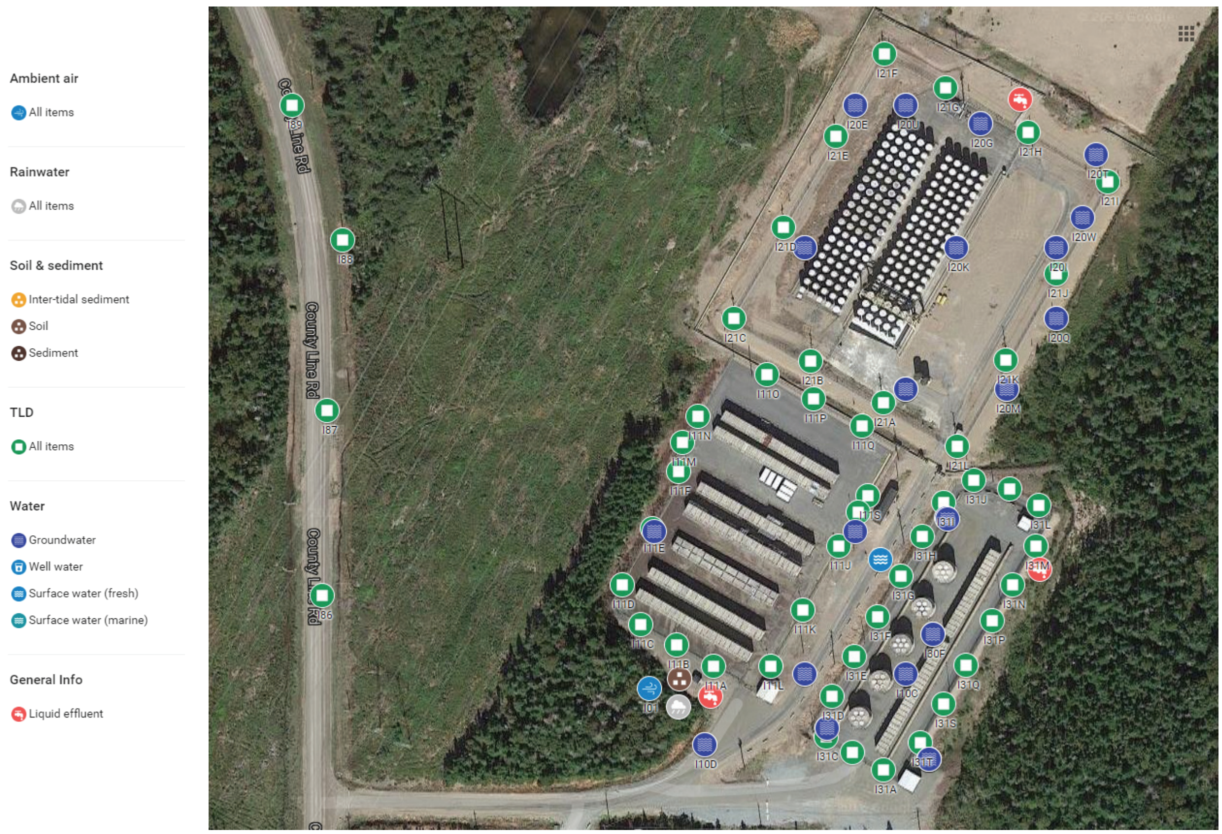


Figure 3.06: Environmental Monitoring at the Solid Radioactive Waste Management Facility (SRWMF)

4 Summary and Discussion of REMP Data

The following is a summary and discussion of the data on environmental samples collected for the year 2017.

Most samples contained low levels of naturally occurring K-40 or cosmogenically produced Be-7. Some samples contained Cs-137 (soils, sediments, lichen) from the atmospheric weapons tests of past years and international events (at Chernobyl and Fukushima). Tritium (in air and fresh water) is the only radionuclide originating from PLNGS that is detected consistently. In 2017, analyses that indicated releases traceable to PLNGS were:

- H-3 in airborne water vapour and fresh water
- H-3 in Parshall flume and bore hole water from the Solid Radioactive Waste Management Facility (SRWMF)
- H-3 in water from onsite monitoring wells

The only assessable radiation dose from PLNGS on the local population is that from tritiated water vapour in air. Offsite, the activity of H-3 in air ranges from less than 3E-02 $Bq \cdot m^{-3}$ (below the lower limit of detection by the method used) to approximately 2E+00 $Bq \cdot m^{-3}$ of air. The natural concentration of H-3 is up to 7E-01 $Bq \cdot L^{-1}$ in most surface waters and up to 1E-03 $Bq \cdot m^{-3}$ in air.

The natural concentration of C-14 in the atmosphere is approximately 4E-02 $Bq \cdot m^{-3}$. This level is usually detected by the sensitive analytical method used in the monitoring program.

Only detected radionuclides are listed in the following tables. (Refer to Tables A.01 to A.11 in Appendix A for detailed listings of detection limits. Refer to Appendix C for a listing of location codes.) Most tables contain the following data:

Column 1 - Shows the type of analysis or nuclide.

Column 2 - Shows the total number of samples analysed.

Column 3 – Shows the mean of the Critical Levels (CLs) for all samples. Any measurement greater than the CL is considered detected at the 99% confidence level (an explanation of the statistical protocol is given in Appendix A).

Column 4 - Shows the range of the Critical Levels (CLs) for all samples. Any measurement greater than the CL is considered detected at the 99% confidence level (an explanation of the statistical protocol is given in Appendix A).

Column 5 - Shows the mean of the detected values (i.e., values exceeding the CL) for all Indicator stations.

Column 6 - Shows the ratio of the number of detected values to the total number of Indicator samples.

Column 7 - Shows the range of detected values for the Indicator stations.

Column 8 - Shows the mean of detected values at the Reference location(s).

Column 9 - Shows the ratio of detected values to the total number of samples at this location.

Column 10 - Shows the range of detected values for the Reference location(s).

4.01 Airborne Particulates

Of the 96 filters analyzed, gross alpha was detected on 94, gross beta on 96, Be-7 on 90 and K-40 on one. None of these results are attributable to the operation of PLNGS.

Air is continuously monitored from the eight locations shown in Figure 3.05. Once per month the filters are changed and analysed.

Gross alpha and gross beta measurements are an indication of total activity in the environment. This includes naturally occurring radon progeny, cosmogenic (Be-7), and anthropogenic sources of radiation. The maximum concentration of gross beta in air onsite was 6.9E-04 $Bq\cdot m^{-3}$ of air. Offsite gross beta reached 5.1E-04 $Bq\cdot m^{-3}$.

When Sr-89,90 releases are low, the expected concentration of these radionuclides in environmental air samples is below the detection limit. The Gaseous Effluent Monitor (GEM) monitors PLNGS gaseous releases continuously at their source. The GEM filter was changed weekly. Fifty GEM filters were analysed for Sr-89,90. If the weekly release is more than one percent of the weekly DRL, or if elevated beta activity is detected in environmental air samples, a Sr-89,90 analysis is performed on the environmental air particulate samples. Since no Sr-89 releases were detected in 2017 and the Sr-90 release was 4.4E-7% DRL (and in no week exceeded one percent of the weekly DRL), no further analyses were required.

Table 4.01 is a summary of detected radionuclides. Figures 4.01 and 4.02 show the gross beta results for each location throughout the year.

Table 4.01: Airborne Particulates (Bq·m^{-3})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
ALPHA	96	3.5E-6	1.9E-6 to 1.1E-5	2.5E-5	82/84	8.5E-6 to 5.2E-5	2.0E-5	12/12	1.0E-5 to 3.4E-5
BETA	96	6.8E-6	2.8E-6 to 2.3E-5	3.1E-4	84/84	9.6E-5 to 6.9E-4	2.5E-4	12/12	8.5E-5 to 4.6E-4
Be-7	96	1.3E-4	3.6E-5 to 4.2E-4	1.8E-3	79/84	3.0E-4 to 3.4E-3	1.1E-3	11/12	4.5E-4 to 2.3E-3
K-40	96	4.2E-4	2.1E-4 to 1.3E-3	6.9E-4	1/84	6.9E-4 to 6.9E-4	*	*	*

* The activity is less than or equal to the Critical Level (99 % Confidence Level).

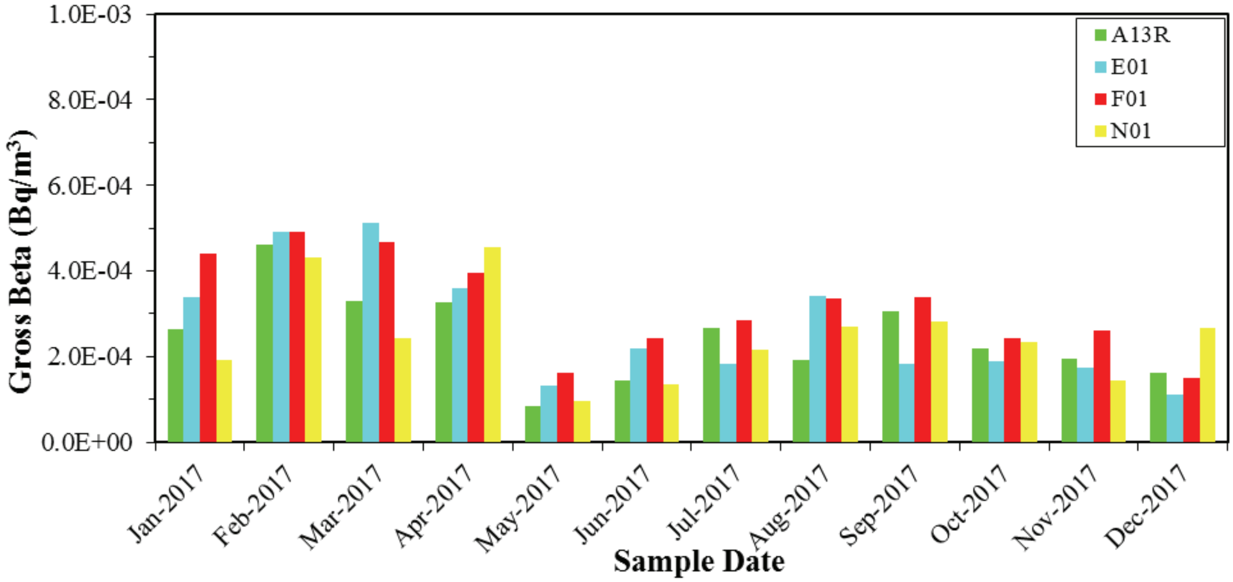


Figure 4.01: Gross Beta (Air Particulates) at Offsite Air Stations

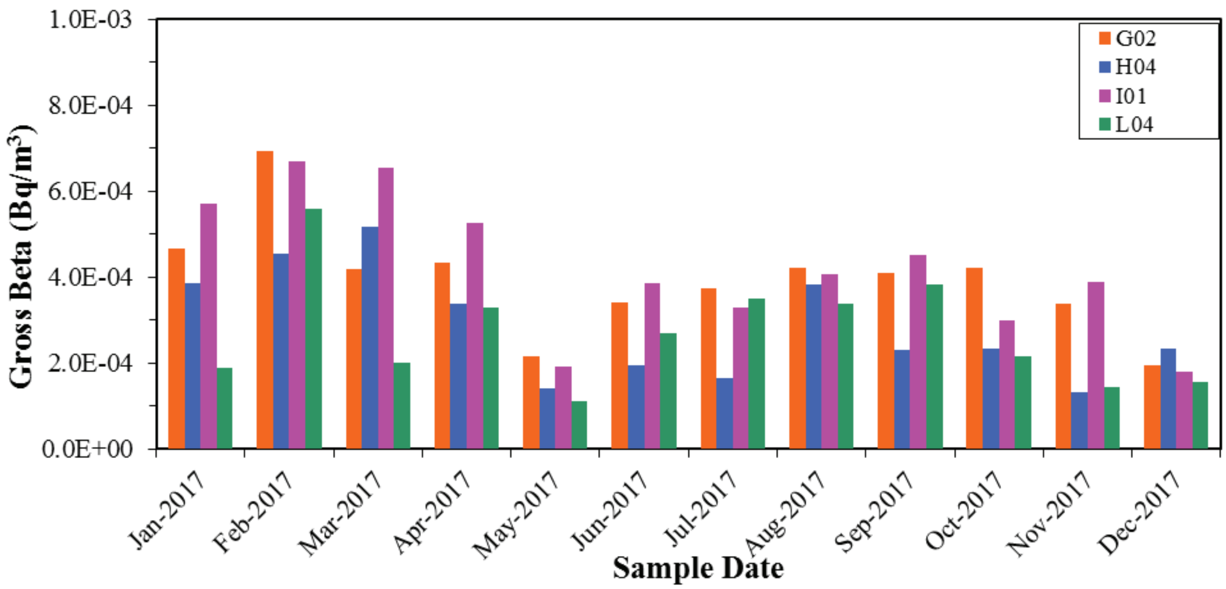


Figure 4.02: Gross Beta (Air Particulates) at Onsite Air Stations

4.02 Airborne Iodines

No radioiodines were detected in any of the 96 samples analysed.

Air is monitored continuously, using charcoal cartridges, from the eight locations shown in Figure 3.05. Once per month the cartridges are changed and analysed.

Iodine-131 was consistently below the Critical Level (average 1E-05 $Bq \cdot m^{-3}$).

4.03 Water Vapour

Tritium was detected in 75 of the 84 samples collected from the air monitoring stations on the Point Lepreau peninsula, and in one of the 12 samples from the reference location (i.e., not as a result of station operation) .

Water vapour is collected continuously in molecular sieve canisters from the eight locations shown in Figure 3.05. Once a month the canisters are changed and analysed.

The maximum concentration of tritium in air onsite was 3.7E+00 $Bq \cdot m^{-3}$ of air. Offsite it reached 2.0E+00 $Bq \cdot m^{-3}$. Tritium has been detected occasionally at the reference location, even before PLNGS became operational.

Table 4.02 is a summary of the tritium data and Table 4.03 gives details of the tritium results by location. Figures 4.03 and 4.04 show the H-3 results for each location. "Less Than" values are plotted for non-detected results. Generally, locations to the northeast (H04, I01 and N01) have elevated H-3 measurements in the warmer months due to the predominant summer wind direction which influences where the H-3 is detected. This changes in the winter to impact the southwest locations (G02 and L04).

When H-3 releases are low, the expected H-3 concentration in other environmental samples is below the detection limit. If the weekly H-3 releases are more than one percent of the weekly DRL, a H-3 analysis is performed on berries and garden vegetables. Since the H-3 releases in 2017 were 5.2E-02% DRL (and in no week exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.05 shows the weekly H-3 releases from PLNGS. Figure 4.06 compares the releases with the environmental air monitoring results. "Less Than" values are plotted for non-detected results.

Table 4.02: Water Vapour (Bq·m^3)

Analysis Type	Total Number	Critical Level		Indicator Locations			Reference Locations		
		Mean	Range	Mean	Frequency	Range	Mean	Frequency	Range
H-3	96	7.2E-2	3.0E-2 to 1.4E-1	1.0E+0	75/84	3.2E-2 to 3.7E+0	7.8E-2	1/12	7.8E-2 to 7.8E-2

Table 4.03: Tritium (Water Vapour) at Each Air Station (Bq·m^{-3})

Location Code		***A13R***	***E01***	***F01***	***G02***	***H04***	***I01***	***L04***	***N01***
Location		***Saint Andrews***	***Maces Bay***	***Welch Cove***	***Lepreau Lighthouse***	***Former Information Centre Site***	***SRWMF***	***Construction Stores***	***Dipper Harbour***
Distance from PLNGS		***47 km***	***4.5 km***	***1.6 km***	***1.0 km***	***0.75 km***	***1.2 km***	***0.55 km***	***3.7 km***
Collection Start Date The sample collection periods are approximately one month in duration. All sample stations are changed at the same time. The start date is the stop date for the previous sample.	2017-01-04	<5.6E-2	<7.5E-2	8.4E-2	1.3E+0	2.1E+0	1.2E+0	5.8E-1	2.2E-1
	2017-02-02	<3.1E-2	1.6E-1	2.3E-1	9.9E-1	1.9E+0	3.7E+0	1.1E+0	3.6E-1
	2017-03-08	<3.9E-2	6.4E-2	4.0E-1	1.0E+0	3.0E+0	3.2E+0	2.4E+0	4.6E-1
	2017-04-12	7.8E-2	2.0E+0	6.9E-1	4.7E-1	1.5E+0	1.3E+0	3.1E+0	5.7E-1
	2017-05-04	<4.3E-2	<1.0E-1	1.7E-1	6.8E-1	1.9E+0	1.4E+0	6.2E-1	2.2E-1
	2017-06-08	<2.1E-1	3.0E-1	8.3E-1	<1.7E-1	2.7E+0	2.4E+0	5.9E-1	7.5E-1
	2017-07-18	<1.7E-1	1.5E-1	3.9E-1	2.3E-1	1.6E+0	1.2E+0	1.1E+0	5.5E-1
	2017-08-08	<9.9E-2	<1.0E-1	4.0E-1	1.5E-1	9.3E-1	1.4E+0	6.3E-1	3.1E-1
	2017-09-05	<1.1E-1	<1.1E-1	2.2E-1	4.0E-1	1.4E+0	1.8E+0	6.7E-1	3.7E-1
	2017-10-04	<1.1E-1	<1.2E-1	3.1E-1	2.0E-1	2.2E+0	2.0E+0	7.0E-1	4.1E-1
	2017-11-01	<9.5E-2	1.4E-1	2.1E-1	2.8E+0	2.2E+0	2.0E+0	<1.3E-1	<1.2E-1
	2017-12-07	<3.8E-2	<6.2E-2	3.2E-2	4.4E-1	1.5E-1	6.0E-1	2.6E-1	5.4E-2

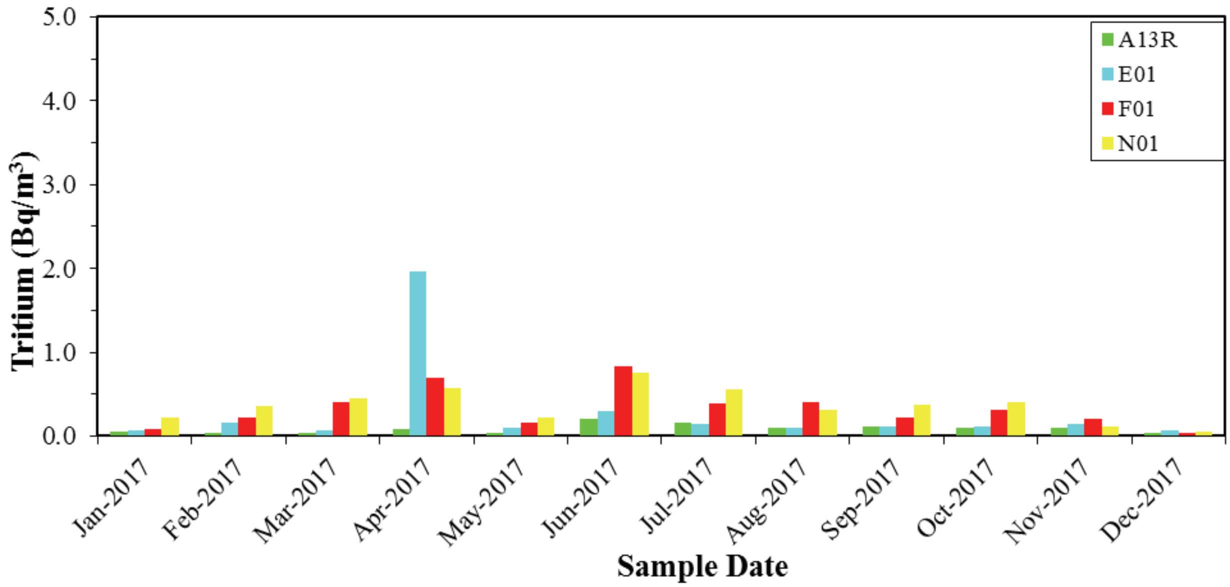


Figure 4.03: Tritium (Water Vapour) at Offsite Air Stations

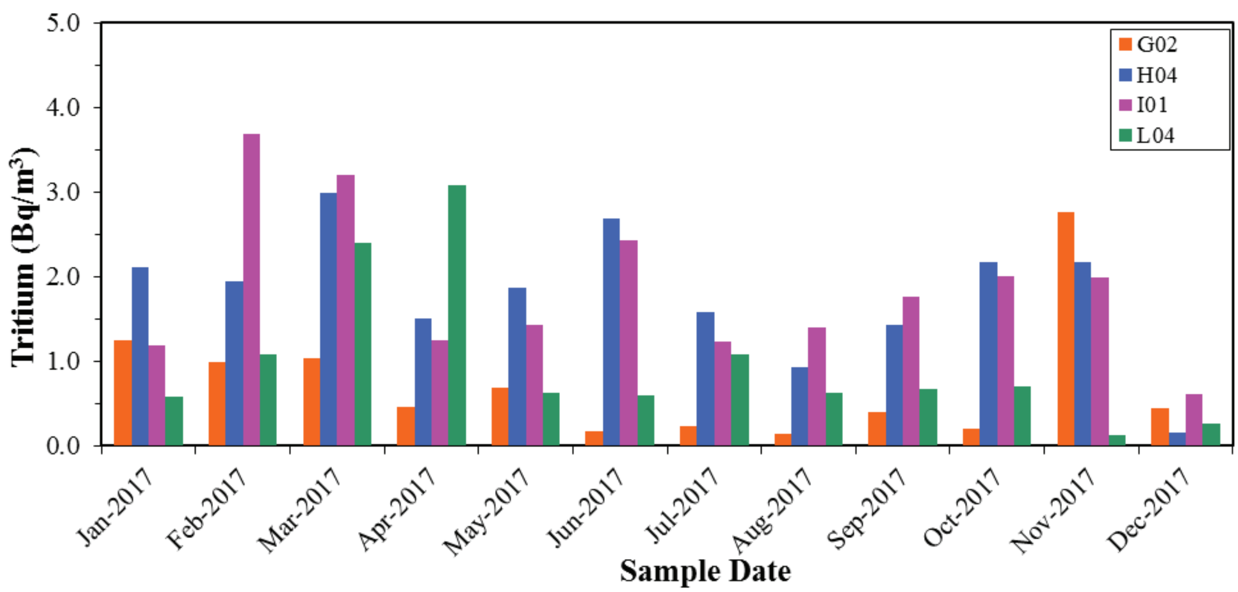
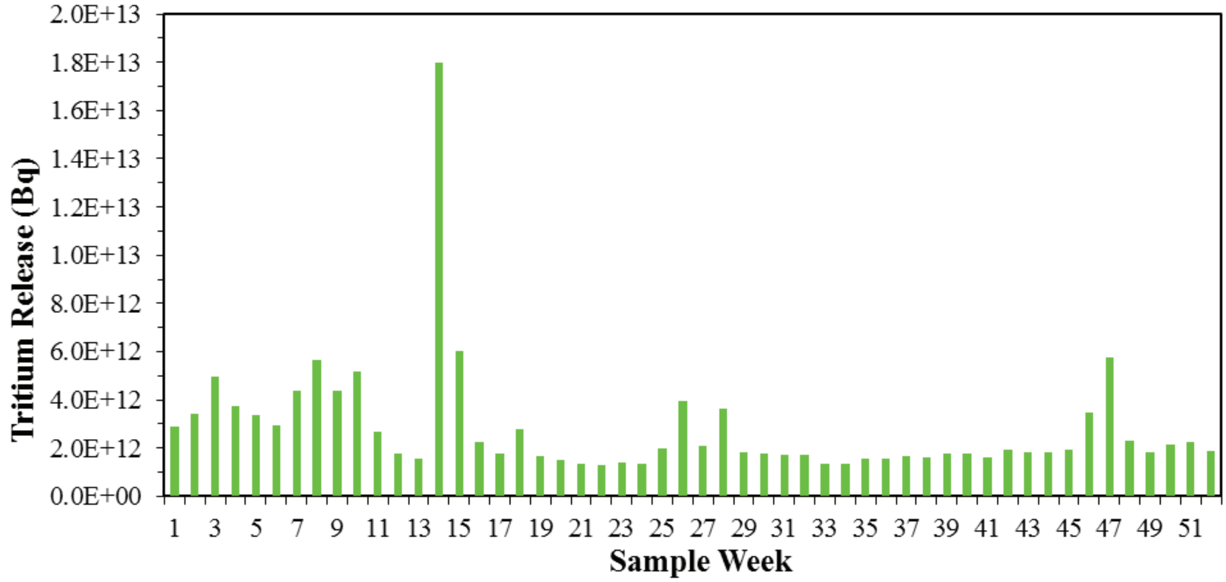


Figure 4.04: Tritium (Water Vapour) at Onsite Air Stations



Note: The Weekly DRL for H-3 is 5.4E+15 Bq

Figure 4.05: Gaseous H-3 Releases for 2017

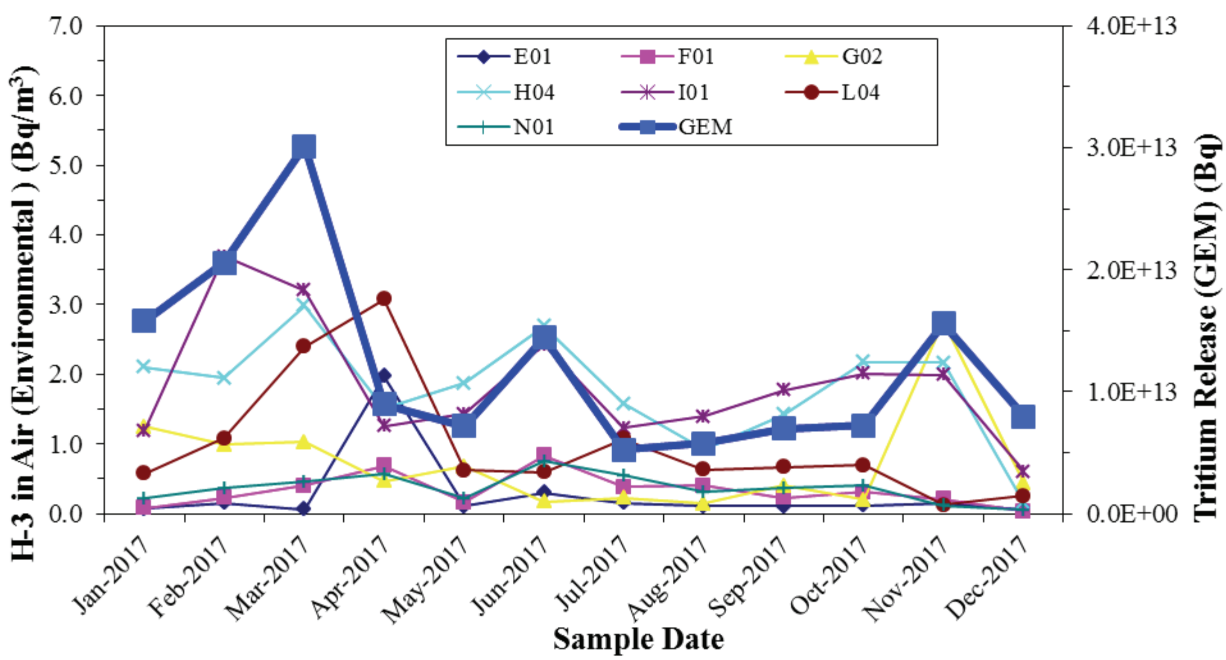


Figure 4.06: Gaseous H-3 Releases and H-3 (Water Vapour) Results

4.04 Carbon Dioxide

Carbon-14 was detected in 22 of the 23 samples from the onsite monitors and 10 of the 11 samples from the offsite monitor.

Air is continuously bubbled through a caustic solution at two onsite locations (G02 and H04 in Figure 3.05) and at one reference location. The caustic bubblers are changed monthly and returned to the lab for analysis.

The maximum concentration of gaseous C-14 onsite was 7.2E-02 $Bq \cdot m^{-3}$. Offsite the gaseous C-14 concentration was 6.5E-02 $Bq \cdot m^{-3}$. Based on stack releases, the calculated incremental concentration of C-14 in air at the boundary fence for 2017 was less than 1E-03 $Bq \cdot m^{-3}$ (a fraction of the natural level of 4E-02 $Bq \cdot m^{-3}$).

A summary of the analysis results is given in Table 4.04. Table 4.05 gives details of C-14 results (graphically shown in Figure 4.07).

When C-14 releases are low, the expected concentration of C-14 in other environmental samples is below the detection limit. If the weekly C-14 release is more than one percent of the weekly DRL, a C-14 analysis is performed on berries, milk, water and garden vegetables. Since the C-14 releases in 2017 were 4.6E-03% DRL (and in no week exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.08 shows the weekly C-14 releases from PLNGS. Figure 4.09 compares the releases with the environmental air monitoring results. “Less Than” values are plotted for non-detected results.

Table 4.04: Carbon Dioxide ($Bq{\cdot}m^{-3}$)

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
C-14	34	2.2E-2	1.9E-2 to 3.3E-2	4.9E-2	22/23	2.8E-2 to 7.2E-2	4.3E-2	10/11	2.9E-2 to 6.5E-2

Table 4.05: Carbon-14 (Carbon Dioxide) at Each Monitoring Location (Bq·m^{-3})

Location Code		***G02***	***H04***	***X03R***
Location		***Lepreau Lighthouse***	***Former Information Centre Site***	***Fredericton Laboratory***
Distance from PLNGS		***1.0 km***	***0.75 km***	***100 km***
Collection Start Date The sample collection periods are approximately one month in duration. All sample stations are changed at the same time. The start date is the stop date for the previous sample.	2017-01-04	4.6E-2	5.7E-2	<5.0E-2
	2017-02-02	4.7E-2	5.3E-2	3.0E-2
	2017-03-08	6.4E-2	4.0E-2	5.1E-2
	2017-04-12	5.7E-2	5.5E-2	NA
	2017-05-04	4.3E-2	5.1E-2	3.2E-2
	2017-06-08	5.2E-2	NA	6.5E-2
	2017-07-18	4.4E-2	5.7E-2	2.9E-2
	2017-08-08	6.3E-2	5.3E-2	5.4E-2
	2017-09-05	3.3E-2	4.3E-2	3.9E-2
	2017-10-04	3.5E-2	2.8E-2	3.9E-2
	2017-11-01	7.2E-2	4.2E-2	4.4E-2
	2017-12-07	<4.6E-2	3.0E-2	4.1E-2

NA: Data not available due to equipment malfunction

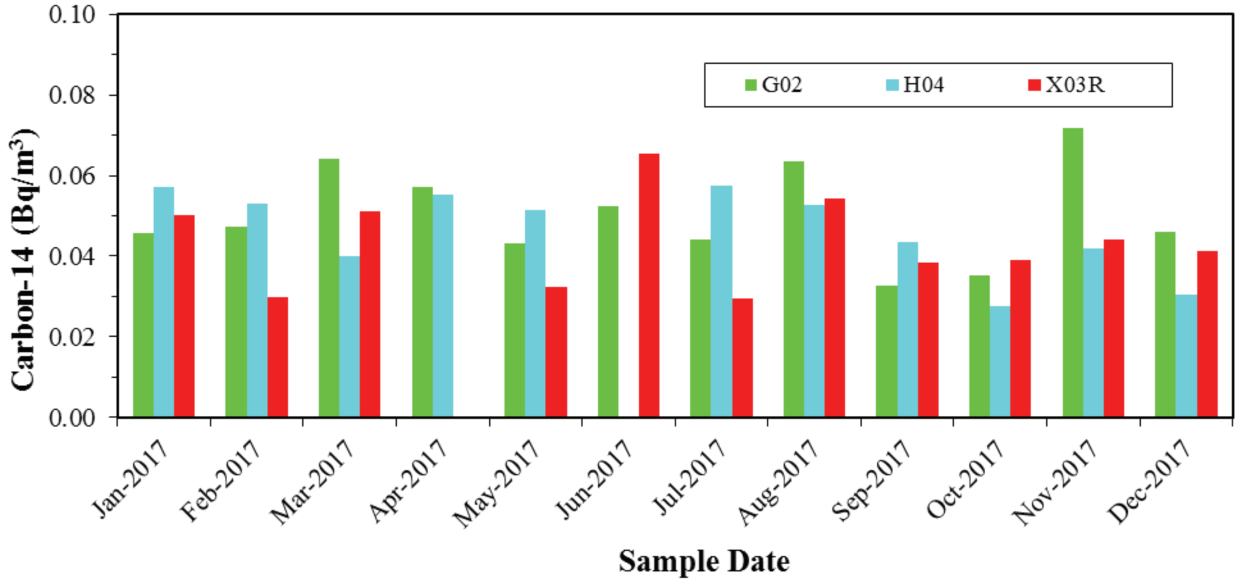
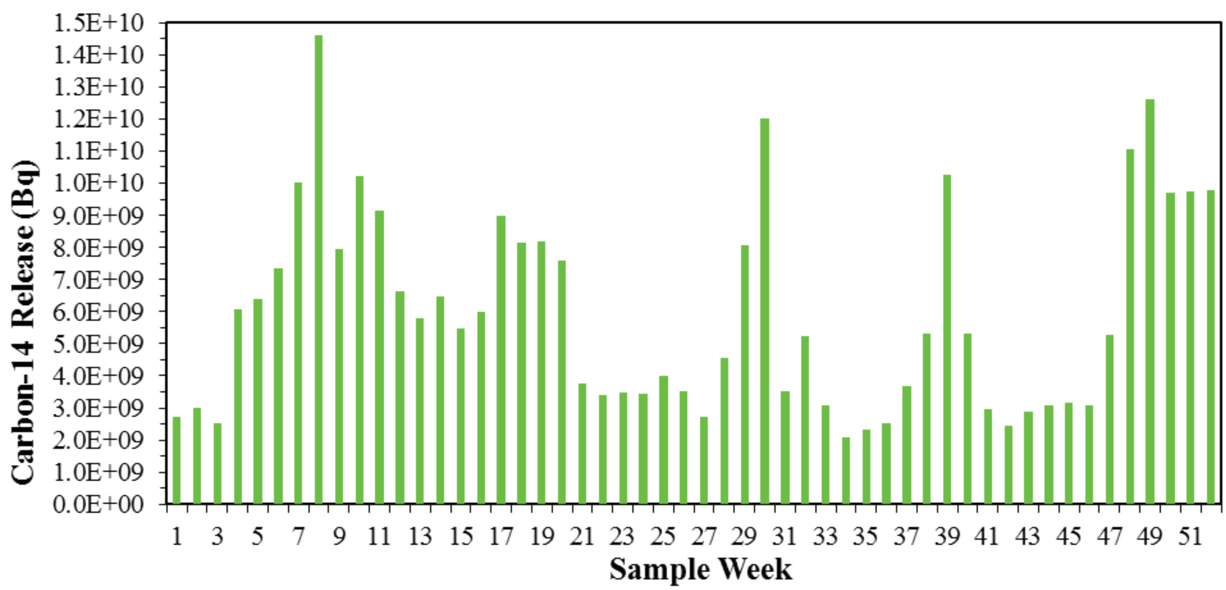


Figure 4.07: Carbon-14 (Carbon Dioxide)



Note: The Weekly DRL for C-14 is 1.3E+14 Bq

Figure 4.08: Gaseous C-14 Releases for 2017

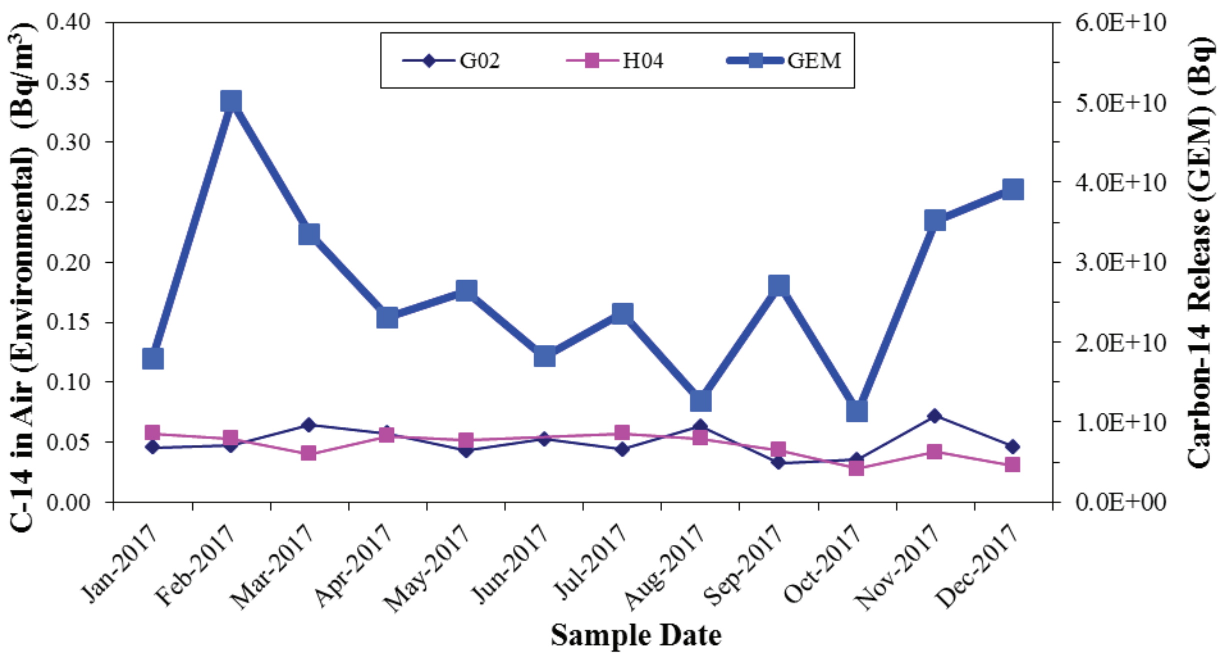


Figure 4.09: Gaseous C-14 Releases and C-14 (Carbon Dioxide) Results

4.05 Ambient Gamma Measurements (TLD)

Gamma exposure measurements were slightly lower offsite compared with onsite. The elevated measurements were at the locations near the SRWMF and reactor building.

Ambient gamma radiation is measured by TLDs at the 76 locations shown in Figures 3.03 to 3.06. Forty-six of these locations are near the SRWMF. TLDs are changed quarterly. Four of the 304 dosimeters placed in the environment were unavailable for readout.

The average measurement at the SRWMF (1012 $\mu Gy \cdot a^{-1}$) is higher than for other onsite locations (686 $\mu Gy \cdot a^{-1}$) and boundary locations (705 $\mu Gy \cdot a^{-1}$). The measurements at other onsite locations are not significantly different from those at offsite locations (693 $\mu Gy \cdot a^{-1}$) and that at the reference location (690 $\mu Gy \cdot a^{-1}$). A location was added in 2001 in a community (York Mills) 120 km north west of PLNGS. The area is noted for its natural uranium content and the measurement at this site (1334 $\mu Gy \cdot a^{-1}$) is higher than the highest location at PLNGS.

Data are given in Table 4.06. Increases in measurements at the SRWMF locations (I11A to I11T on the perimeter fence of the SRWMF-Phase 1, I21A to I21L on the perimeter fence of the SRWMF-Phase 2 and I31A to I31T on the perimeter fence of the SRWMF-Phase 3) are due to low-level waste, used fuel emplacement and refurbishment waste, and not to station releases. There were 204 concrete canisters filled to the end of 2017 with 110,158 used-fuel bundles. A small, but indefinable, portion of the measurement on the TLDs at the SRWMF is due to enhanced natural radiation from the aggregate used in making the concrete structures. Figure 4.10 compares the reference location results with the results for other locations. The elevated readings from TLD's I11N, I11O, and I11P in Phase 1 of, can be attributed to the loading operations associated with the 2017 Radioactive Waste Processing Campaigns and the return shipment of return-to-client material.

Table 4.06: Ambient Gamma – TLD (µGy)

Location	Dose (µGy± 10%)				
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Year
A13R	158 ± 16	173 ± 17	183 ± 18	175 ± 18	690 ± 30
B03	139 ± 14	144 ± 14	148 ± 15	156 ± 16	590 ± 30
C03	186 ± 19	206 ± 21	205 ± 20	203 ± 20	800 ± 40
D02	189 ± 19	172 ± 17	189 ± 19	179 ± 18	730 ± 40
E01	150 ± 15	149 ± 15	168 ± 17	163 ± 16	630 ± 30
E04	162 ± 16	167 ± 17	187 ± 19	187 ± 19	700 ± 40
E05	155 ± 15	161 ± 16	181 ± 18	NA	660 ± 30
E06	257 ± 26	242 ± 24	252 ± 25	239 ± 24	990 ± 50
F01	138 ± 14	139 ± 14	130 ± 13	124 ± 12	530 ± 30
G02	192 ± 19	192 ± 19	188 ± 19	189 ± 19	760 ± 40
H04	155 ± 16	145 ± 14	154 ± 15	143 ± 14	600 ± 30
H05	126 ± 13	126 ± 13	129 ± 13	126 ± 13	510 ± 30
I11A	229 ± 23	239 ± 24	236 ± 24	231 ± 23	930 ± 50
I11B	239 ± 24	229 ± 23	245 ± 24	248 ± 25	960 ± 50
I11C	220 ± 22	220 ± 22	231 ± 23	230 ± 23	900 ± 50
I11D	209 ± 21	232 ± 23	242 ± 24	230 ± 23	910 ± 50
I11E	208 ± 21	226 ± 23	235 ± 23	234 ± 23	900 ± 50
I11F	222 ± 22	472 ± 47	243 ± 24	314 ± 31	1250 ± 70
I11J	248 ± 25	226 ± 23	280 ± 28	267 ± 27	1020 ± 50
I11K	200 ± 20	218 ± 22	241 ± 24	228 ± 23	890 ± 40
I11L	203 ± 20	223 ± 22	233 ± 23	232 ± 23	890 ± 40
I11M	231 ± 23	491 ± 49	252 ± 25	407 ± 41	1380 ± 70
I11N	226 ± 23	345 ± 34	239 ± 24	543 ± 54	1350 ± 70
I11O	219 ± 22	250 ± 25	265 ± 27	642 ± 64	1380 ± 80
I11P	238 ± 24	264 ± 26	271 ± 27	587 ± 59	1360 ± 70
I11Q	231 ± 23	258 ± 26	272 ± 27	300 ± 30	1060 ± 50
I11S	218 ± 22	250 ± 25	449 ± 45	275 ± 27	1190 ± 60
I11T	225 ± 23	262 ± 26	532 ± 53	313 ± 31	1330 ± 70
I21A	183 ± 18	213 ± 21	221 ± 22	265 ± 26	880 ± 40
I21B	221 ± 22	232 ± 23	256 ± 26	305 ± 30	1010 ± 50
I21C	218 ± 22	228 ± 23	223 ± 22	252 ± 25	920 ± 50
I21D	277 ± 28	279 ± 28	309 ± 31	286 ± 29	1150 ± 60
I21E	282 ± 28	271 ± 27	256 ± 26	276 ± 28	1090 ± 50
I21F	214 ± 21	212 ± 21	207 ± 21	NA	840 ± 40
I21G	288 ± 29	227 ± 23	214 ± 21	215 ± 21	940 ± 50
I21H	227 ± 23	265 ± 27	234 ± 23	249 ± 25	980 ± 50

Table 4.06 (continued): Ambient Gamma – TLD (µGy)

Location	Dose (µGy± 10%)				
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Year
I21I	212 ± 21	233 ± 23	214 ± 21	228 ± 23	890 ± 40
I21J	202 ± 20	376 ± 38	201 ± 20	228 ± 23	1010 ± 50
I21K	237 ± 24	245 ± 24	195 ± 19	205 ± 21	880 ± 40
I21L	203 ± 20	218 ± 22	225 ± 22	211 ± 21	860 ± 40
I31A	188 ± 19	211 ± 21	219 ± 22	221 ± 22	840 ± 40
I31B	215 ± 21	225 ± 23	219 ± 22	226 ± 23	890 ± 40
I31C	218 ± 22	230 ± 23	242 ± 24	248 ± 25	940 ± 50
I31D	229 ± 23	262 ± 26	255 ± 26	255 ± 26	1000 ± 50
I31E	221 ± 22	247 ± 25	254 ± 25	264 ± 26	990 ± 50
I31F	240 ± 24	267 ± 27	273 ± 27	249 ± 25	1030 ± 50
I31G	238 ± 24	266 ± 27	261 ± 26	297 ± 30	1060 ± 50
I31H	237 ± 24	268 ± 27	263 ± 26	246 ± 25	1010 ± 50
I31I	219 ± 22	255 ± 25	255 ± 25	254 ± 25	980 ± 50
I31J	226 ± 23	254 ± 25	249 ± 25	253 ± 25	980 ± 50
I31K	226 ± 23	259 ± 26	254 ± 25	254 ± 25	990 ± 50
I31L	217 ± 22	229 ± 23	291 ± 29	239 ± 24	980 ± 50
I31M	225 ± 23	239 ± 24	241 ± 24	241 ± 24	950 ± 50
I31N	226 ± 23	233 ± 23	246 ± 25	240 ± 24	940 ± 50
I31P	244 ± 24	241 ± 24	251 ± 25	247 ± 25	980 ± 50
I31Q	243 ± 24	241 ± 24	259 ± 26	238 ± 24	980 ± 50
I31S	227 ± 23	239 ± 24	239 ± 24	245 ± 24	950 ± 50
I31T	206 ± 21	216 ± 22	222 ± 22	223 ± 22	870 ± 40
I86	163 ± 16	161 ± 16	177 ± 18	175 ± 17	680 ± 30
I87	172 ± 17	187 ± 19	191 ± 19	163 ± 16	710 ± 40
I88	154 ± 15	171 ± 17	178 ± 18	167 ± 17	670 ± 30
I89	157 ± 16	165 ± 17	178 ± 18	158 ± 16	660 ± 30
J20	181 ± 18	185 ± 19	193 ± 19	NA	750 ± 30
J35	215 ± 21	179 ± 18	191 ± 19	NA	780 ± 30
K01	169 ± 17	204 ± 20	192 ± 19	186 ± 19	750 ± 40
L01	182 ± 18	178 ± 18	195 ± 19	192 ± 19	750 ± 40
L03	178 ± 18	199 ± 20	215 ± 22	212 ± 21	800 ± 40
L04	185 ± 19	181 ± 18	192 ± 19	191 ± 19	750 ± 40
M02	139 ± 14	133 ± 13	134 ± 13	150 ± 15	560 ± 30
N01	154 ± 15	165 ± 17	172 ± 17	167 ± 17	660 ± 30
P03	136 ± 14	154 ± 15	173 ± 17	169 ± 17	630 ± 30
X12	333 ± 33	323 ± 32	340 ± 34	338 ± 34	1330 ± 70

Table 4.06: Ambient Gamma – TLD (µGy), Continued

Location	Dose (µGy± 10%)				
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Year
YTL1	132 ± 13	122 ± 12	140 ± 14	130 ± 13	520 ± 30
YTL2	134 ± 13	131 ± 13	148 ± 15	139 ± 14	550 ± 30
YTL3	103 ± 10	112 ± 11	138 ± 14	128 ± 13	480 ± 20
YTL4	106 ± 11	107 ± 11	141 ± 14	121 ± 12	470 ± 20

NA: Data Not Available.

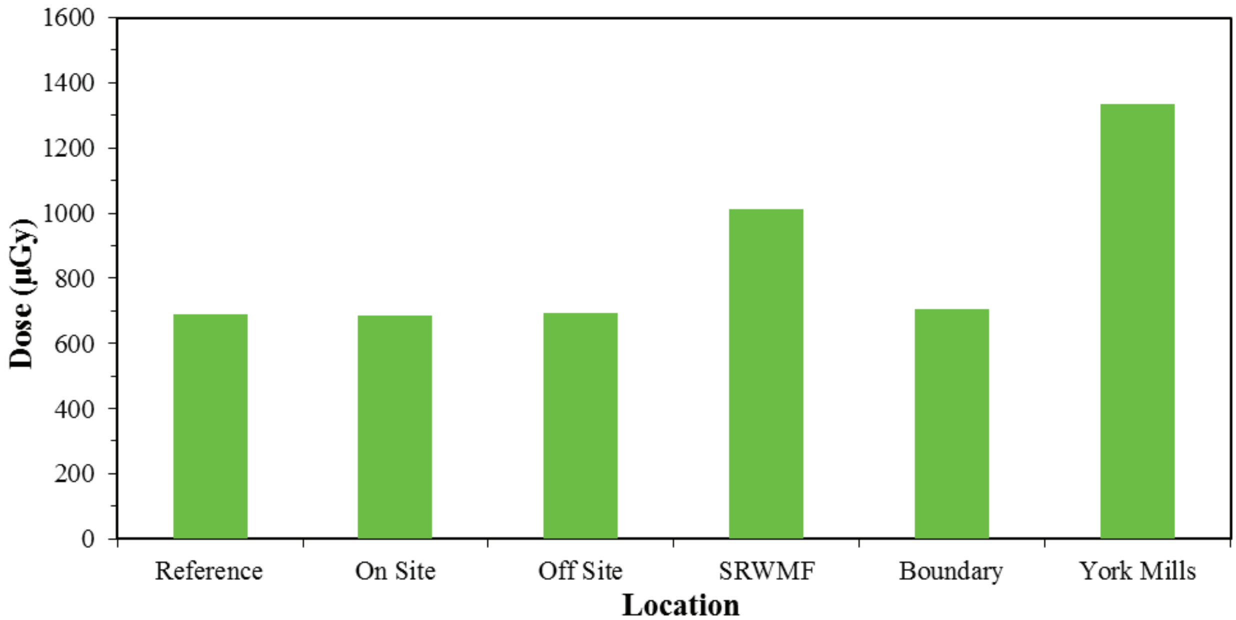


Figure 4.10: Mean Ambient Gamma (TLD) Results

4.06 Milk

Of the 21 samples analysed, K-40 was detected in 21, and H-3 in two. None of these results are attributable to the operation of PLNGS (the H-3 results were deemed false positives).

There are no commercial herds producing milk in the Lepreau area. The closest herds to PLNGS are in Lynnfield (70 km to the northwest), Lincoln (130 km to the north) and Hammond River (60 km to the northeast). Milk from these locations is analysed quarterly. Milk from a commercial dairy is purchased each month from a supermarket in Fredericton. All milk samples are analysed for gamma emitting radionuclides and tritium.

Since C-14 releases are low, the expected concentration of C-14 in milk is below the detection limit. If the weekly C-14 releases are more than one percent of the weekly DRL, a C-14 analysis is performed on milk. Since the C-14 releases in 2017 were 4.6E-03% DRL (and in no week exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.08 shows the weekly C-14 releases.

Naturally occurring K-40 (average of 5.2E+01 $Bq \cdot L^{-1}$) was also detected in milk.

PLNGS releases of tritium and gamma emitters were too low throughout the year to be detected in these milk samples. The two detected tritiums were deemed false positives.

Table 4.07 is a summary of the detected radionuclides in milk.

4.07 GEM Particulates (Sr-89,90)

When Sr-89,90 releases are low, the expected concentration of Sr-89,90 in environmental air samples is below the detection limit. The GEM monitors PLNGS gaseous releases continuously at their source. The GEM filter is changed weekly and is sent to the Fredericton lab for analysis. Fifty of these GEM filters were analysed for Sr-89,90. If the weekly releases are more than one percent of the weekly DRL, or if elevated beta activity is detected in environmental air samples, a Sr-89,90 analysis is performed on these environmental air samples. Since neither of these conditions were met in 2017, no further analyses were required.

Table 4.07: Milk ($Bq \cdot L^{-1}$)

Analysis Type	Total Number	Critical Level		Indicator Locations			Reference Locations		
		Mean	Range	Mean	Frequency	Range	Mean	Frequency	Range
H-3	21	1.2E+1	1.2E+1 to 1.3E+1	1.4E+1	1/10	1.4E+1 to 1.4E+1	1.5E+1	1/11	1.5E+1 to 1.5E+1
K-40	21	4.0E-1	2.8E-1 to 4.9E-1	5.2E+1	10/10	4.8E+1 to 5.5E+1	5.2E+1	11/11	5.0E+1 to 5.3E+1

4.08 Well Water

Of the 17 samples analysed, gross alpha was detected in one, gross beta was detected in eight and H-3 in six. Only the H-3 results are attributable to the operation of PLNGS.

Water is collected semi-annually from the 10 locations shown in Figure 3.05. Two of these wells are onsite. Up to ten additional wells are sampled once per year. These wells are located just outside the exclusion boundary and belong to local residents.

The alpha (up to 4.2E-01 $Bq \cdot L^{-1}$) and beta (up to 2.3E+00 $Bq \cdot L^{-1}$) activities are due to the presence of naturally occurring radionuclides particular to certain locations. Detected H-3 concentrations ranged from 1.6E+01 to 2.9E+01 $Bq \cdot L^{-1}$. Tritium from PLNGS releases washes out into precipitation and subsequently drains into some of the wells. Precipitation analyses (*Section 4.14*) indicate H-3 concentrations ranging from 2.1E+01 to 2.4E+03 $Bq \cdot L^{-1}$ in 21 of 25 samples.

Since C-14 releases are low, the expected concentration of C-14 in well water is below the detection limit. If the weekly C-14 releases are more than one percent of the weekly DRL, a C-14 analysis is performed on well water. Since the C-14 releases in 2017 were 4.6E-03% DRL (and in no week exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.08 shows the weekly C-14 releases.

Table 4.08 is a summary of the detected radionuclides in well water. Figures 4.11 and 4.12 show the gross beta and H-3 results for each sample. “Less Than” values are plotted for non-detected results. The H-3 measurements were made after samples had been allowed to sit for up to two weeks to reduce radioactive interference from the relatively abundant, but short half-life, radon progeny which are common in most well waters.

The Health Canada, 2010 *Guidelines for Canadian Drinking Water Quality* (Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment) recommends 7.0E+03 $Bq \cdot L^{-1}$ as the maximum acceptable average concentration for H-3 in drinking water.

Table 4.08: Well Water (Bq·L^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
ALPHA	17	1.8E-1	4.3E-2 to 7.8E-1	4.2E-1	1/17	4.2E-1 to 4.2E-1	*	*	*
BETA	17	1.3E-1	2.4E-2 to 2.5E-1	3.8E-1	8/17	3.9E-2 to 2.3E+0	*	*	*
H-3	17	1.2E+1	1.2E+1 to 1.2E+1	2.0E+1	6/17	1.6E+1 to 2.9E+1	*	*	*

*There is no reference location.

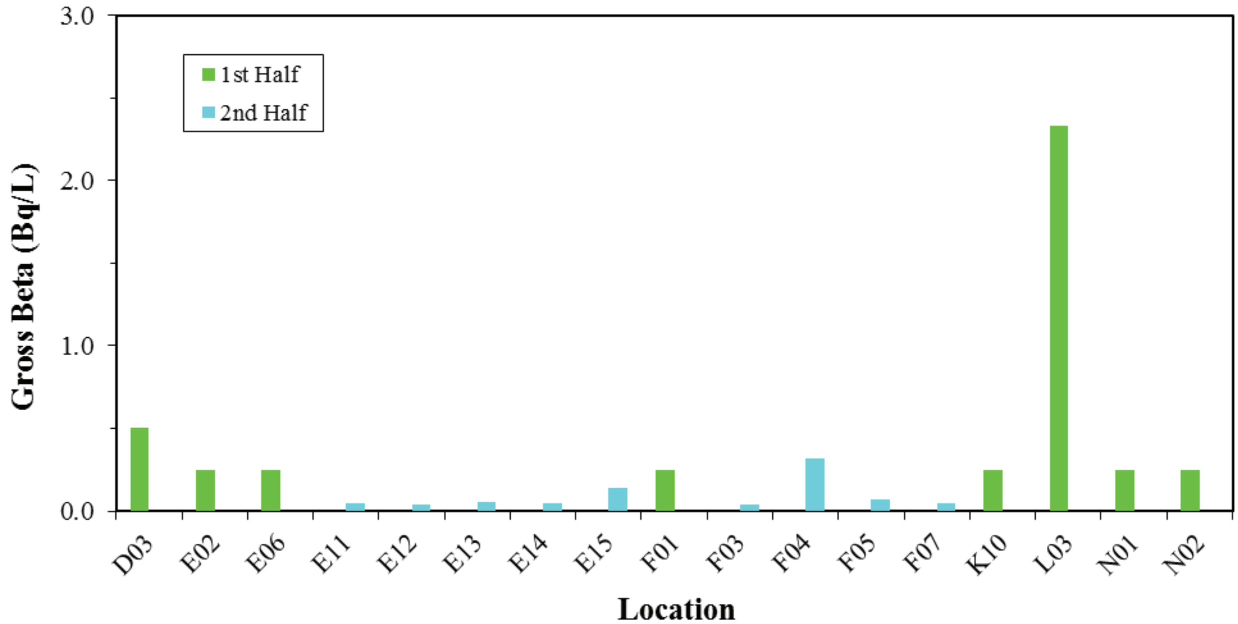


Figure 4.11: Gross Beta (Well Water)

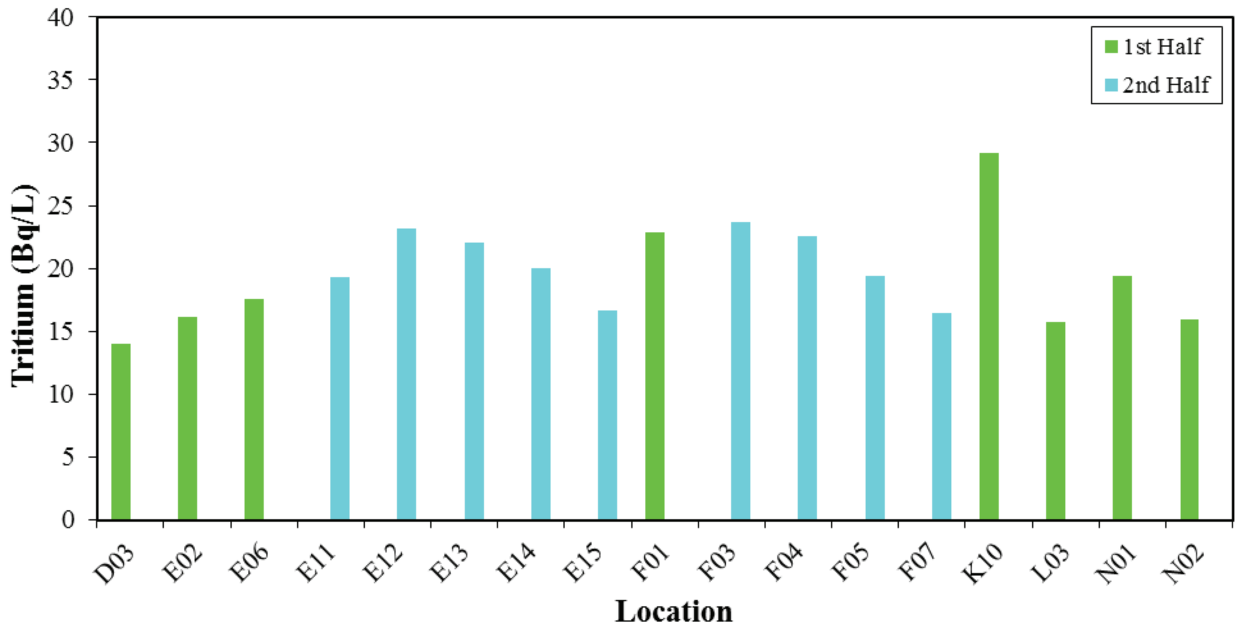


Figure 4.12: Tritium (Well Water)

4.09 Pond/Puddle/Surface Water

Low levels of H-3 were detected in 15 of the 24 samples. No gamma emitters were detected in these samples.

This category includes ponds, lakes, streams and runoff samples. Most of these samples are from onsite locations. Two offsite locations, sampled quarterly, are the former freshwater supply reservoirs for Saint John and PLNGS, at Spruce Lake and Hanson Stream, respectively.

Detected H-3 activities ranged from 4.3E+01 to 1.8E+02 $Bq{\cdot}L^{-1}$. Variability can be due to the size of the water reservoir and the length of time the sample has remained at the location. Tritium from PLNGS releases washes out into precipitation. Precipitation analyses (*Section 4.14*) indicate H-3 concentrations ranging from 2.1E+01 to 2.4E+03 $Bq{\cdot}L^{-1}$ in 30 of 39 samples.

Since C-14 releases are low, the expected concentration of C-14 in water is below the detection limit. If the weekly C-14 releases are more than one percent of the weekly DRL, a C-14 analysis is performed on water. Since the C-14 releases in 2017 were 4.6E-03% DRL (and in no week exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.08 shows the weekly C-14 releases.

Table 4.09 is a summary of the detected radionuclides in surface water. Figure 4.13 shows H-3 results for each location. “Less Than” values are plotted for non-detected results.

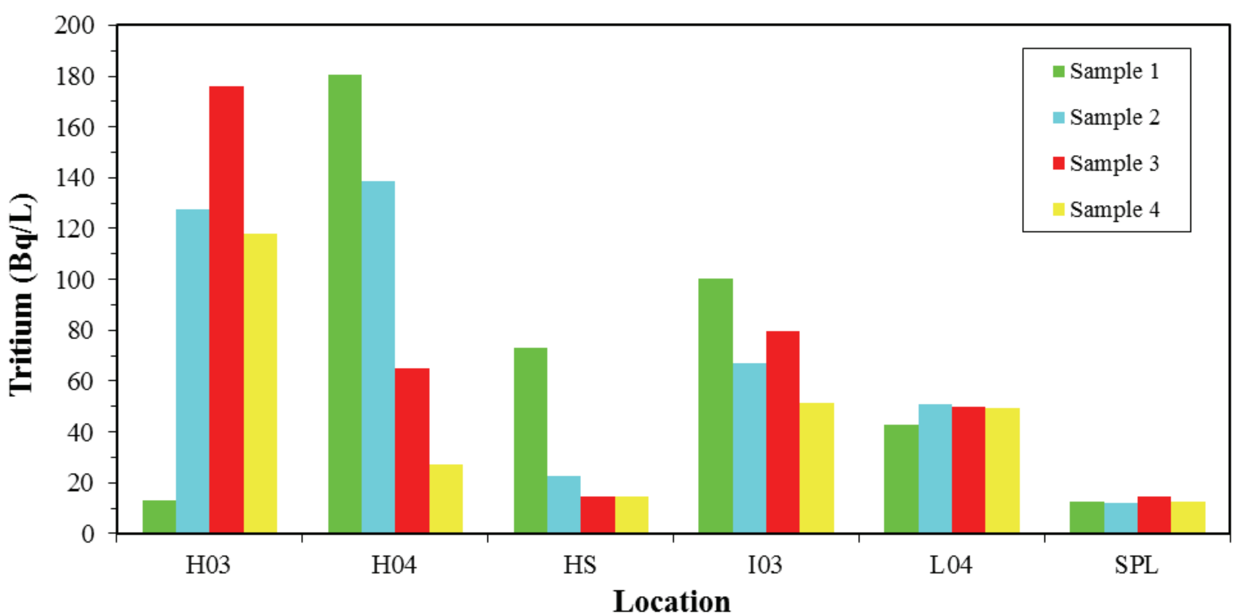


Figure 4.13: Tritium (Pond/Puddle/Surface Water)

Table 4.09: Pond/Puddle/Surface Water ($Bq \cdot L^{-1}$)

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
H-3	24	1.3E+1	1.2E+1 to 1.5E+1	9.1E+1	15/24	4.3E+1 to 1.8E+2	*	*	*

*There is no reference location.

4.10 Berries

No radionuclides were detected in the three samples analysed.

Berries are sampled weekly when in season. Three samples of blueberries were collected from Pennfield.

Since H-3 and C-14 releases are low, the expected concentrations of H-3 and C-14 in berries are below the detection limits. If the H-3 or C-14 weekly releases are more than one percent of the weekly DRL, then H-3 or C-14 analysis is performed on berries. Since the releases in 2017 were 5.2E-02% DRL for H-3 and 4.6E-03% DRL for C-14 (and never exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.05 shows the weekly H-3 releases and Figure 4.08 shows the weekly C-14 releases.

4.11 Garden Vegetables

Potassium-40 was detected in 19 of the 22 samples analysed. These results are not attributable to the operation of PLNGS.

All samples were taken from a local garden in Dipper Harbour (4 km from PLNGS in the predominant downwind direction). These samples were supplied weekly during the growing season.

As in most food samples, naturally occurring K-40 was detected in 19 of the 22 samples (5.6E+01 to 3.4E+02 $Bq{\cdot}kg^{-1}$).

Since H-3 and C-14 releases are low, the expected concentrations of H-3 and C-14 in garden vegetables are below the detection limit. If the H-3 or C-14 weekly releases are more than one percent weekly DRL, then H-3 or C-14 analysis is performed on garden vegetables. Since the releases in 2017 were 5.2E-02% DRL for H-3 and 4.6E-03% DRL for C-14 (and in no week exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.05 shows the weekly H-3 releases and Figure 4.08 shows the weekly C-14 releases.

Table 4.10 is a summary of the detected radionuclides in garden vegetables.

4.12 Vegetation (Lichen)

Of the 14 samples analysed, Be-7 was detected in nine and K-40 in two. These results are not attributable to the operation of PLNGS.

These samples are collected whenever and wherever available from onsite locations.

Different species of lichen and moss concentrate a wide range of radionuclides and are sensitive indicators of radionuclides in the environment. Cosmogenically produced Be-7 was detected in 9 samples (2.5E+02 to 1.0E+03 $Bq \cdot kg^{-1}$). As in most organic samples, naturally occurring K-40 was detected in 2 of the 14 samples (1.6E+02 to 3.6E+02 $Bq \cdot kg^{-1}$).

Table 4.11 is a summary of the detected radionuclides in vegetation.

Table 4.10: Garden Vegetables (Bq·kg^{-1})

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
K-40	22	2.9E+1	1.5E+0 to 2.0E+2	1.5E+2	19/22	5.6E+1 to 3.4E+2	*	*	*

*There is no reference location.

Table 4.11: Vegetation (Bq·kg^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
Be-7	14	1.5E+2	3.1E+1 to 4.3E+2	5.3E+2	9/14	2.5E+2 to 1.0E+3	*	*	*
K-40	14	2.8E+2	1.0E+2 to 4.7E+2	2.6E+2	2/14	1.6E+2 to 3.6E+2	*	*	*

*There is no reference location.

4.13 Soil

Of the 35 samples analysed, Cs-137 was detected in 26, Ac-228 in 22 and K-40 in 33. These results are not attributable to the operation of PLNGS.

Soil samples are taken quarterly from the eight air monitoring location sites shown in Figure 3.05 and from the local elementary school. Samples are collected at E02 rather than E01 due to a lack of readily available soil at that site.

Thirty-three samples contained naturally occurring K-40 (1.5E+02 to 9.3E+02 Bq·kg^{-1}), 22 samples contained naturally occurring Ac-228 (2.3E+01 to 4.5E+01 Bq·kg^{-1}) and 26 samples contained Cs-137 (1.3E+00 to 1.2E+02 Bq·kg^{-1}). Most Cs-137 results were at typical levels for the region. Cesium-137 from fallout of past atmospheric weapons tests and international events tends to accumulate in the organic layer of the soil. Most fluctuation in Cs-137 and K-40 levels seems to be due to the quantity of organic load in the sample. Levels seen in 2017 are less than those seen before PLNGS became operational.

Table 4.12 is a summary of the detected radionuclides in soil. Figure 4.14 shows individual Cs-137. “Less Than” values are plotted for non-detected results.

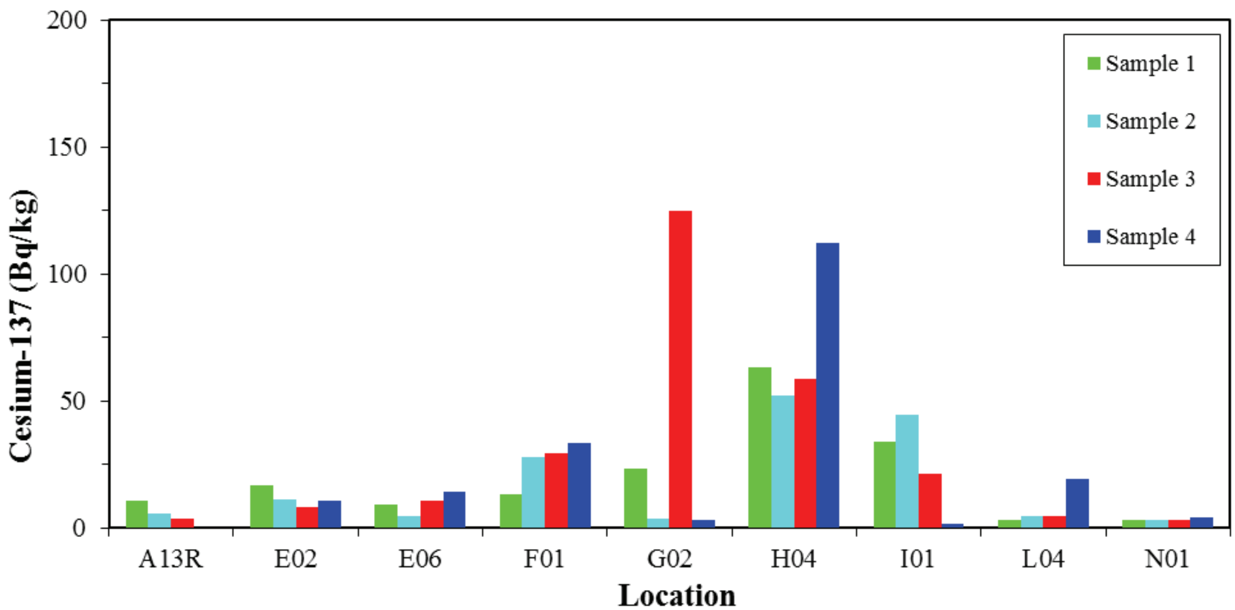


Figure 4.14: Cesium-137 (Soil)

Table 4.12: Soil (Bq·kg^{-1})

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
Cs-137	35	1.8E+0	8.2E-1 to 5.3E+0	3.1E+1	24/32	1.3E+0 to 1.2E+2	8.2E+0	2/3	5.6E+0 to 1.1E+1
Ac-228	35	6.2E+0	2.2E+0 to 2.9E+1	3.4E+1	19/32	2.3E+1 to 4.5E+1	3.5E+1	3/3	2.6E+1 to 4.0E+1
K-40	35	3.3E+1	6.0E+0 to 1.7E+2	6.0E+2	30/32	1.5E+2 to 9.3E+2	6.7E+2	3/3	5.8E+2 to 7.5E+2

4.14 Precipitation

Of the 39 samples analysed, H-3 was detected in 30. The H-3 results are attributable to the operation of PLNGS.

Precipitation is collected continuously at the four onsite air monitoring stations (locations shown in Figure 3.05). The samples are changed approximately monthly, depending on rainfall and freeze up.

Detected H-3 levels spanned 2.1E+01 to 2.4E+03 Bq·L^{-1}. Samples taken during periods of heavy rainfall have lower H-3 levels due to dilution

Since C-14 releases are low, the expected concentration of C-14 in water is below the detection limit. If the C-14 weekly releases are more than one percent of the weekly DRL, a C-14 analysis is performed on water. Since the C-14 releases in 2017 were 4.6E-03% DRL (and in no week exceeded one percent of the weekly DRL), no further analyses were required. Figure 4.08 shows the weekly C-14 releases.

Table 4.13 is a summary of the detected radionuclides in precipitation. Figures 4.03 and 4.04 show average monthly H-3 results and Figure 4.05 shows gaseous H-3 release. Figure 4.15 shows average monthly H-3 results and gaseous H-3 release. “Less Than” values are plotted for non-detected results.

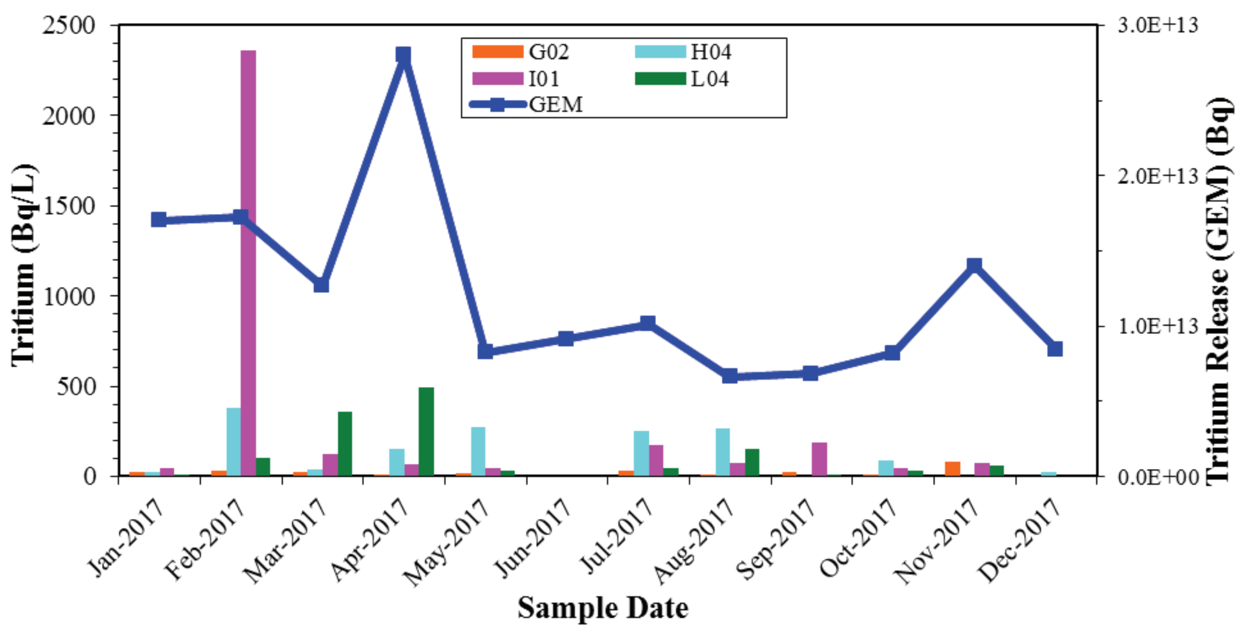


Figure 4.15: Gaseous H-3 Releases and Tritium (Precipitation) Results

Table 4.13: Precipitation ($Bq \cdot L^{-1}$)

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
H-3	39	1.2E+1	1.1E+1 to 1.3E+1	2.0E+2	30/39	2.1E+1 to 2.4E+3	*	*	*

*There is no reference location.

4.15 Monitoring Well Water, Near Plant

Low levels of H-3 were detected in all samples analysed. These results are attributable to PLNGS releases.

Eleven monitoring wells are sampled once per year. This frequency will be increased for some or all wells if H-3 concentrations greater than 7000 $Bq\cdot L^{-1}$ are detected. As well, additional samples may be collected if an abnormal release is suspected or an elevated result is obtained.

Tritium concentrations averaged 1.5E+02 $Bq\cdot L^{-1}$, ranging up to 3.4E+02 $Bq\cdot L^{-1}$.

Table 4.14 is a summary of the detected radionuclides in monitoring well water. Figure 4.16 shows individual H-3 results. "Less Than" values are plotted for non-detected results.

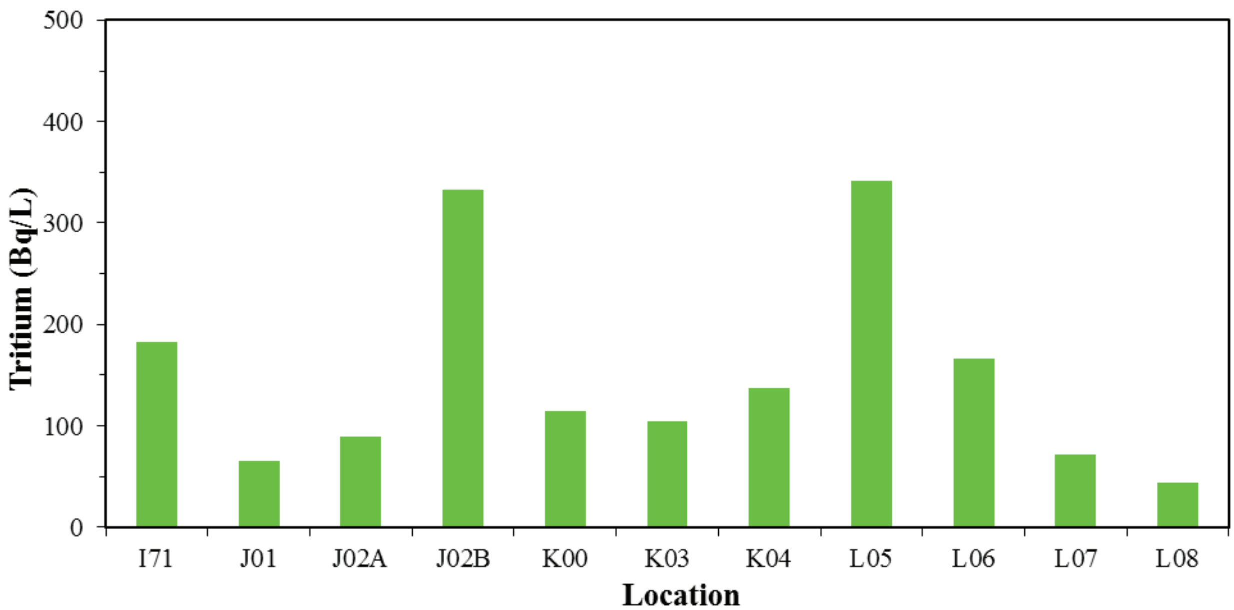


Figure 4.16: Tritium (Monitoring Well Water, Near Plant)

Table 4.14: Monitoring Well Water, Near Plant (Bq·L^{-1})

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
H-3	11	1.2E+1	1.2E+1 to 1.3E+1	1.5E+2	11/11	4.4E+1 to 3.4E+2	*	*	*

*There is no reference location.

4.16 Seawater

Potassium-40 was detected in 11 of the 16 samples analysed and H-3 was detected in two. The H-3 results are attributable to the operation of PLNGS.

Seawater is collected quarterly from three locations close to PLNGS and one reference location near Saint John (shown in Figure 3.05).

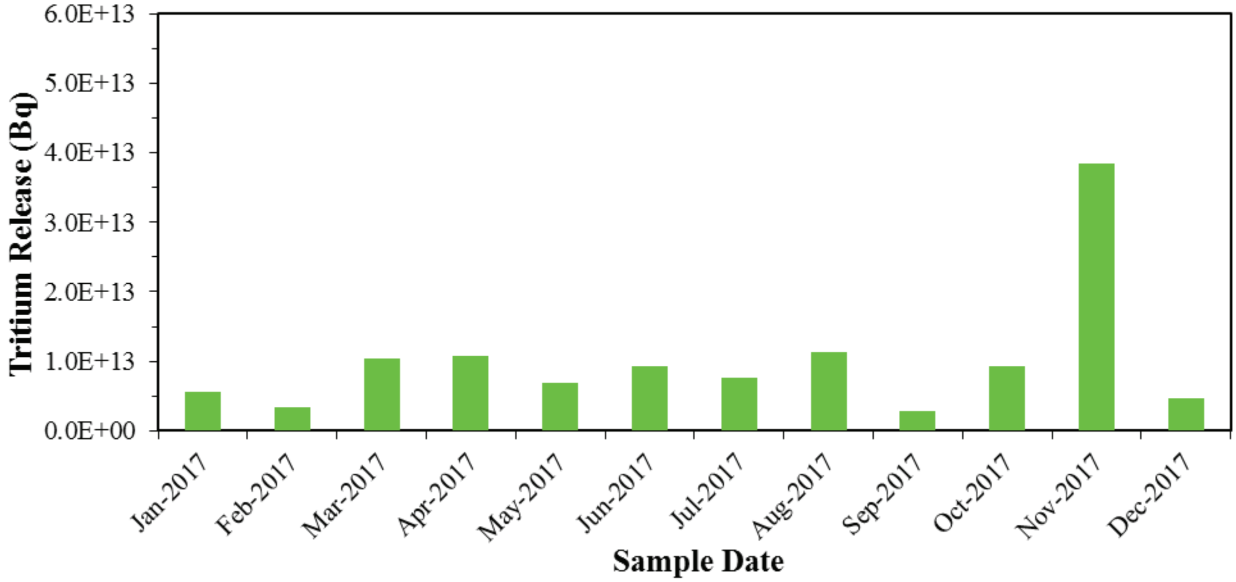
Naturally occurring K-40 was detected (7.9E+00 to 1.2E+01 $Bq \cdot L^{-1}$) in 11 samples. Tritium was detected in two (1.7E+01 to 4.3E+01 $Bq \cdot L^{-1}$). Calculations suggest that the 2017 average concentration of tritium in seawater, due to releases from PLNGS in the liquid pathway (see Figure 4.17), would be about 7E+00 $Bq \cdot L^{-1}$ at the out-fall (samples are not collected at this point, but are taken at the shoreline nearby). This calculation takes into account the total tritium released over the year, the flow rate of the condenser cooling water (about 2.5E+01 $m^3 \cdot s^{-1}$), and tidal mixing. A dilution factor of 20 is assumed for tidal mixing at the out-fall during normal coolant flows. For collection further away from the outfall, a tidal mixing factor of 40, or even higher, is more realistic. A factor of 40 would result in an average H-3 concentration of about 6E-01 $Bq \cdot L^{-1}$ in seawater during 2017 at the H03 location. In past years, when samples were taken soon after pump out of higher than usual amounts of H-3, the results were much less than the predicted levels. These results further confirm the conservatism in the calculation.

When C-14 and Sr-89,90 releases are low, the expected concentration of these radionuclides in seawater is below the detection limit. If the monthly releases are more than one percent of the monthly DRL, a C-14 or Sr-89,90 analysis is performed on seawater. Since the liquid releases in 2017 were 5.5E-04% DRL for C-14 and 7.7E-09% DRL for Sr-90 (and in no month exceeded one percent of the monthly DRL), no further analyses were required. Strontium-89 was not detected in releases. Figure 4.18 shows the monthly C-14 releases.

Table 4.15 is a summary of the detected radionuclides in seawater.

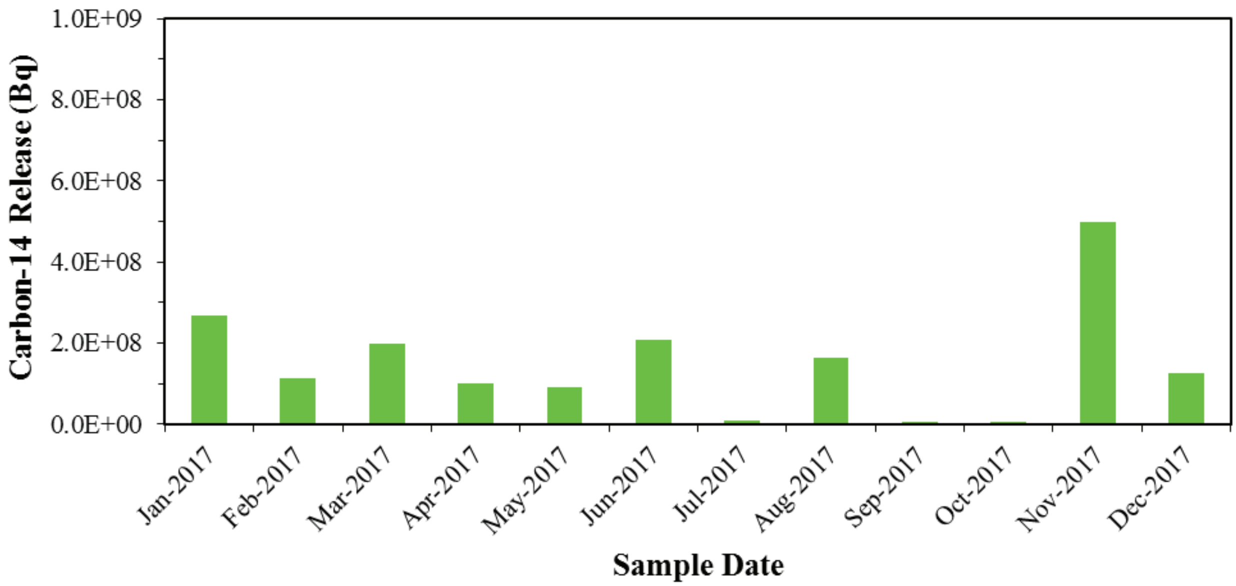
4.17 Tritium and C-14 Analyses of Seafood

When H-3 and C-14 releases are low, the expected concentrations of these radionuclides in seafood are below the detection limit. If the monthly releases are more than one percent of the monthly DRL, a H-3 or C-14 analysis is performed on seafood. Since the releases in 2017 were 2.6E-04% DRL for H-3 and 5.5E-04% DRL for C-14 (and in no month exceeded one percent of the monthly DRL), no further analyses were required. Figures 4.17 and 4.18 show the releases of these radionuclides.



Note: The Monthly DRL for H-3 is 3.8E+18 Bq

Figure 4.17: Liquid H-3 Releases for 2017



Note: The Monthly DRL for C-14 is 2.7E+13 Bq

Figure 4.18: Liquid C-14 Releases for 2017

Table 4.15: Seawater ($Bq \cdot L^{-1}$)

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
H-3	16	1.2E+1	1.2E+1 to 1.3E+1	3.0E+1	2/12	1.7E+1 to 4.3E+1	*	*	*
K-40	16	3.2E+0	8.4E-1 to 5.9E+0	1.0E+1	7/12	7.9E+0 to 1.2E+1	1.2E+1	4/4	9.0E+0 to 1.5E+1

* The activity is less than or equal to the Critical Level (99% Confidence Level).

4.18 Seafood

Potassium-40 is usually detected in these samples. The results are not attributable to the operation of PLNGS. Figure 3.05 shows the locations for most of these samples.

Clams – Three samples were collected from Deer Island, one from St Andrews and four from the Lepreau area. The inshore fishery often faces restrictions placed upon the harvesting of shellfish, either for conservation of stocks or because of bacterial contamination or algal blooms. The restrictions affect the availability of these sample types for analysis. Data are shown in Table 4.16.

Crab - As in most years, there was no active crab fishery in the local area. No samples were collected in 2017.

Dulse - Dulse is an edible seaweed that is a popular snack food in the area. Six samples were collected (three from the Lepreau area and three from Grand Manan). Data are shown in Table 4.17.

Fish - The fish category now tends to be made up of haddock and halibut, if they are available at all. Five samples were collected in 2017 (two from Grand Manan, one from Back Bay and two from unknown locations in the Bay of Fundy near Nova Scotia). Data are shown in Table 4.18.

Lobster – Six samples were collected from the Lepreau area. A few lobster are obtained during each of the two federally regulated fishing seasons per year. Data are shown in Table 4.19.

Periwinkles – Thirteen samples were collected from the Lepreau area. Data are shown in Table 4.20.

Aquaculture Salmon - The aquaculture salmon industry is important to the area west of PLNGS. Five samples were collected from Back Bay. Data are shown in Table 4.21.

4.19 Other Sea Plants

Potassium-40 was detected in all 12 samples analysed. These results are not attributable to the operation of PLNGS.

Sea plants other than dulse are analysed. Various species of seaweed (for example, *Ascophylum*) occur on the rocks on the Point Lepreau peninsula and are collected quarterly. Sample locations are shown in Figure 3.05.

Naturally occurring K-40 ranged from 1.5E+02 to 3.3E+02 Bq·kg^{-1}. Data are shown in Table 4.22.

Table 4.16: Clams, Edible, Raw Mass (Bq·kg^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
K-40	8	8.4E+1	2.0E+1 to 1.3E+2	1.8E+2	5/8	1.5E+2 to 2.0E+2	*	*	*

*There were no reference samples.

Table 4.17: Dulse, Wet Mass (Bq·kg^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
K-40	6	3.1E+1	1.3E+1 to 9.9E+1	5.6E+2	3/3	4.3E+2 to 7.5E+2	1.4E+3	3/3	4.5E+2 to 3.3E+3

Table 4.18: Fish, Raw Mass (Bq·kg-1)

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
K-40	5	2.7E+1	8.6E+0 to 5.7E+1	1.1E+2	3/3	8.7E+1 to 1.5E+2	8.5E+1	2/2	7.8E+1 to 9.1E+1

*There were no reference samples.

Table 4.19: Lobster, Edible, Cooked Mass (Bq·kg^{-1})

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
K-40	6	6.2E+1	2.1E+1 to 1.3E+2	8.6E+1	4/6	6.5E+1 to 1.1E+2	*	*	*

* There are no reference samples.

Table 4.20: Periwinkles, Edible, Raw Mass (Bq·kg^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
K-40	13	5.0E+1	1.6E+1 to 1.1E+2	1.3E+2	10/13	5.8E+1 to 2.7E+2	*	*	*

*There were no reference samples.

Table 4.21: Aquaculture Salmon, Raw Mass (Bq·kg^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
K-40	5	1.3E+1	6.0E+0 to 2.1E+1	1.1E+2	5/5	9.1E+1 to 1.2E+2	*	*	*

*There were no reference samples.

Table 4.22: Sea Plants, Wet Mass ($Bq \cdot kg^{-1}$)

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
K-40	12	2.0E+1	3.4E+0 to 5.8E+1	2.2E+2	12/12	1.5E+2 to 3.3E+2	*	*	*

*There were no reference samples.

4.20 Sediment

Of the 40 samples analysed, Be-7 was detected in six, Ac-228 in 25 and K-40 in 40 samples. None of these results are attributable to the operation of PLNGS.

Sediments are collected quarterly from ten locations shown in Figure 3.05. The finer grains are analysed by selective sieving of the material.

Forty samples contained K-40 (4.5E+02 to 1.4E+03 $Bq \cdot kg^{-1}$) from the natural potassium in feldspar, a common mineral. Six samples contained cosmogenically produced Be-7 (1.9E+01 to 8.3E+01 $Bq \cdot kg^{-1}$). Twenty-five samples contained Ac-228 (1.3E+01 to 4.3E+01 $Bq \cdot kg^{-1}$), a radioactive progeny of naturally occurring Th-232. Sediment samples analysed between 1977 and 1982, before PLNGS began operations, contained an average Cs-137 concentration of 5.0E+00 $Bq \cdot kg^{-1}$. A small additional Cs-137 component was added to this reservoir from Chernobyl in 1986 and from Fukushima in 2011. Finer grain sediments have a higher natural radioactivity content than coarse sediments.

Table 4.23 is a summary of the detected radionuclides in sediment. Figure 4.19 shows individual Cs-137 results. “Less Than” values are plotted for non-detected results. Sample 4 for C01 and Sample 3 for D04 were not detected. Their “Less Than” values were exceptionally high due to small sample size.

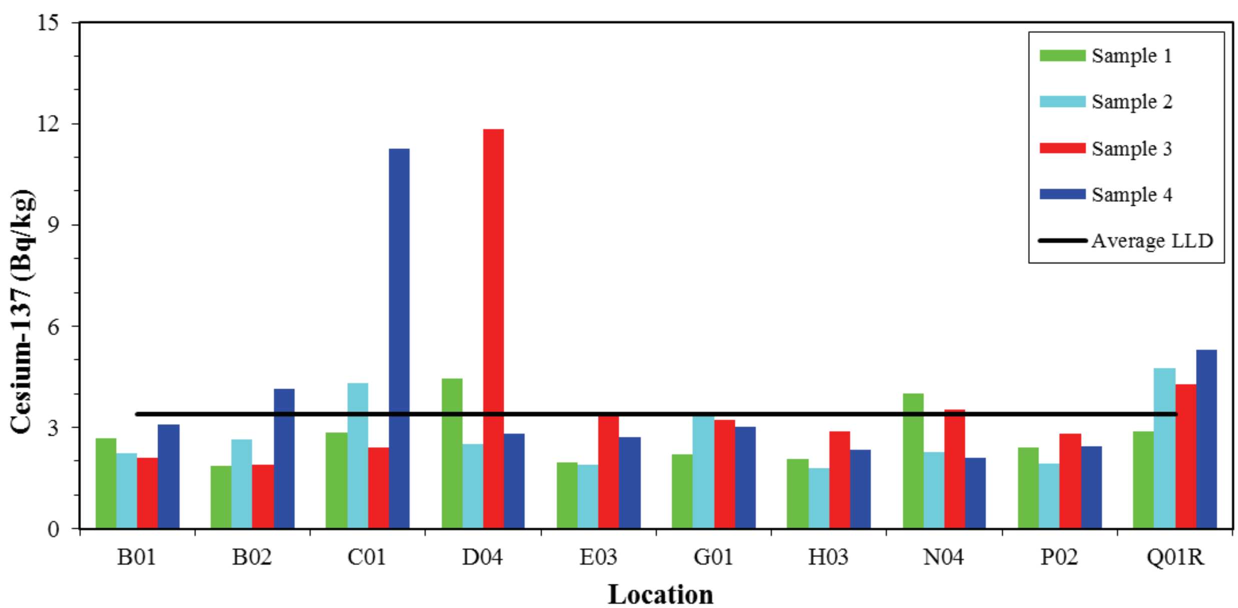


Figure 4.19: Cesium-137 (Sediment)

Table 4.23: Sediment (Bq·kg^{-1})

Analysis Type	Total Number	Critical Level		Indicator Locations			Reference Locations		
		Mean	Range	Mean	Frequency	Range	Mean	Frequency	Range
Be-7	40	1.6E+1	6.6E+0 to 7.4E+1	3.1E+1	4/36	1.9E+1 to 5.4E+1	6.3E+1	2/4	4.4E+1 to 8.3E+1
Ac-228	40	4.6E+0	1.4E+0 to 3.1E+1	2.4E+1	24/36	1.3E+1 to 4.3E+1	2.5E+1	1/4	2.5E+1 to 2.5E+1
K-40	40	3.2E+1	5.1E+0 to 1.3E+2	6.6E+2	36/36	4.5E+2 to 1.4E+3	6.0E+2	4/4	4.4E+2 to 6.7E+2

4.21 Ambient Gamma Measurements of Intertidal Zone (Ion Chamber)

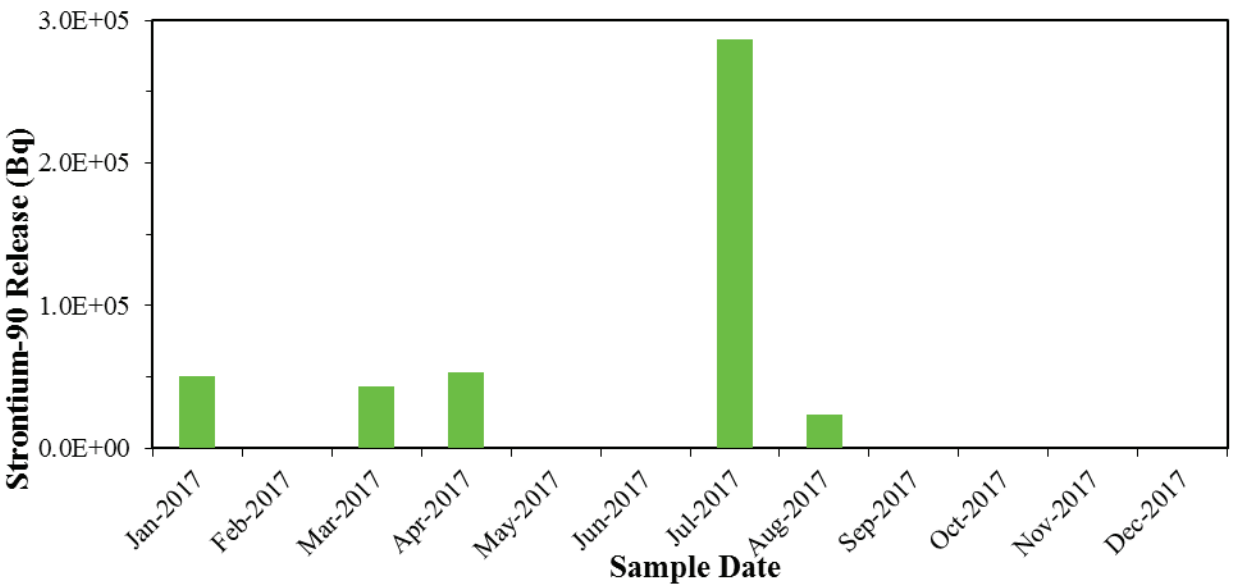
Environmental gamma survey measurements are made in the intertidal zone on beaches in the Lepreau area and at the reference location 28 km to the east-northeast (Figure 3.05). Although TLDs are preferred in measuring such exposures since they span the entire year and provide integrated measurements, they cannot be used in these locations. Instead, beach surveys are performed and grab samples of sediments are analysed. Radiation values measured in 2017 were consistent with those measured prior to station start-up in 1982. These values are summarised in Table 4.24.

Table 4.24: Ambient Gamma Measurements of Intertidal Zone (Ion Chamber) – (μSv·h^{-1})

Location	*1st Quarter*	*2nd Quarter*	*3rd Quarter*	*4th Quarter*
B01	0.14	0.15	0.13	0.21
B02	0.15	0.11	0.16	0.12
C01	0.16	0.17	0.12	0.19
D04	0.12	0.14	0.17	0.13
E03	0.16	0.18	0.09	0.21
G01	0.14	0.12	0.10	0.13
H03	0.13	0.19	0.15	0.13
N04	0.11	0.18	0.17	0.17
P02	0.09	0.09	0.11	0.15
Q01R	0.07	0.17	0.11	0.08

4.22 LEM Composite Water (Sr-89,90)

When Sr-89,90 releases are low, the expected concentration of Sr-89,90 in seawater is below the detection limit. The LEM collects samples of PLNGS liquid releases at their source. A monthly composite is sent to the lab for analysis. Twelve of these composites were analysed for Sr-89,90. If the monthly releases are more than one percent of the monthly DRL, a Sr-89,90 analysis is performed on seawater. Since the releases in 2017 were 7.7E-09% DRL (and in no month exceeded one percent of the monthly DRL) for Sr-90, and Sr-89 was not detected, no further analyses were required. Figure 4.20 shows the Sr-90 releases from PLNGS.



Note: The Monthly DRL for Sr-90 is 5.0E+14 Bq

Figure 4.20: Liquid Sr-90 Releases

4.23 Bore Hole Water, SRWMF

Of the 103 samples analysed, low levels of H-3 were detected in 100, Be-7 in four and K-40 in one. The H-3 results are attributable to the operation of PLNGS.

Samples are taken three times per year from 35 drilled wells. Occasionally, a well is dry or inaccessible and no sample is available.

Tritium concentrations averaged 1.8E+02 $Bq{\cdot}L^{-1}$ (3.7E+01 to 3.7E+02 $Bq{\cdot}L^{-1}$) near the Phase 1 facility, 6.4E+01 $Bq{\cdot}L^{-1}$ (1.3E+01 to 3.2E+02 $Bq{\cdot}L^{-1}$) near the Phase 2 facility and 1.6E+02 $Bq{\cdot}L^{-1}$ (6.1E+01 to 3.8E+02 $Bq{\cdot}L^{-1}$) near the Phase 3 facility. Tritium washes out into precipitation and subsequently drains into some of the bore holes. Precipitation analyses (*Section 4.14*) indicate H-3 concentrations ranging from 2.1E+01 to 2.4E+03 $Bq{\cdot}L^{-1}$ in 30 of 39 samples.

Four samples contained cosmogenically produced Be-7 (2.3E+00 to 8.9E+00 $Bq \cdot L^{-1}$). Naturally occurring K-40 was detected in one sample (2.9E+00 $Bq \cdot L^{-1}$).

Results are presented in Tables 4.25 to 4.27. Figure 4.21 shows the H-3 activity at each bore hole for each sample. "Less Than" values are plotted for non-detected results.

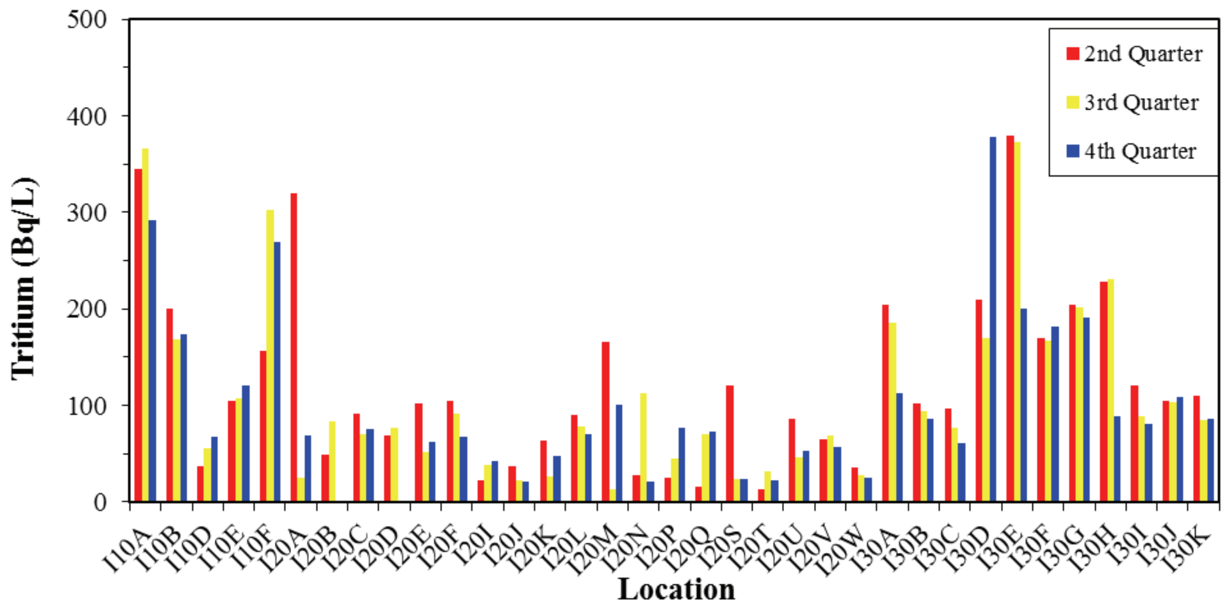


Figure 4.21: Tritium (Bore Hole Water, SRWMF)

Table 4.25: Bore Hole Water, SRWMF - Phase 1 ($Bq \cdot L^{-1}$)

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
H-3	15	1.2E+1	1.2E+1 to 1.3E+1	1.8E+2	15/15	3.7E+1 to 3.7E+2	*	*	*

*There is no reference location.

Table 4.26: Bore Hole Water, SRWMF - Phase 2 (Bq·L^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
H-3	55	1.2E+1	1.1E+1 to 1.4E+1	6.4E+1	52/55	1.3E+1 to 3.2E+2	*	*	*
Be-7	55	1.5E+0	9.1E-1 to 4.4E+0	5.3E+0	4/55	2.3E+0 to 8.9E+0	*	*	*
K-40	55	3.3E+0	1.6E+0 to 7.8E+0	2.9E+0	1/55	2.9E+0 to 2.9E+0	*	*	*

*There is no reference location.

Table 4.27: Bore Hole Water, SRWMF - Phase 3 ($Bq \cdot L^{-1}$)

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
H-3	33	1.2E+1	1.2E+1 to 1.3E+1	1.6E+2	33/33	6.1E+1 to 3.8E+2	*	*	*

*There is no reference location.

4.24 SRWMF Parshall Flume Water

Of the 162 samples analysed, H-3 was detected in 140. These results are attributable to the releases from PLNGS and the material stored in the Phase 1 structures.

Rainwater and snow melt at the onsite SRWMF (Phases 1, 2 and 3) are obtained from drainage channels (flumes) constructed to collect surface runoff from these areas. Samples are collected and analysed on a weekly basis.

There is little or no flow into or out of these collection locations during the winter months and values for H-3 tend to vary little from one week to the next except after heavy rain. The average H-3 value for each phase is:

- 6.5E+02 Bq·L^{-1} at Phase 1
- 1.6E+02 Bq·L^{-1} at Phase 2
- 8.7E+02 Bq·L^{-1} at Phase 3.

Tables 4.28 to 4.30 are summaries of the detected radionuclides in the flumes. Figure 4.22 compares the H-3 in the samples from the three facilities. "Less Than" values are plotted for non-detected results. The elevated Phase I, II, and III H-3 results coincided with an elevated release of 2.5E+12 Bq/day of tritium in early March 2017 from the main ventilation stack and the opportune meteorological conditions to produce exchange with the snow cover. The SRWMF H-3 in Precipitation result for the period of 02 February 2017 to 08 March 2017 was 2.37E+03 Bq/L, which was also elevated as a result of this stack release.

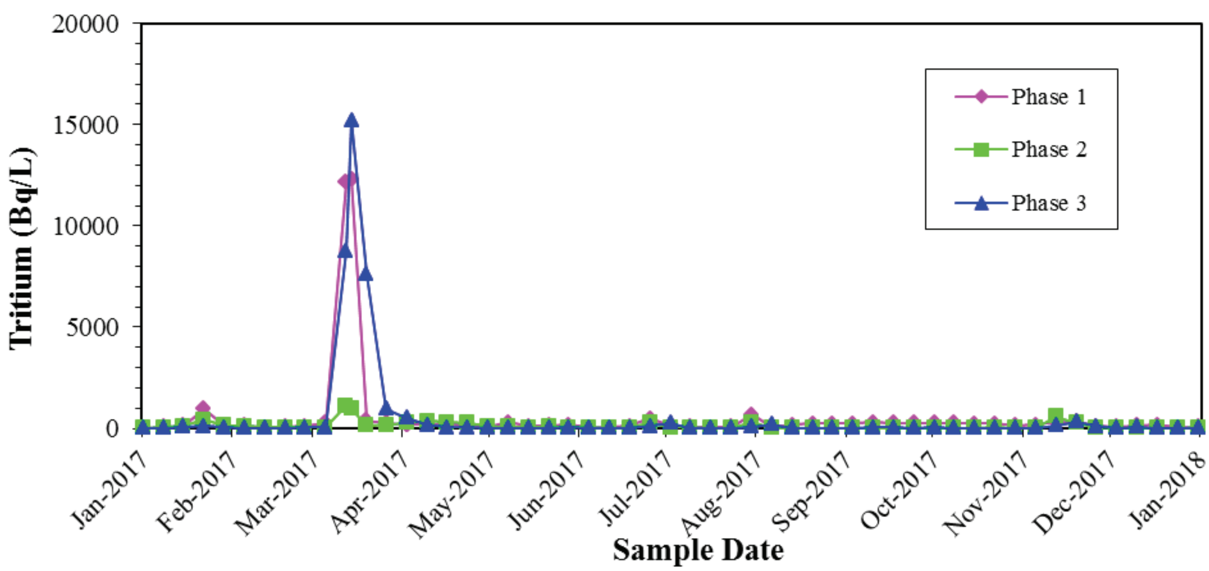


Figure 4.22: Tritium (Parshall Flume Water, SRWMF)

Table 4.28: Parshall Flume Water, SRWMF - Phase 1 (Bq·L^{-1})

Analysis Type	*Total Number*	*Critical Level*		*Indicator Locations*			*Reference Locations*		
		Mean	*Range*	*Mean*	*Frequency*	*Range*	*Mean*	*Frequency*	*Range*
H-3	54	1.3E+1	1.1E+1 to 1.9E+1	6.5E+2	54/54	3.0E+1 to 1.2E+4	*	*	*

*There is no reference location.

Table 4.29: Parshall Flume Water, SRWMF - Phase 2 ($Bq \cdot L^{-1}$)

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
H-3	54	1.2E+1	1.1E+1 to 1.4E+1	1.6E+2	45/54	1.6E+1 to 1.1E+3	*	*	*

*There is no reference location.

Table 4.30: Parshall Flume Water, SRWMF - Phase 3 (Bq·L^{-1})

Analysis Type	***Total Number***	***Critical Level***		***Indicator Locations***			***Reference Locations***		
		Mean	***Range***	***Mean***	***Frequency***	***Range***	***Mean***	***Frequency***	***Range***
H-3	54	1.3E+1	1.1E+1 to 2.0E+1	8.7E+2	41/54	1.3E+1 to 1.5E+4	*	*	*

*There is no reference location.

4.25 Hemlock Knoll Regional Sanitary Landfill Program

PLNGS disposes of its non-active waste at the public landfill facility at Hemlock Knoll. The monitoring program consists of dosimeter placement at key locations.

There were 16 TLD results from Hemlock Knoll in 2017. TLD results appear in Table 4.06 (location codes YTL1 to YTL4).

4.26 Meteorological Data

The meteorological data for 2017 were collected at ten minutes intervals and are presented in Table 4.31. Wind Rose data for 2017 are presented in Figure 4.23.

Table 4.31: Meteorological Data for Point Lepreau (2017)

	Temperature (Degrees Celsius) 10 Metre Tower Data					Wind Direction* (Relative %) 42 Metre Tower Data							
		Mean Daily		Extreme		% Observations from							
Month	**Avg**	**Max**	**Min**	**Max**	**Min**	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
January	-2.1	1.6	-5.9	9.4	-18.3	15	7	4	6	8	22	25	13
February	-3.1	1.1	-7.4	11.7	-19.0	21	9	2	10	8	16	22	12
March	-2.7	1.5	-6.9	9.0	-19.1	13	7	4	11	8	12	28	17
April	4.9	8.3	2.1	14.3	-2.1	26	19	7	13	12	7	10	5
May	9.0	13.7	5.8	23.2	2.5	21	15	9	15	12	7	9	11
June	12.1	16.4	9.0	25.7	4.9	8	8	10	27	22	16	4	5
July	15.1	19.5	12.0	24.3	10.0	8	9	6	28	20	16	7	6
August	15.6	20.0	12.4	23.9	9.1	7	11	9	21	19	19	12	3
September	14.9	18.5	12.2	24.0	4.7	19	13	4	20	16	10	10	7
October	12.5	16.0	9.0	22.4	1.3	7	9	10	20	22	11	12	9
November	4.3	8.6	-0.5	15.4	-8.1	11	6	7	17	7	14	25	14
December	-4.2	-0.3	-8.5	11.3	-20.9	11	5	4	2	4	25	31	18
Average for 2017	6.4	Max 10.5	Min 2.8	Extreme Max 25.7	Extreme Min -20.9	14	10	6	16	13	14	16	10

*Each compass direction covers ±22.5 degrees.

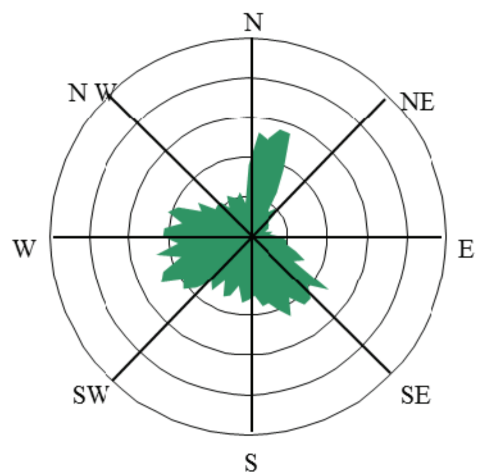


Figure 4.23: Wind Rose for Point Lepreau (2017)

5 Trends (REMP)

The following trends were observed in the historical data:

- Gaseous tritium and C-14 releases remained low in 2017.
- Tritium continues to be detected in air and water samples (lower offsite than onsite).
- There continues to be a difference between onsite and offsite thermoluminescent dosimeter (TLD) measurements (lower offsite compared with onsite).
- The radionuclide concentration in most sample types continues to remain at preoperational (background) levels due to the history of low releases.

As in the figures in *Section 4*, “Less Than” values are plotted for non-detected values. All location codes are described in Appendix C.

5.01 Dose from Airborne and Liquid Pathways

Radiation dose from PLNGS releases continues to be well below the public dose limit (1000 microsieverts per annum), and also well below the design and operating target for PLNGS (50 microsieverts per annum). See Figure 5.01.

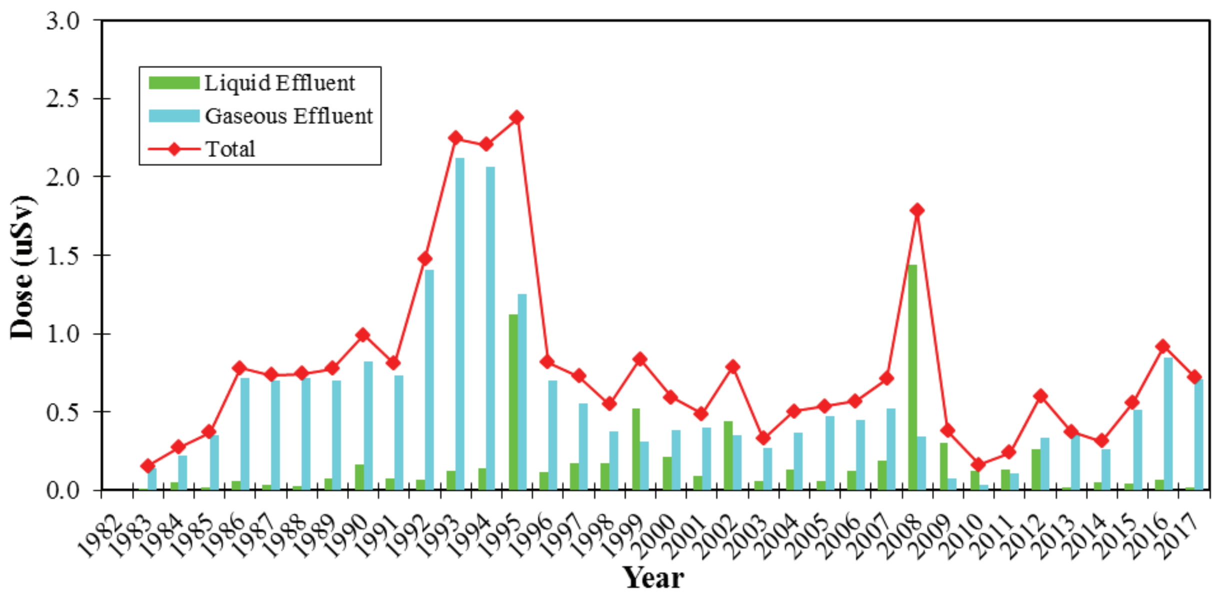
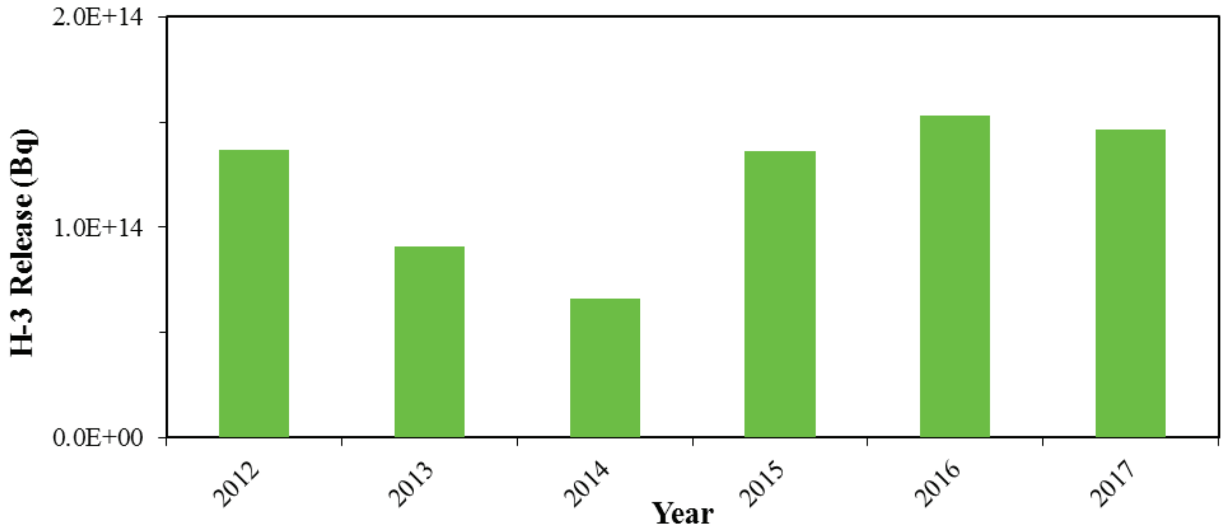


Figure 5.01: Dose from Airborne and Liquid Pathways

5.02 Tritium (Water Vapour)

Station airborne tritium releases are shown in Figure 5.02. Figure 5.04 shows the airborne H-3 concentration at the onsite stations and the offsite locations are shown in Figure 5.03. The differences are due to increasing dilution with distance from the release stack.



Note: The current Annual DRL for H-3 is 2.8E+17 Bq

Figure 5.02: Airborne H-3 Releases

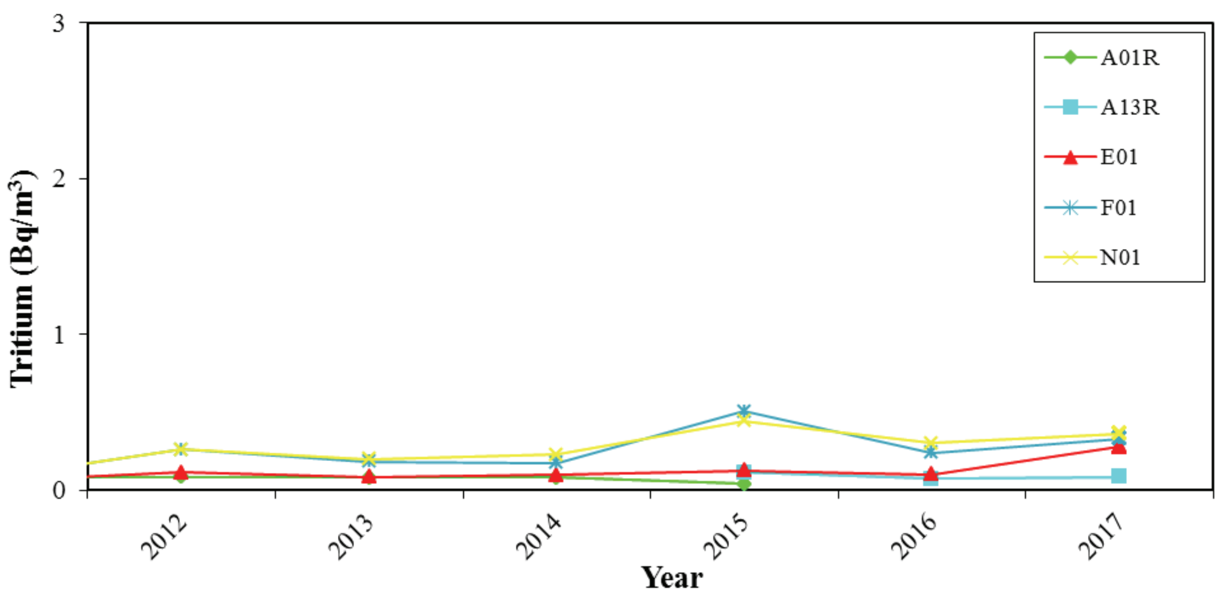


Figure 5.03: Tritium (Water Vapour) at Offsite Air Stations

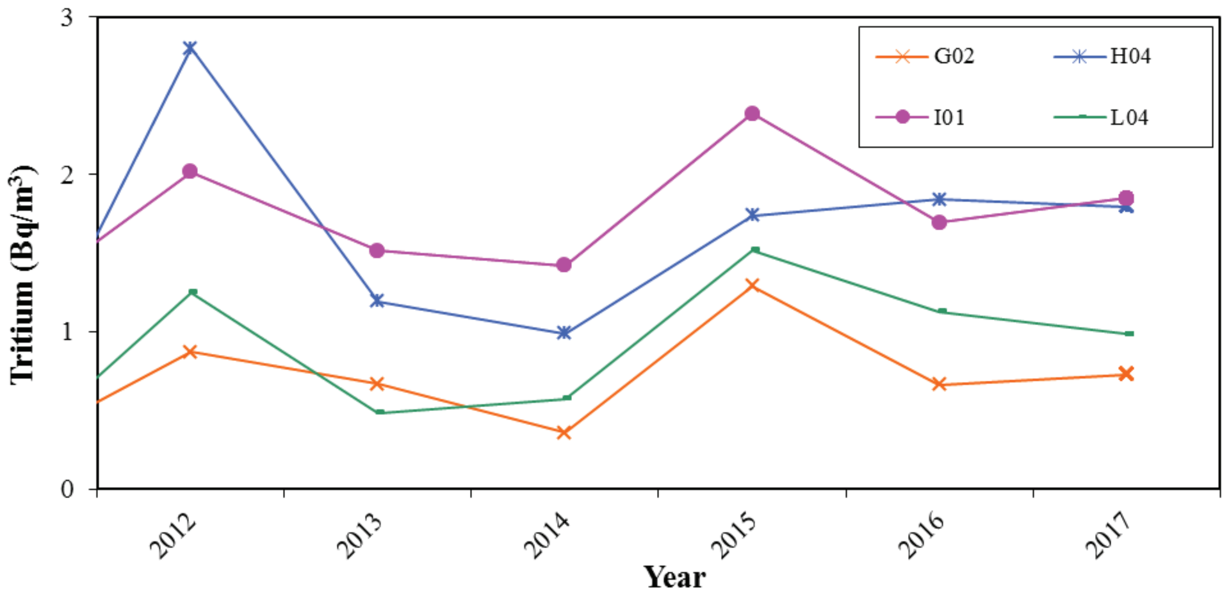


Figure 5.04: Tritium (Water Vapour) at Onsite Air Stations

5.03 Cesium-137 (Soil)

Cesium-137 from the fallout of past atmospheric weapons tests and international events tends to accumulate in the organic layer of soil. Most fluctuation in Cs-137 levels seems to be due to the quantity of organic load in the sample

The value plotted for each year in Figure 5.05 is the mean of all values for that year. "Less Than" values are plotted for non-detected values.

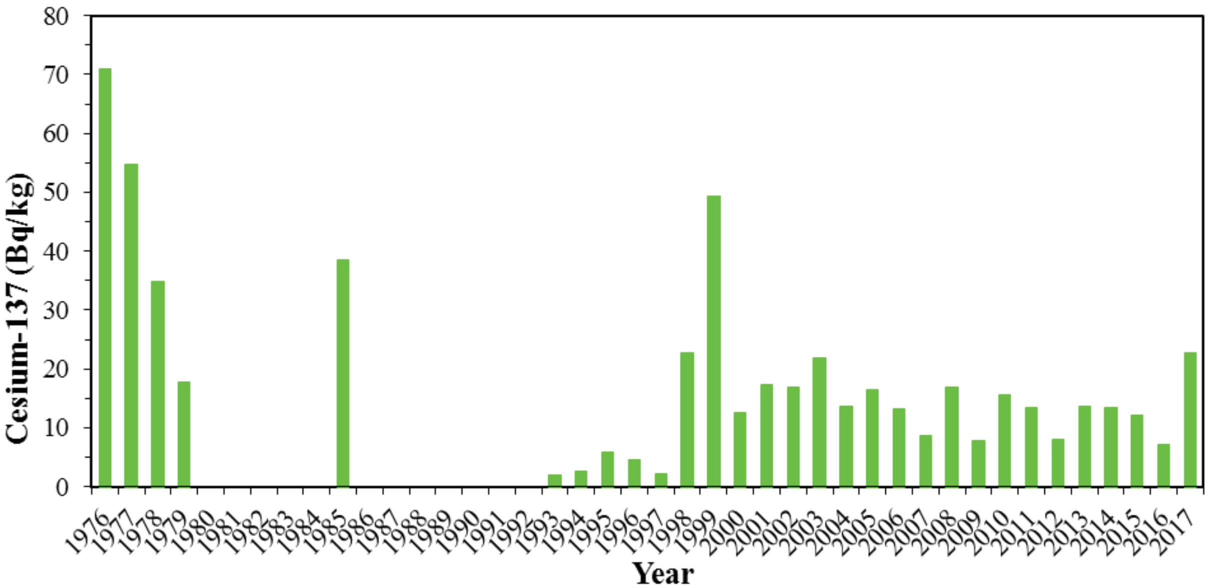


Figure 5.05: Cesium-137 (Soil)

5.04 Tritium (Monitoring Well Water, Near Plant)

The concentration of H-3 in the monitoring wells is shown in Figure 5.06.

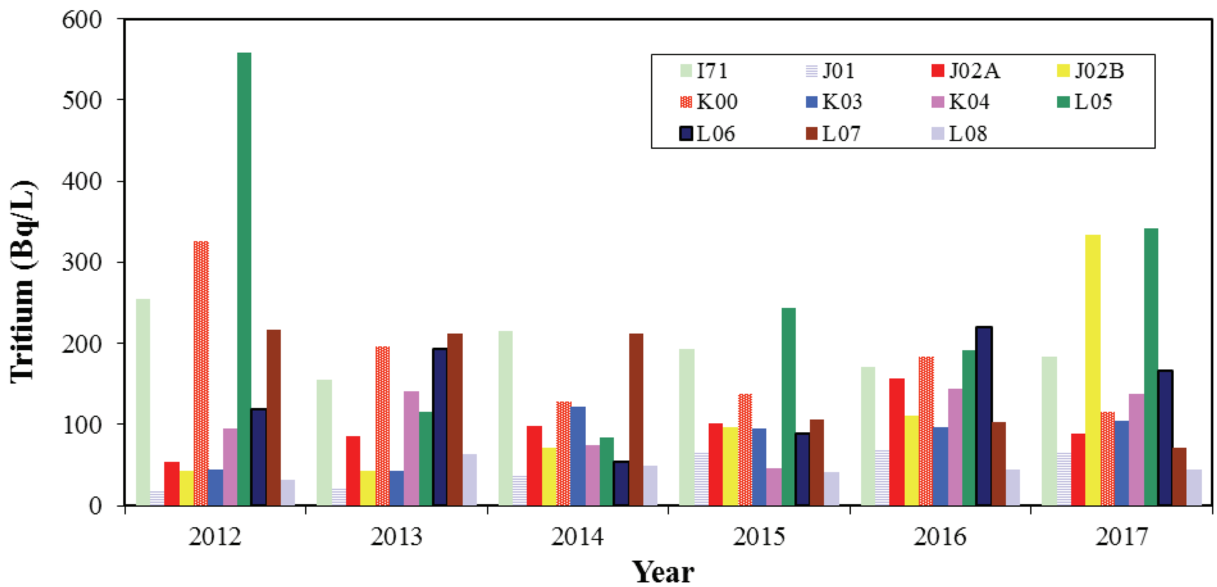


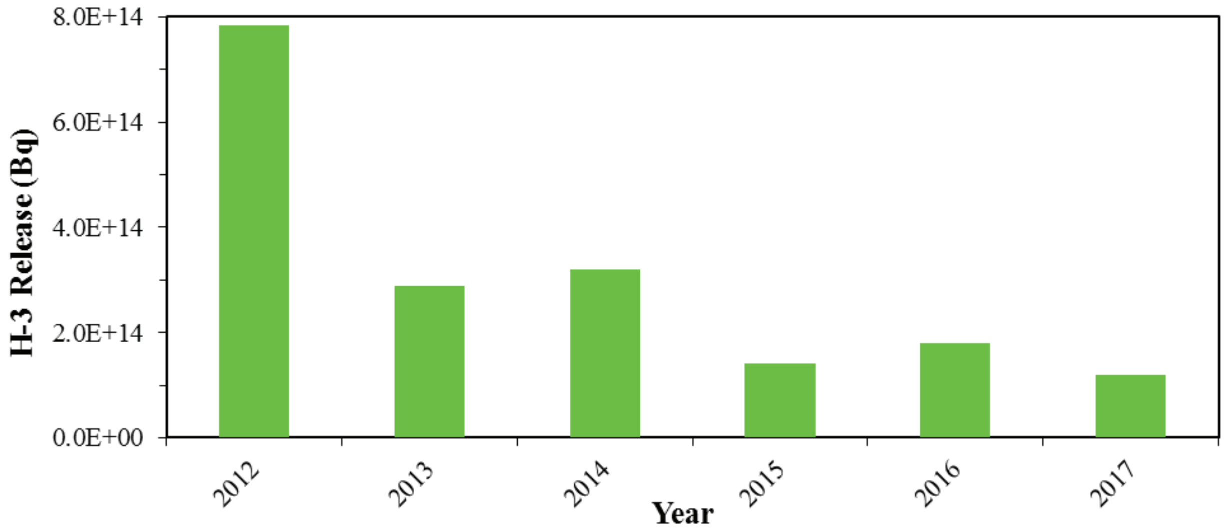
Figure 5.06: Tritium (Monitoring Well Water, Near Plant)

5.05 Tritium and C-14 (Seawater)

Tritium releases to seawater have been declining since start up activities after the refurbishment outage in 2012 (Figure 5.07). The increase in 2012 was due to restart activities.

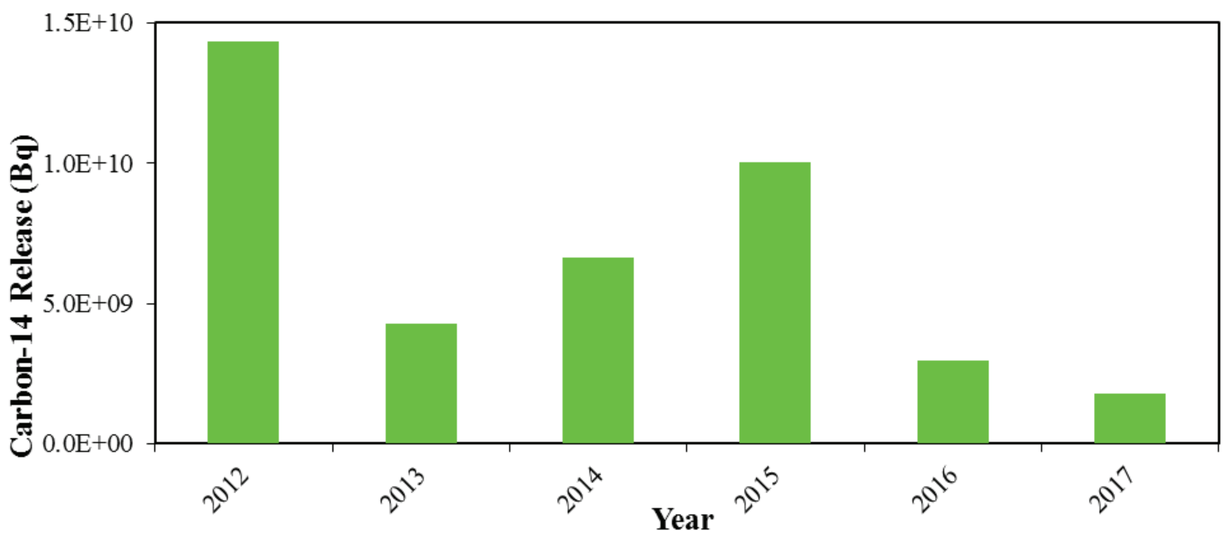
The value plotted for each year in Figure 5.07 is the mean of all values for that year. “Less Than” values are plotted for non-detected values.

Carbon-14 releases were up in 2012 due to restart activities including the transfer of moderator water to the calandria. The expected concentration of C-14 in seawater is below the detection limit (Figure 5.08).



Note: The current Annual DRL for H-3 is 4.6E+19 Bq

Figure 5.07: Liquid H-3 Releases

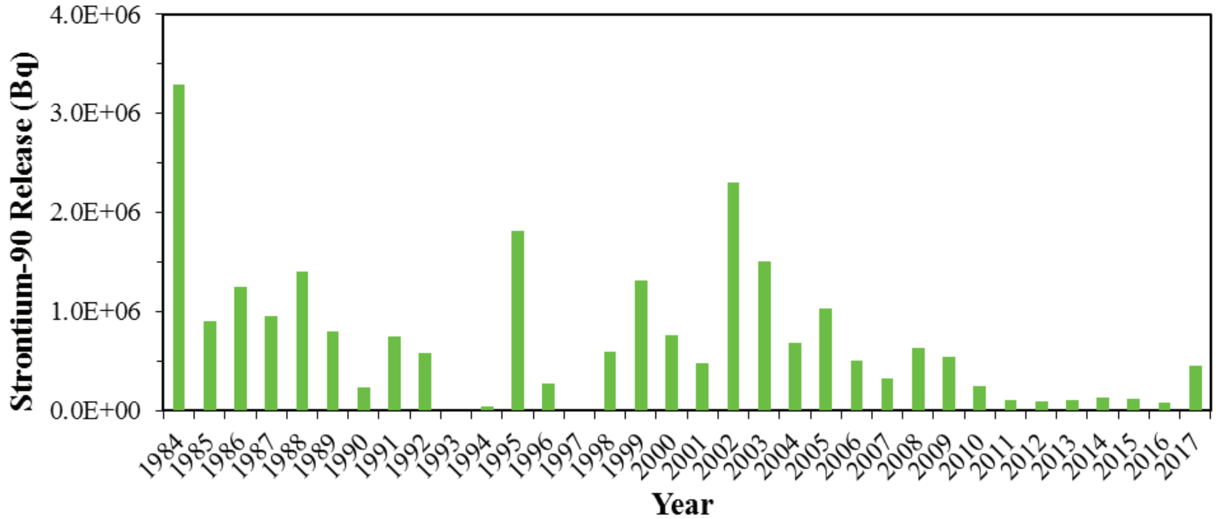


Note: The current Annual DRL for C-14 is 3.3E+14 Bq

Figure 5.08: Liquid C-14 Releases

5.06 Strontium-90 (LEM Water)

The maximum values for Sr-90 still represent only a small fraction of the DRL and are due to activity slightly above the detection limit (Figure 5.09).



Note: The current Annual DRL for Sr-90 is 6.0E+15 Bq

Figure 5.09: Liquid Sr-90 Releases

5.07 Tritium (Parshall Flume Water)

The H-3 values at Phase 2 and Phase 3 are typically less than those at Phase 1. The Phase 1 results are due to H-3 vapour escaping from the structures and condensing onto surfaces (Figure 5.10).

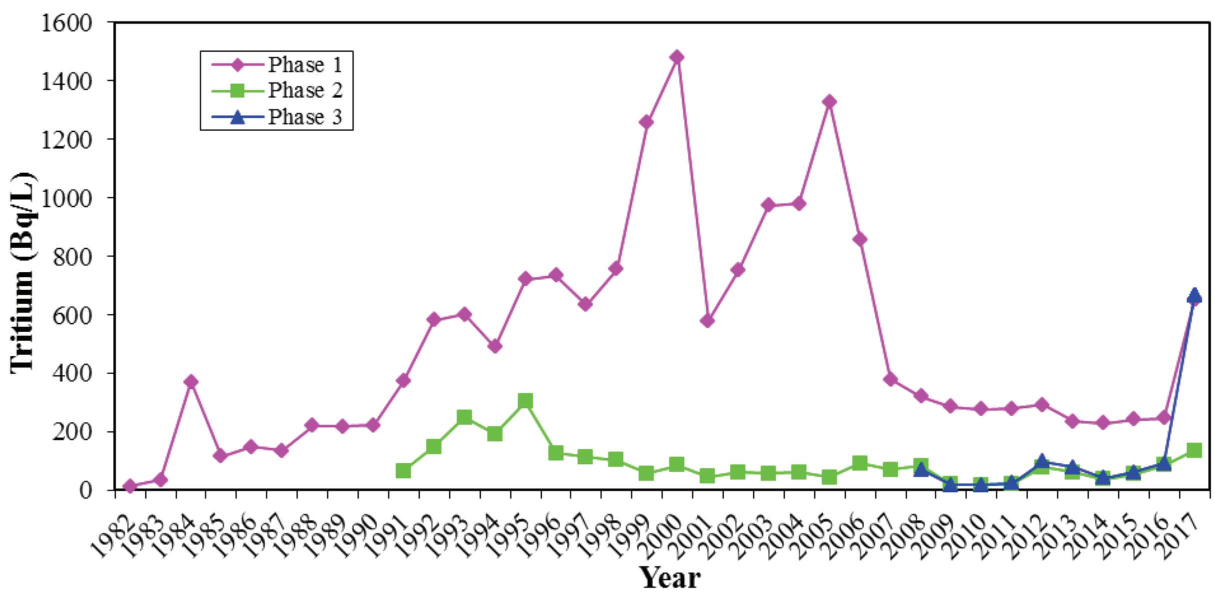


Figure 5.10: Tritium (Parshall Flume Water)

6 Dose Estimation

The DRLs apply to the release point for each of the two effluent pathways for PLNGS: the ventilation stack for airborne releases; and, for liquid releases, the discharge point of the Condenser Cooling Water (CCW) duct into the Bay of Fundy. The releases are assumed to be continuous. All relevant exposure routes to the public are factored into the DRL calculations. Crossover routes between the two pathways are insignificant, and therefore they are not considered.

The DRL document identifies the Representative Person associated with radioactive airborne and liquid effluent releases from the PLNGS, and documents the magnitude of activity of each nuclide released through either pathway in one calendar year that would cause the Representative Person to receive or be committed to the regulatory dose limit for a member of the public. This activity is called the derived release limit (DRL) for that nuclide.

Dose estimates to members of the local communities that are based on the DRLs are conservative *CSA Standard N288.1-08, Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities*, which forms the basis for DRLs, includes conservative values for food intake and other parameters. In some cases, even more conservative site-specific data are used.

The detailed discussion of these pathways may be found in *RD-01364-L1, Derived Release Limits for Radionuclides in Airborne and Liquid Effluents.*

The airborne exposure pathways from PLNGS to the public are:

- internal from inhalation
- external from immersion in a plume
- external from contaminated ground (ground shine)
- internal from ingestion of contaminated well water
- external from immersion in contaminated well water
- internal from ingestion of contaminated soil, plants and animals.

The selection of Representative Person is based upon which local residential areas might receive a slightly higher exposure from airborne releases, and the potential of intakes based upon dietary and behavioral habits.

Welch Cove was selected as the location for the representative group for all airborne releases. Welch Cove is a small community of approximately 32 residences along a two kilometre stretch of road that extends from northwest to north-northwest of PLNGS.

A hypothetical family consisting of two adults, a ten year old child and a one year old infant is considered to be representative of the community.

The liquid exposure pathways from PLNGS to the public are:

- external from diving in contaminated water
- external from exposure to contaminated sediment (while harvesting clams and dulse)
- internal from ingestion of contaminated fish, lobster, clams, and dulse.
- external from diving for sea urchins

The selection of a Representative Person is based upon dietary and behavioural habits of local residents. A representative family of two adults, a ten-year-old child and a one-year-old infant was selected.

The DRLs are based on *CSA Standard N288.1-08, Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities*. Station releases of a radionuclide at 100% DRL for a year would result in a dose to the Representative Person of 1000 μSv. In 2017 (Table 6.01), the liquid releases were 1.6E-03% DRL, which corresponds to 0.02 μSv to the Representative Person. Airborne releases for 2017 were 7.1E-02% DRL, which corresponds to a public dose of 0.71μSv. Adjustments are made to the DRL based on operational considerations or release location. For example, a reduced CCW flow changes the dilution factor which decreases the DRL.

As shown in Table 6.02 and Figures 6.01 and 6.02, H-3 accounts for 73.8% of the dose from airborne releases, and 16.8% of the dose from liquid releases in 2017. The other major contributor to dose from airborne releases was Argon-41 (18.6%). The other major contributors to dose from liquid releases were C-14 (35.0%) and Co-60 (28.8%).

Because of the protective assumptions used in the DRL calculations, and the relatively low level of releases, the most exposed member of the general public received less than the calculated dose of 0.73 μSv. This radiation dose may be compared with the individual natural radiation dose in Canada of approximately 2000 to 3000 μSv per annum. (TLDs show only the external, penetrating component, amounting to about 500 to 1000 μSv.) This includes natural dose contributions from ground, air, food and from an assumed low concentration of radon in homes. A significant fraction of Canadian homes contain natural radon levels that give a much larger radiation dose than the 2000 to 3000 μSv.

Table 6.01: Annual Dose (2017)

Source of Dose to the Representative Person	***Dose to the Representative Person ($\mu Sv.a^{-1}$)***
PLNGS airborne releases	0.71
PLNGS liquid releases	0.02

Table 6.02: Contribution of Radionuclides to Dose in Each Pathway (2017)

Radiouclide	***Contribution to Dose (from Airborne Releases)***	***Contribution to Dose (from Liquid Releases)***
H-3	73.8 %	16.8 %
C-14	6.5 %	35.0 %
Ar-41	18.6 %	----
Fe-59	----	6.2 %
Co-60	----	28.8 %
Zr-95	----	2.8 %
Ag-110m	----	1.1 %
Sn-113	----	1.6 %
Sb-124	----	4.7 %
All others	1.1 %	2.9 %
TOTAL	***100 %***	***100 %***

Note: Only radionuclides contributing 0.5% or more are itemized.

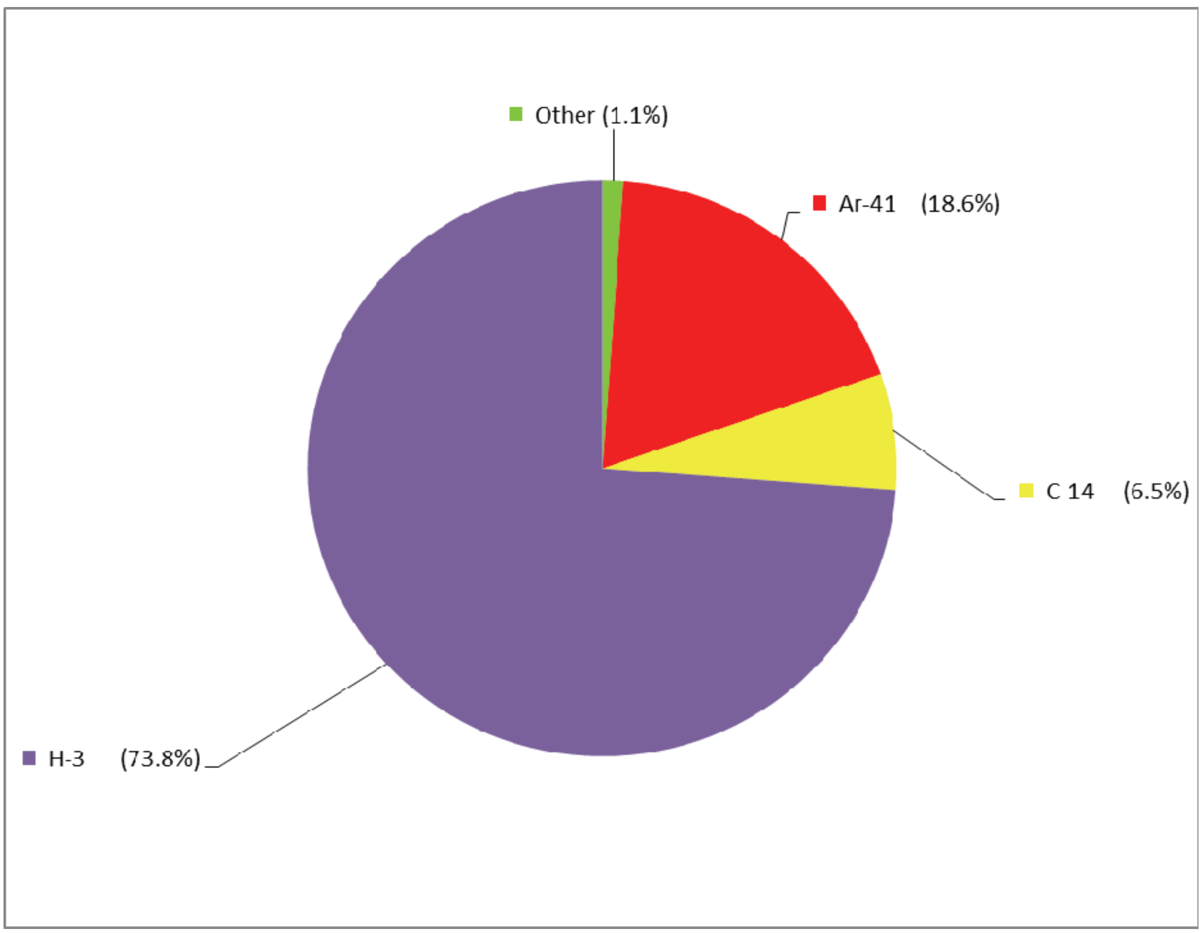


Figure 6.01: Contribution of Radionuclide to Total Dose (Airborne Pathway)-2017

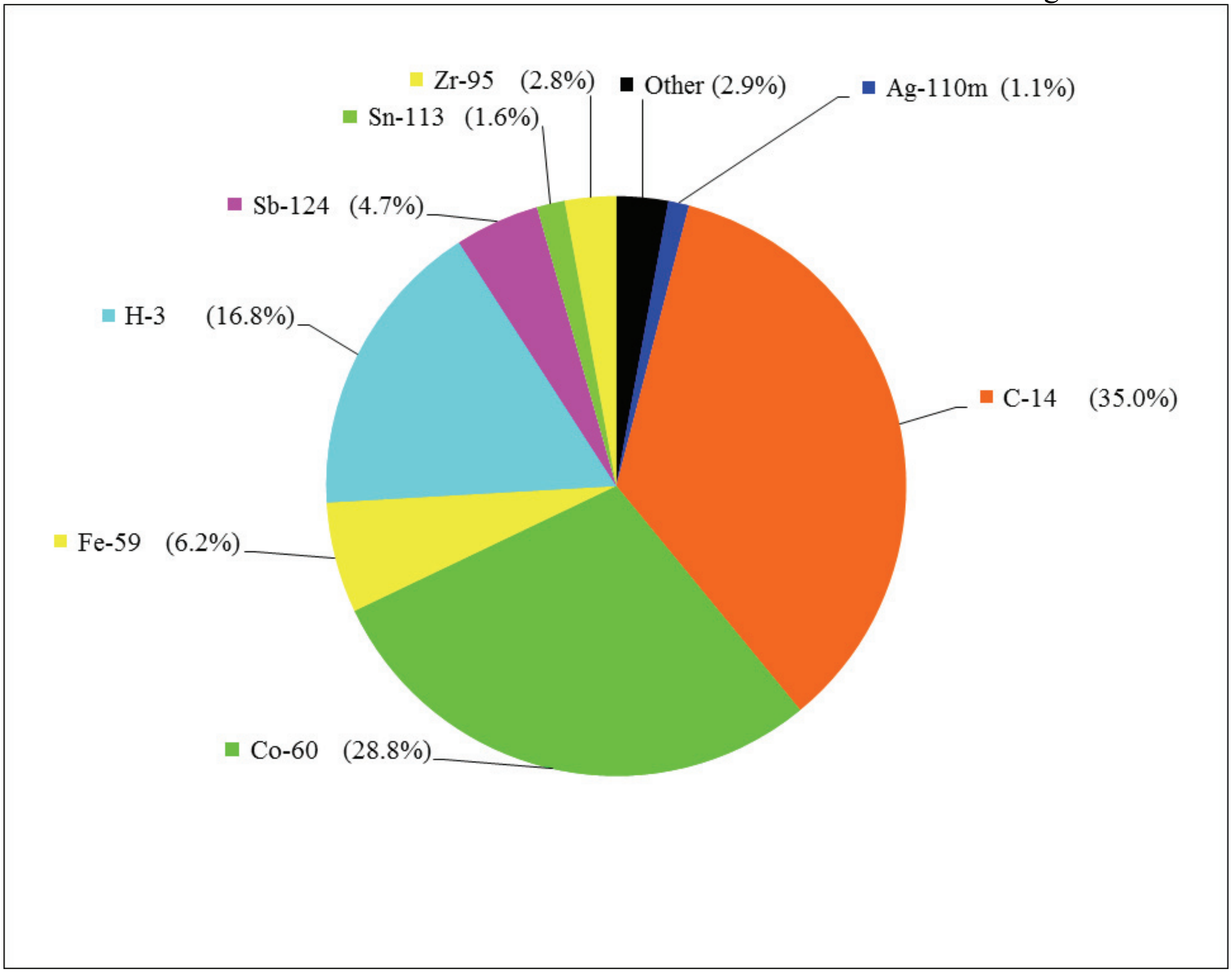


Figure 6.02: Contribution of Radionuclide to Total Dose (Liquid Pathway) – 2017

7 Quality Assurance Results (REMP)

The purpose of Quality Assurance is to provide confidence in the program and demonstrate that the program is able to meet its objectives. QA is a system whereby the laboratory can assure the regulator and NB Power that the laboratory is generating accurate and reproducible data. It encompasses:

- personnel
- procedures
- measurements
- sample integrity
- records
- annual review
- program audits
- program improvement

This section describes how QA was achieved for the year 2017. The specific procedures can be found in *HPF-03541-EN04, Quality Assurance of the Environmental Program.*

7.01 Quality Control Checks

The six main pieces of analytical equipment used in the REMP have a quality control (QC) check performed at the start of each working day. A background count is made each weekend to ensure the absence of contamination in the gamma spectrometer sample chamber. Key instrument parameters are checked and the results are compared against tolerance limits, and are also compared with previous results to detect trends in performance. This ensures that the parameters are consistent and remain free from significant drift or random variation that could influence the analyses. A compilation of the results and statistical fluctuations is maintained, and from these data the upper and lower flag limits are determined. If any equipment exceeds these limits, it is not used for analytical work until the problem has been resolved. To perform the quality control checks, radiation sources traceable to US or Canadian standards (National Institute of Standards and Technology and National Research Council) are used.

The QC evaluations in the laboratory cover the following instruments:

1. Canberra Intrinsic Ge Gamma Spectrometer
2. Beckman LS 6000TA Liquid Scintillation Counter
3. Tennelec LB-5100 Gross Alpha/Beta Counter
4. Protean WPC 9550 Alpha/Beta Counter
5. Panasonic UD-716AGL TLD Reader
6. Panasonic UD-7900 TLD Reader

Throughout the year there were some results outside expectations for each of the instruments (Table 7.01). Most of these involved only one of the six to ten parameters monitored for each system. All of these results were resolved before analytical work resumed.

Table 7.01: QC Check Results

Instrument	*Number of Parameters Monitored Per Check*	*Number of Checks*	*Number of Individual Parameters Tested*	*Number of Individual Parameters Outside Expected Limits*
Canberra Intrinsic Ge Gamma Spectrometer	6	249	1494	11
Canberra Intrinsic Ge Gamma Spectrometer (Weekend Long Background)	8	51	408	8
Beckman LS 6000TA Liquid Scintillation Counter	10	241	2410	5
Tennelec LB-5100 Gross Alpha/Beta Counter	8	212	1696	7
Protean WPC 9550 Alpha/Beta Counter	8	242	1934	13
Panasonic UD-716AGL TLD Reader	7	180	1260	0
Panasonic UD-7900 TLD Reader	7	174	1218	4

7.01.01 Intrinsic Ge Gamma Spectrometer

A daily check of seven system parameters is performed for the germanium gamma spectroscopy system. Measurements are made of the energy centroids, full width half maxima (FWHM) and efficiencies of two widely separated photon energies of Eu-152. These show the accuracy and precision of the system relative to the defined limits of acceptance. The rate of liquid nitrogen consumption is monitored to verify the physical integrity of the cryostat (this parameter is not reflected in the numbers in Table 7.01). A computer program processes the results to generate QC plots and performs statistical tests to detect out-of-range values. A 200 000 s background count is made each weekend to ensure the absence of contamination in the sample chamber. The QC program evaluates the total counts in eight separate regions of the background spectrum, and out-of-range values are flagged for assessment.

The efficiency calibration of the gamma spectroscopy system is checked annually for each of the counting geometries. This is accomplished using calibration standards derived from a mixed nuclide standard traceable to the U.S. National Institute of Standards and Technology (NIST).

7.01.02 Beckman LS 6000TA Liquid Scintillation Counter

A set of sealed tritium, C-14 and background standards traceable to NIST is analysed daily. Statistical parameters must lie within defined limits or the equipment will not be used. These same standards are used to calibrate the instrument for each analysis run.

7.01.03 Tennelec LB-5100 Gross Alpha/Beta Counter

Planchet standards of Am-241 and Sr-Y-90 are analysed daily. Alpha and Beta discrimination allows the simultaneous analysis of alpha and beta activity on all samples analysed. Planchet and filter backgrounds are included in the QC checks. These same standards are used to calibrate the instrument for each analysis run.

7.01.04 Protean WPC 9550 Alpha/Beta Counter

Planchet standards of Am-241, Tc-99 and Sr-Y-90 are analysed daily. Alpha and Beta discrimination allows the simultaneous analysis of alpha and beta activity on all samples analysed. Planchet backgrounds are included in the QC checks. The Tennelec standards are used to calibrate the instrument for each analysis run.

7.01.05 Panasonic UD-716AGL and UD-7900U TLD Readers

In each of the two TLD readers, a set of 16 TLDs is exposed in the Panarad Irradiator and read out in the TLD reader. The mean of each of the four elements, dark current, reference light, reference element, and lamp flashes must all be within specified limits. The QA aspect of this system is covered in detail in the TLD procedures:

- *HPF-03541-TL03, Performing a Quality Control Check on Panasonic Automatic TLD Readers.*
- *HPF-03541-TL09, Performing Quality Assurance Testing of the Dosimetry System.*
- *HPF-03541-TL13, Processing Internal Quality Assurance Test Data*.

7.01.06 Other Instruments

Other instruments (balances, pipettors) are checked or calibrated at least annually. As per *HPF-03541-EN05, Calibration, Maintenance and Repair of Equipment Used for the Environmental Program,*. Frequencies of calibration are based on reproducibility of measurements and on time stability tests to ensure that the measurements are within the specified tolerances for accuracy.

The gamma survey and contamination meters are calibrated at PLNGS on an annual basis.

7.02 External QA

The external quality assurance program consists of inter-comparisons with other laboratories to give independent verification of analytical performance. The frequency of each program may vary at the discretion of the sponsoring agency (see Table 7.03). Four such groups – Kinectrics, Eckert & Ziegler Analytics, Environmental Resource Associates (ERA) and the National Research Council (NRC) - provide five percent of the sample load in the laboratory with blind samples. Environmental Resource Associates (ERA) samples were unavailable in 2017. Results of our performance with these samples give an indication of the quality of measurements the laboratory is capable of producing. The results are tabulated by medium in Tables 7.04 to 7.11.

The QA agent defines acceptable performance, generally in terms of an expected range. A result outside expectations signals the need to assess the procedures, analytical methods, or equipment calibrations. There were eight results that were outside expectations out of 192 nuclide comparisons on 46 samples in the external QA program. The reasons are given in Table 7.02.

Table 7.02: External Quality Assurance Results Outside Expected Range

Medium	***Nuclide***	***Number***	***Reason***
Filter	Sr -90	1	Under investigation.
Water	Beta	1	One of the three results was an outlier which skewed the mean.
	Am-241	1	Pass/Fail limits of ±10% compared to all others who use ±3s. At ±15% this would be a pass.
	C-14	4	• Equipment malfunction for two results outside expected range (occurred on same day). • The other two were due to Pass/Fail limits of ±10% compared to all others who use ±3s. At ±15% this would be a pass.
	H-3	1	Equipment malfunction (counted on same day as C-14 result which was outside expected range).

Table 7.03: External Quality Assurance Frequency

Media	*Analyses*	*Number of QA Samples*	*External Agencies*
Filters	Gross Alpha/Beta	*	ERA
		2	Eckert & Ziegler Analytics
		4 (2 gross beta only, 2 gross alpha only)	Kinectrics
	Gamma	*	ERA
		2	Eckert & Ziegler Analytics
	Sr-89,90	*	ERA
		4	Eckert & Ziegler Analytics
Charcoal Cartridges	Gamma	4	Eckert & Ziegler Analytics
Environmental Gamma	TLD	5	NRC
Milk	Gamma	4	Eckert & Ziegler Analytics
Water	Gross Alpha/Beta	*	ERA
		2	Eckert & Ziegler Analytics
		1 (gross beta only)	Kinectrics
	H-3	4	Kinectrics
	C-14	4	Kinectrics
	Gamma	2	Kinectrics
		4	Eckert & Ziegler Analytics
	Sr-89,90	4 (on gamma sample)	Eckert & Ziegler Analytics
Food/Vegetation	Gamma	*	ERA
		2	Eckert & Ziegler Analytics
Soil/Sediment	Gamma	*	ERA
		2	Eckert & Ziegler Analytics

*Environmental Resource Associates (ERA) samples were unavailable in 2017.

Table 7.04: Filter Performance (External QA)

Analysis	QA Agent (pCi·filter^{-1} ± 2 sigma)	NB Power (pCi·filter^{-1} ± 2 sigma)	NB Power/ QA Agent (ratio)
ALPHA	1.47 ± 0.15	1.74 ± 0.04	1.18
	1.96 ± 0.20	2.11 ± 0.04	1.08
	10.0 ± 1.0	9.10 ± 0.08	0.91
	10.5 ± 1.1	10.8 ± 0.1	1.02
BETA	7.77 ± 0.78	7.51 ± 0.06	0.97
	6.55 ± 0.65	6.88 ± 0.06	1.05
	15.8 ± 1.6	15.4 ± 0.1	0.97
	17.6 ± 1.8	18.5 ± 0.1	1.05
Ce-141	4.29 ± 0.43	4.48 ± 0.30	1.04
	2.53 ± 0.25	2.46 ± 0.18	0.97
Co-58	4.40 ± 0.44	4.55 ± 0.34	1.03
	2.31 ± 0.23	2.24 ± 0.21	0.97
Co-60	5.40 ± 0.54	5.66 ± 0.30	1.05
	4.44 ± 0.44	4.48 ± 0.26	1.01
Cr-51	8.92 ± 0.89	9.32 ± 0.95	1.05
	6.22 ± 0.62	5.96 ± 0.68	0.96
Cs-134	5.33 ± 0.53	5.14 ± 0.69	0.97
	3.21 ± 0.32	3.15 ± 0.55	0.98
Cs-137	4.26 ± 0.43	4.18 ± 0.31	0.98
	3.64 ± 0.36	3.46 ± 0.27	0.95
Fe-59	3.26 ± 0.33	3.77 ± 0.47	1.16
	2.92 ± 0.29	3.29 ± 0.42	1.13
Mn-54	4.85 ± 0.48	5.44 ± 0.39	1.12
	4.14 ± 0.41	4.18 ± 0.32	1.01
Sr-89	3.64 ± 0.12	3.51 ± 0.07	0.96
	3.08 ± 0.31	3.20 ± 0.07	1.04
	2.99 ± 0.30	2.26 ± 0.12	0.76
	3.64 ± 0.36	2.73 ± 0.28	0.75
Sr-90	0.932 ± 0.031	0.788 ± 0.034	0.85
	0.448 ± 0.045	0.440 ± 0.026	0.98
	0.437 ± 0.044	0.284 ± 0.032	0.65 *
	0.666 ± 0.067	0.492 ± 0.082	0.74
Zn-65	5.77 ± 0.58	6.85 ± 0.60	1.19
	5.44 ± 0.54	6.14 ± 0.53	1.13

*Outside expected Range

Table 7.05: Charcoal Cartridge Performance (External QA)

Analysis	*QA Agent ($pCi \cdot cartridge^{-1}$ ± 2 sigma)*	*NB Power ($pCi \cdot cartridge^{-1}$ ± 2 sigma)*	*NB Power/QA Agent (ratio)*
I-131	3.61 ± 0.12	2.89 ± 0.27	0.80
	3.14 ± 0.31	2.87 ± 0.28	0.92
	2.39 ± 0.24	2.18 ± 0.24	0.91
	1.78 ± 0.18	1.64 ± 0.20	0.92

Table 7.06: Milk Performance (External QA)

Analysis	*QA Agent ($pCi \cdot L^{-1}$ ± 2 sigma)*	*NB Power ($pCi \cdot L^{-1}$ ± 2 sigma)*	*NB Power/ QA Agent (ratio)*
Ce-141	4.40 ± 0.14	4.88 ± 0.32	1.11
	5.59 ± 0.56	5.40 ± 0.35	0.97
	3.22 ± 0.32	2.95 ± 0.24	0.91
	3.64 ± 0.36	3.96 ± 0.28	1.09
Co-58	6.59 ± 0.22	7.18 ± 0.46	1.09
	5.74 ± 0.57	5.96 ± 0.39	1.04
	4.33 ± 0.43	4.11 ± 0.31	0.95
	3.33 ± 0.33	3.57 ± 0.26	1.07
Co-60	10.8 ± 0.4	12.1 ± 0.5	1.12
	7.07 ± 0.71	7.25 ± 0.33	1.03
	9.69 ± 0.97	9.21 ± 0.45	0.95
	6.40 ± 0.64	7.07 ± 0.33	1.10
Cr-51	7.84 ± 0.26	8.88 ± 0.95	1.13
	11.7 ± 1.2	11.2 ± 1.0	0.96
	8.03 ± 0.80	7.73 ± 1.02	0.96
	8.95 ± 0.90	9.51 ± 1.00	1.06
Cs-134	6.99 ± 0.23	6.99 ± 0.69	1.00
	6.96 ± 0.70	6.48 ± 0.54	0.93
	7.44 ± 0.74	5.85 ± 0.50	0.79
	4.63 ± 0.46	4.77 ± 0.51	1.03
Cs-137	8.40 ± 0.27	9.03 ± 0.56	1.07
	5.55 ± 0.56	5.59 ± 0.36	1.01
	6.36 ± 0.64	5.85 ± 0.41	0.92
	5.22 ± 0.52	5.70 ± 0.37	1.09
Fe-59	4.70 ± 0.15	5.37 ± 0.47	1.14
	4.26 ± 0.43	4.70 ± 0.43	1.10
	4.63 ± 0.46	4.74 ± 0.47	1.02
	4.18 ± 0.42	4.51 ± 0.43	1.08

Table 7.06 (continued): Milk Performance (External QA)

Analysis	QA Agent ($pCi \cdot L^{-1}$ ± 2 sigma)	NB Power ($pCi \cdot L^{-1}$ ± 2 sigma)	NB Power/ QA Agent (ratio)
I-131	3.58 ± 0.12	3.85 ± 0.34	1.07
	3.46 ± 0.35	3.46 ± 0.33	1.00
	2.63 ± 0.26	2.42 ± 0.24	0.92
	2.14 ± 0.21	2.08 ± 0.78	0.97
Mn-54	9.21 ± 0.30	10.1 ± 0.6	1.09
	6.36 ± 0.64	6.62 ± 0.42	1.04
	4.55 ± 0.46	4.55 ± 0.33	1.00
	5.96 ± 0.60	6.59 ± 0.42	1.11
Zn-65	11.0 ± 0.4	12.2 ± 0.8	1.11
	7.55 ± 0.75	7.47 ± 0.54	0.99
	6.81 ± 0.68	6.73 ± 0.54	0.99
	7.81 ± 0.78	8.55 ± 0.60	1.09

Table 7.07: Water Performance (External QA)

Analysis	QA Agent ($pCi \cdot L^{-1}$ ± 2 sigma) or ($pCi \cdot kg^{-1}$ ± 2 sigma)	NB Power ($pCi \cdot L^{-1}$ ± 2 sigma) or ($pCi \cdot kg^{-1}$ ± 2 sigma)	NB Power/ QA Agent (ratio)
ALPHA	1.89 ± 0.19	2.29 ± 0.08	1.21
	2.94 ± 0.29	2.23 ± 0.15	0.76
BETA	9.99 ± 1.00	9.62 ± 0.14	0.96
	9.81 ± 0.98	5.33 ± 0.25	0.54 Fail
	8.77 ± 0.88	8.14 ± 0.13	0.93
Am-241	73300 ± 7300	74700 ± 4500	1.02
	71800 ± 7200	63300 ± 3700	0.88 *
C-14	11100 ± 1100	6850 ± 300	0.62 *
	407000 ± 41000	216000 ± 2000	0.53 *
	37700 ± 3800	32900 ± 200	0.87 *
	130000 ± 13000	102000 ± 1000	0.79 *
Cd-109	975000 ± 97000	981000 ± 59000	1.01
	962000 ± 96000	895000 ± 55000	0.93
Ce-139	35200 ± 3500	35900 ± 2100	1.02
	34000 ± 3400	32900 ± 1900	0.97
Ce-141	4.40 ± 0.14	5.03 ± 0.57	1.14
	7.36 ± 0.74	6.99 ± 0.70	0.95
	3.68 ± 0.37	3.67 ± 0.56	1.00
	2.31 ± 0.23	2.31 ± 0.35	1.00

*Outside expected Range

Table 7.07 (continued): Water Performance (External QA)

Analysis	*QA Agent ($pCi \cdot L^{-1}$ ± 2 sigma) or ($pCi \cdot kg^{-1}$ ± 2 sigma)*	*NB Power ($pCi \cdot L^{-1}$ ± 2 sigma) or ($pCi \cdot kg^{-1}$ ± 2 sigma)*	*NB Power/ QA Agent (ratio)*
Co-57	23300 ± 2300	23300 ± 1000	1.00
	22600 ± 2300	21100 ± 900	0.93
Co-58	6.55 ± 0.21	6.73 ± 0.75	1.03
	7.55 ± 0.75	7.40 ± 0.77	0.98
	4.96 ± 0.50	5.48 ± 0.71	1.10
	2.11 ± 0.21	1.99 ± 0.35	0.94
Co-60	10.8 ± 0.4	12.4 ± 0.8	1.15
	9.25 ± 0.93	9.32 ± 0.67	1.01
	11.1 ± 1.1	10.7 ± 0.8	0.96
	4.07 ± 0.41	3.62 ± 0.39	0.89
	47700 ± 4800	49200 ± 2000	1.03
	46300 ± 4600	46600 ± 2700	1.01
Cr-51	7.81 ± 0.26	9.99 ± 2.41	1.28
	15.3 ± 1.5	13.1 ± 2.8	0.86
	9.18 ± 0.92	8.66 ± 2.72	0.94
	5.70 ± 0.57	5.88 ± 1.73	1.03
Cs-134	6.96 ± 0.23	7.66 ± 0.80	1.10
	9.14 ± 0.91	9.58 ± 0.08	1.05
	8.47 ± 0.85	7.66 ± 0.77	0.90
	2.93 ± 0.29	2.54 ± 0.43	0.87
Cs-137	8.36 ± 0.27	9.51 ± 0.91	1.14
	7.29 ± 0.73	7.07 ± 0.72	0.97
	7.25 ± 0.73	7.22 ± 0.75	0.99
	3.32 ± 0.33	3.50 ± 0.46	1.06
	30300 ± 3000	31500 ± 1800	1.04
	28500 ± 2800	27000 ± 1600	0.95
Fe-59	4.70 ± 0.15	5.92 ± 1.15	1.26
	5.59 ± 0.56	6.44 ± 1.26	1.15
	5.29 ± 0.53	5.11 ± 1.14	0.97
	2.66 ± 0.27	2.42 ± 0.73	0.91
H-3	179000 ± 18000	175000 ± 1000	0.98
	8.2E+6 ± 8.2E+5	9.7E+6 ± 6.4E+4	1.19 *
	108000 ± 11000	103000 ± 1000	0.96
	6.0E+6 ± 6.0E+5	5.7E+6 ± 3.1E+4	0.95
Hg-203	76600 ± 7700	77000 ± 4500	1.00
	71800 ± 7200	69900 ± 4000	0.97
I-131	3.00 ± 0.30	2.21 ± 2.56	0.74
	2.93 ± 0.29	3.23 ± 3.74	1.10
	1.83 ± 0.18	2.00 ± 0.39	1.09

*Outside expected Range

Table 7.07 (continued): Water Performance (External QA)

Analysis	*QA Agent (pCi·L^{-1} ± 2 sigma) or (pCi·kg^{-1} ± 2 sigma)*	*NB Power (pCi·L^{-1} ± 2 sigma) or (pCi·kg^{-1} ± 2 sigma)*	*NB Power/ QA Agent (ratio)*
Mn-54	9.18 ± 0.30	10.5 ± 1.0	1.15
	8.33 ± 0.83	8.66 ± 0.82	1.04
	5.18 ± 0.52	5.70 ± 0.67	1.10
	3.77 ± 0.38	3.92 ± 0.50	1.04
Sn-113	61100 ± 6100	63600 ± 3700	1.04
	58800 ± 5900	57000 ± 3300	0.97
Sr-85	71400 ± 7100	73600 ± 4300	1.03
	71000 ± 7100	69200 ± 4000	0.97
Sr-89	8.66 ± 0.28	9.21 ± 0.13	1.06
	3.08 ± 0.31	2.44 ± 0.07	0.79
	3.25 ± 0.32	2.94 ± 0.15	0.91
	3.35 ± 0.34	2.94 ± 0.08	0.88
Sr-90	2.22 ± 0.07	1.71 ± 0.06	0.77
	0.448 ± 0.045	0.448 ± 0.036	1.00
	0.474 ± 0.047	0.349 ± 0.042	0.74
	0.614 ± 0.061	0.437 ± 0.038	0.71
Y-88	101000 ± 10000	105000 ± 4000	1.04
	97300 ± 9700	95500 ± 3900	0.98
Zn-65	10.9 ± 0.4	11.9 ± 1.5	1.09
	9.88 ± 0.99	10.0 ± 1.3	1.01
	7.77 ± 0.78	7.99 ± 1.22	1.03
	4.96 ± 0.50	5.48 ± 0.92	1.10

Table 7.08: Food/Vegetation Performance (External QA)

Analysis	*QA Agent (pCi·kg^{-1} ± 2 sigma)*	*NB Power (pCi·kg^{-1} ± 2 sigma)*	*NB Power/ QA Agent (ratio)*
Ce-141	13.5 ± 1.3	16.0 ± 1.7	1.19
	7.22 ± 0.72	9.03 ± 1.04	1.25
Co-58	13.8 ± 1.4	15.5 ± 1.7	1.12
	6.59 ± 0.66	7.88 ± 1.08	1.20
Co-60	16.9 ± 1.7	17.5 ± 1.3	1.03
	12.7 ± 1.3	13.7 ± 1.2	1.08
Cr-51	28.0 ± 2.8	34.9 ± 8.4	1.25
	17.7 ± 1.8	18.5 ± 4.4	1.04
Cs-134	16.7 ± 1.7	17.9 ± 1.5	1.07
	9.14 ± 0.91	8.81 ± 1.18	0.96
Cs-137	13.3 ± 1.3	15.4 ± 1.5	1.16
	10.4 ± 1.0	12.2 ± 1.3	1.18
Fe-59	10.2 ± 1.0	10.1 ± 2.5	0.98
	8.29 ± 0.83	8.81 ± 2.11	1.06

Table 7.08 (continued): Food/Vegetation Performance (External QA)

Analysis	*QA Agent ($pCi \cdot kg^{-1}$ ± 2 sigma)*	*NB Power ($pCi \cdot kg^{-1}$ ± 2 sigma)*	*NB Power/QA Agent (ratio)*
Mn-54	15.3 ± 1.5	16.1 ± 1.6	1.05
	11.8 ± 1.2	14.2 ± 1.5	1.21
Zn-65	18.1 ± 1.8	20.5 ± 2.7	1.13
	15.5 ± 1.5	16.7 ± 2.4	1.08

Table 7.09: Soil Performance (External QA)

Analysis	*QA Agent ($pCi \cdot kg^{-1}$ ± 2 sigma)*	*NB Power ($pCi \cdot kg^{-1}$ ± 2 sigma)*	*NB Power/ QA Agent (ratio)*
Ce-141	11.0 ± 1.1	8.51 ± 1.38	0.78
Co-58	11.2 ± 1.1	9.55 ± 1.31	0.85
	4.70 ± 0.47	5.25 ± 1.16	1.12
Co-60	13.8 ± 1.4	11.8 ± 1.0	0.86
	9.07 ± 0.91	8.51 ± 0.80	0.94
Cr-51	22.8 ± 2.3	23.9 ± 7.9	1.05
Cs-134	13.6 ± 1.4	12.8 ± 1.2	0.94
	6.55 ± 0.65	6.73 ± 1.02	1.03
Cs-137	13.7 ± 1.4	11.4 ± 1.2	0.83
	10.2 ± 1.0	9.36 ± 1.09	0.92
Fe-59	8.36 ± 0.84	7.88 ± 2.18	0.94
Mn-54	12.4 ± 1.2	11.7 ± 1.3	0.94
	8.40 ± 0.84	8.77 ± 1.09	1.04
Zn-65	14.7 ± 1.5	15.5 ± 1.7	1.05
	11.1 ± 1.1	10.7 ± 1.2	0.96

Table 7.10: Environmental TLD Performance (External QA)

Analysis	*QA Agent (mR ± 2 sigma)*	*NB Power (mR ± 2 sigma)*	*NB Power/QA Agent (ratio)*
Gamma	113 ± 6	102 ± 10	0.90

7.03 Internal QA

There are three parts to Internal QA:

1) duplicate samples – two samples collected at the same time and analysed separately
2) replicate analyses – two analyses done on the same sample
3) in house analyses – lab staff irradiate the TLDs which are subsequently analyzed

Duplicate samples and replicate analyses are employed as part of the overall quality assurance program. For those media where two samples can be obtained from the same location at the same time, similar analytical results are expected. This approach demonstrates that the samples are representative of the medium in that area. Where duplicate samples are not possible, e.g., air filters, a sample is counted twice to demonstrate reproducibility in the counting system. Tracking of results is done in a spreadsheet and performance is charted. If the range of the ratio (of the two detected measurements) plus or minus the combined uncertainty (95% confidence interval) includes 1.00, then performance is acceptable. See Table 7.11 for the frequency.

There were 158 radionuclide comparisons performed. Six of these had results outside expectations.

The results are presented graphically in Figures 7.01 to 7.12 (plotted against the analysis date).

Table 7.11: Internal Quality Assurance Frequency

Medium	***Duplicate/Replicate***	***Number of Radionuclide Comparisons***	***Analyses***
Airborne Carbon Dioxide	Replicate analysis (single location)	11	LSC C-14
Airborne Iodines	Replicate count (1 composite set)	12	Gamma
Airborne Particulates	Replicate analysis	12	Gamma
		12	Alpha/Beta
Food	Replicate analysis	7	Gamma
Milk	Duplicate sample	4	Gamma
Parshall Flume	Replicate analysis	12	LSC H-3
LEM Composite	Replicate analysis	12	Gamma
		12	Alpha/Beta
		12	Sr-89,90
Sea Food	Replicate analysis	4	Gamma
Sediment / Soil	Duplicate sample	4	Gamma
Environmental Gamma	Duplicate sample	4	TLD

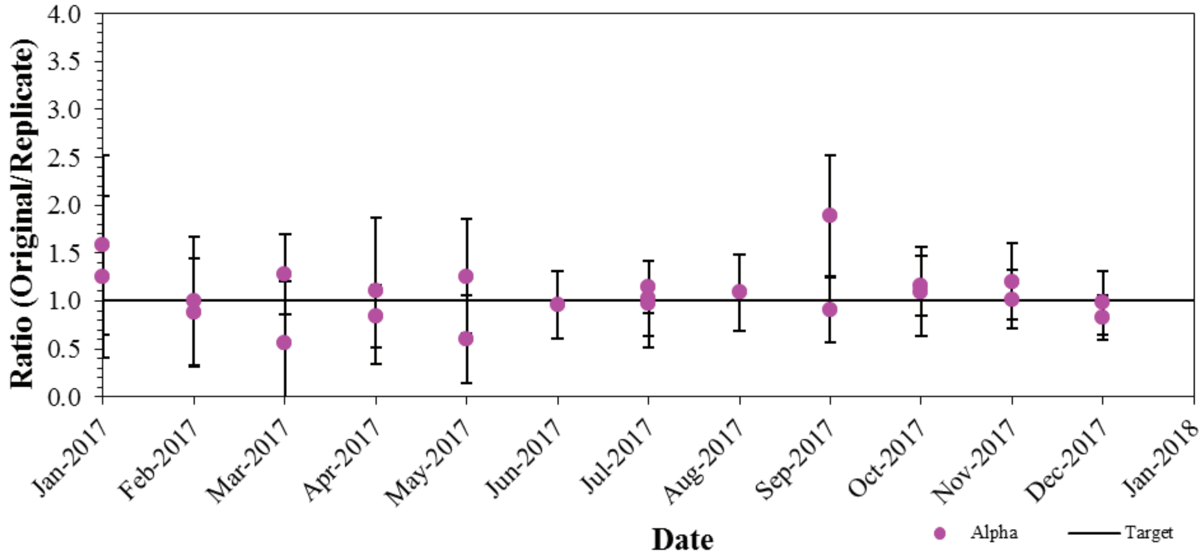


Figure 7.01: Alpha Performance (Internal QA – duplicate/replicate)

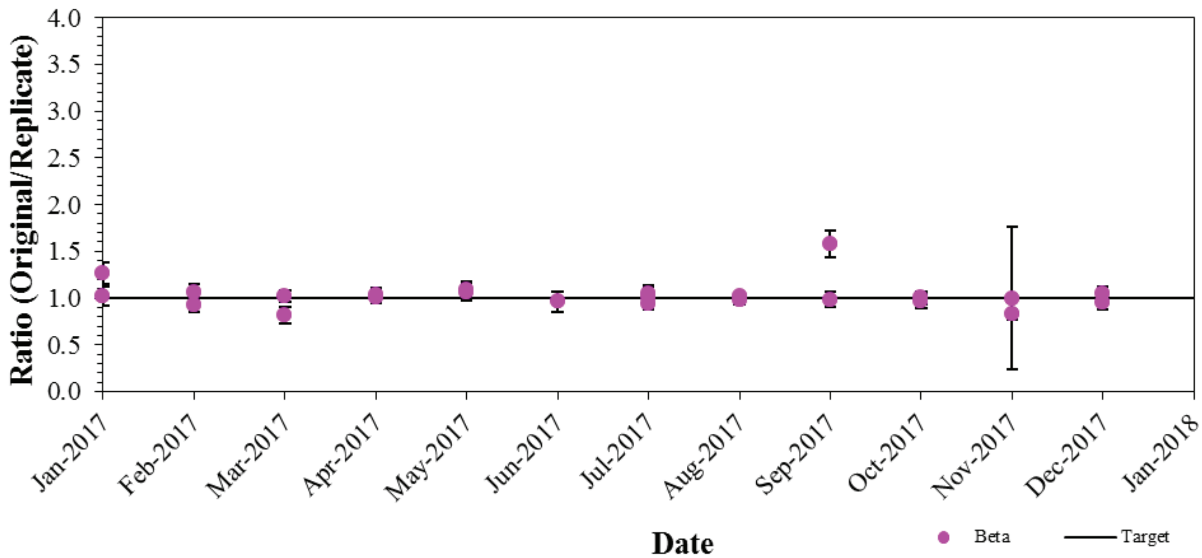


Figure 7.02: Beta Performance (Internal QA – duplicate/replicate)

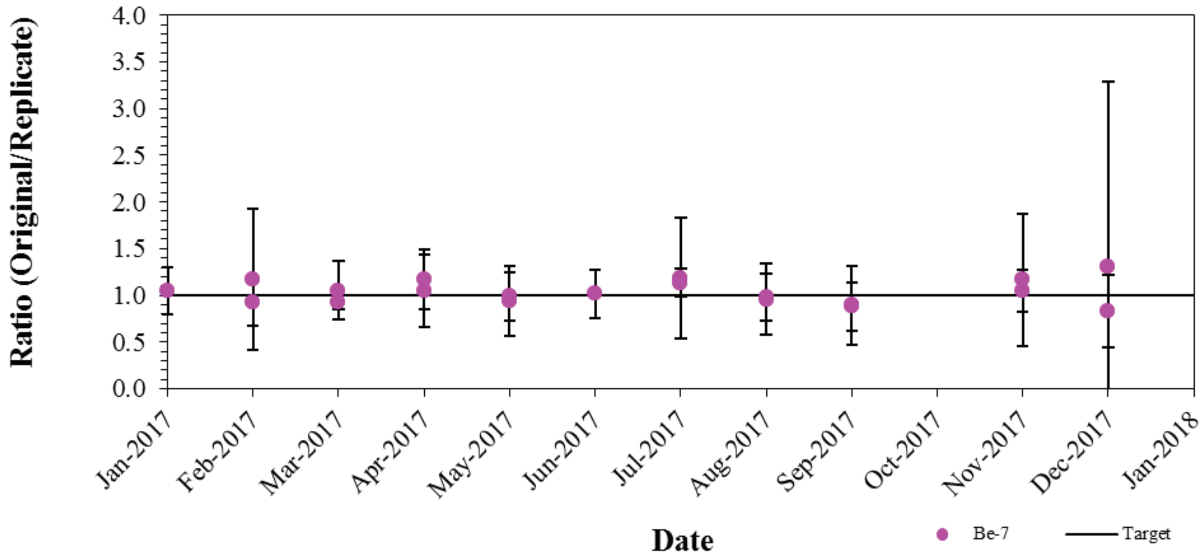


Figure 7.03: Beryllium-7 Performance (Internal QA – duplicate/replicate)

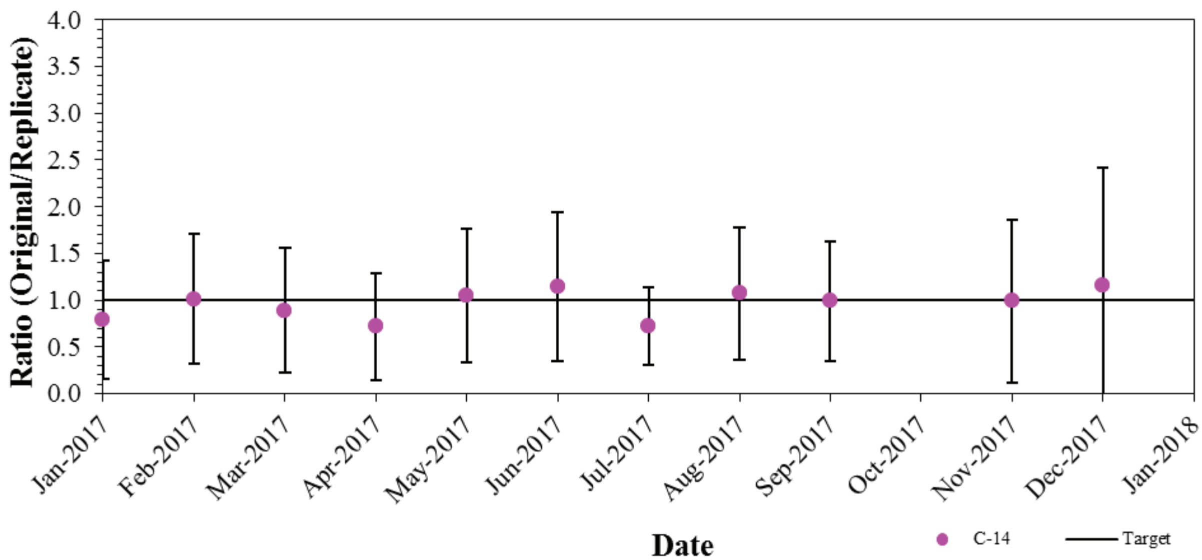


Figure 7.04: Carbon-14 Performance (Internal QA – duplicate/replicate)

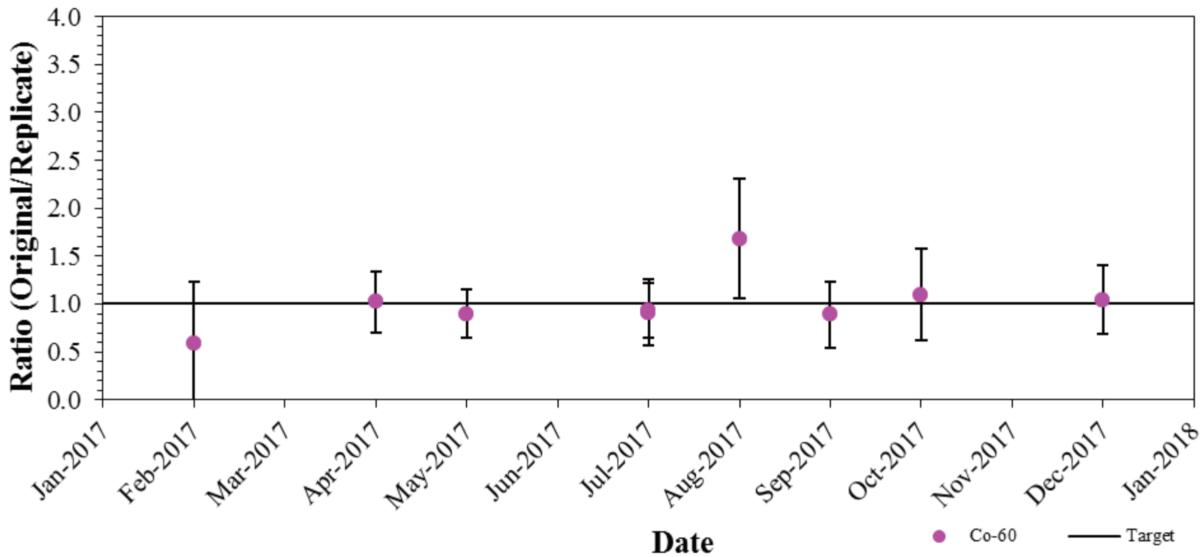


Figure 7.05: Cobalt-60 Performance (Internal QA – duplicate/replicate)

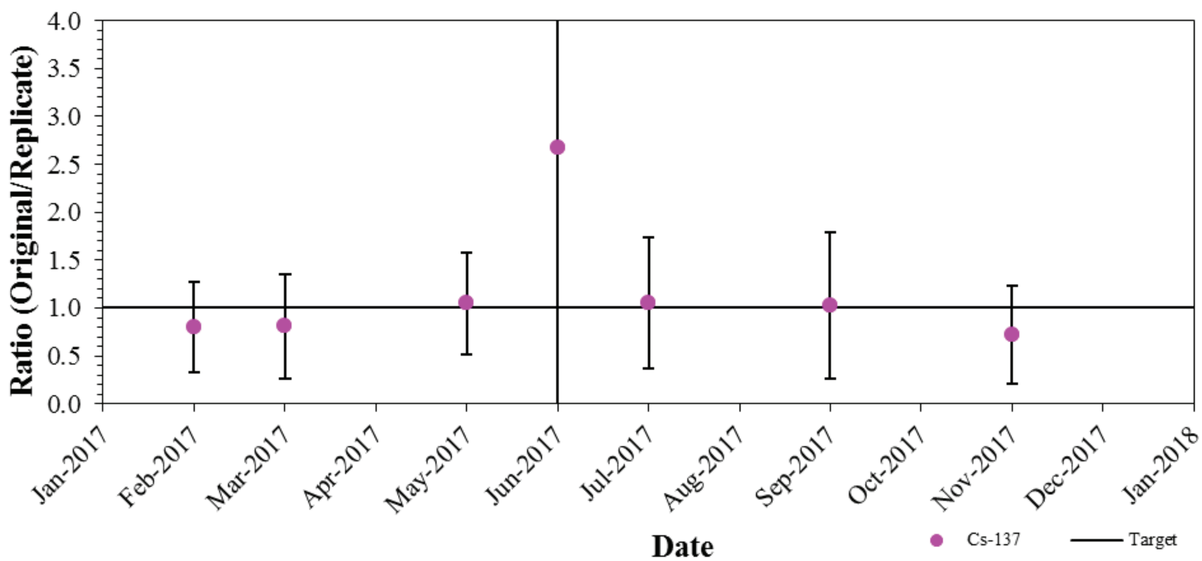


Figure 7.06: Cesium-137 Performance (Internal QA – duplicate/replicate)

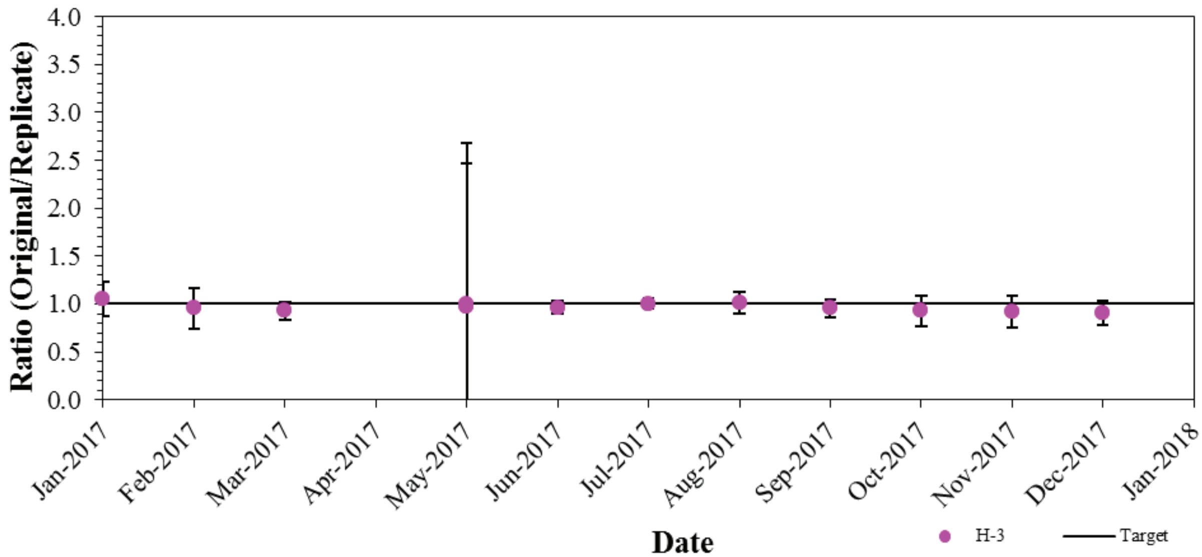


Figure 7.07: Tritium Performance (Internal QA – duplicate/replicate)

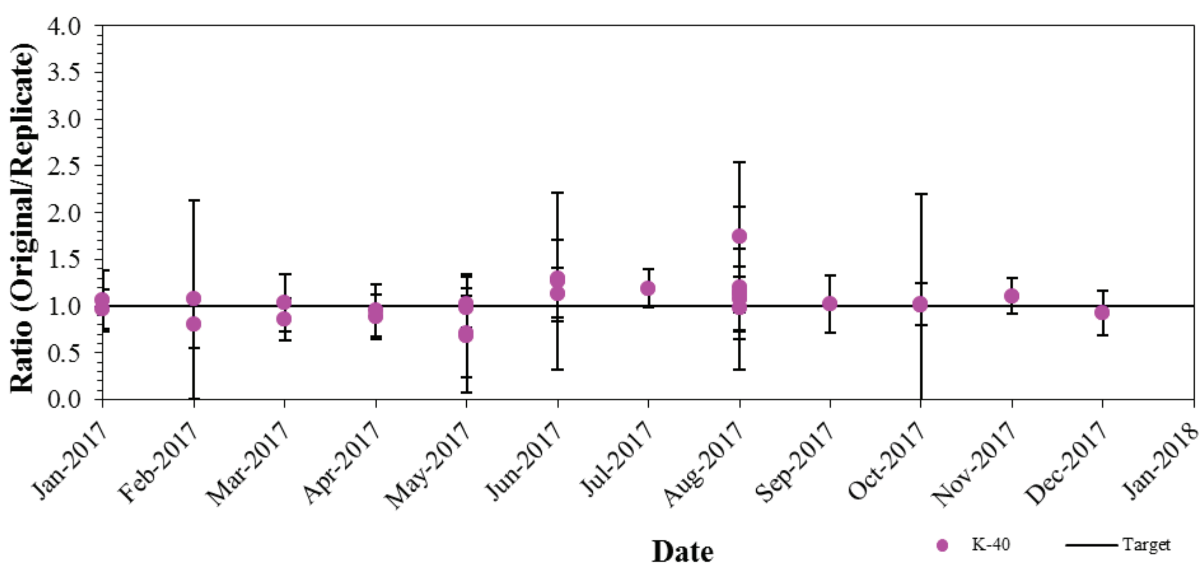


Figure 7.08: Potassium-40 Performance (Internal QA – duplicate/replicate)

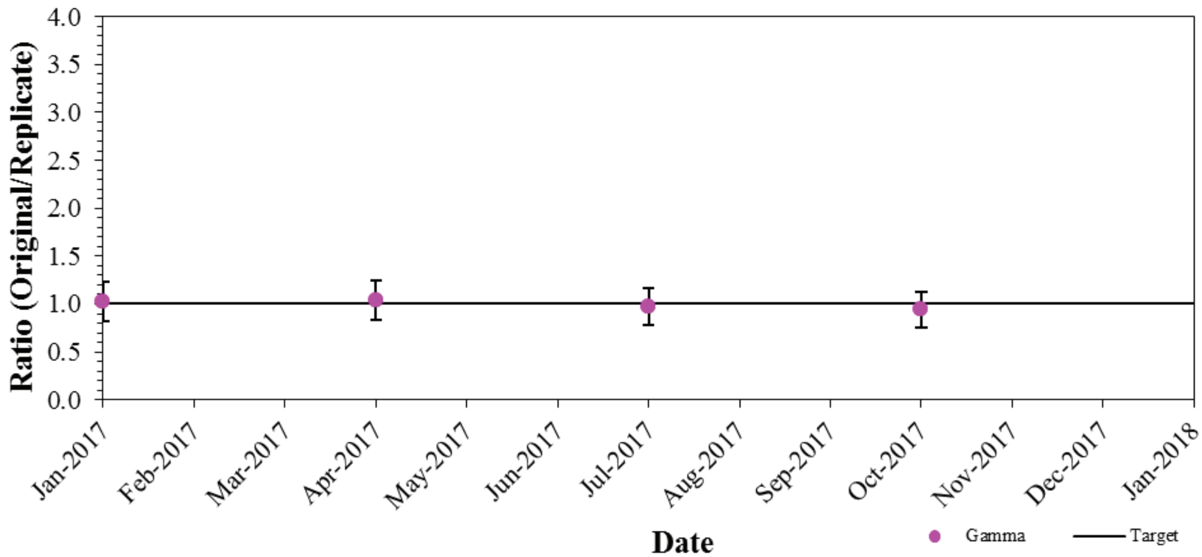


Figure 7.09: Gamma Performance (Internal QA – duplicate/replicate)

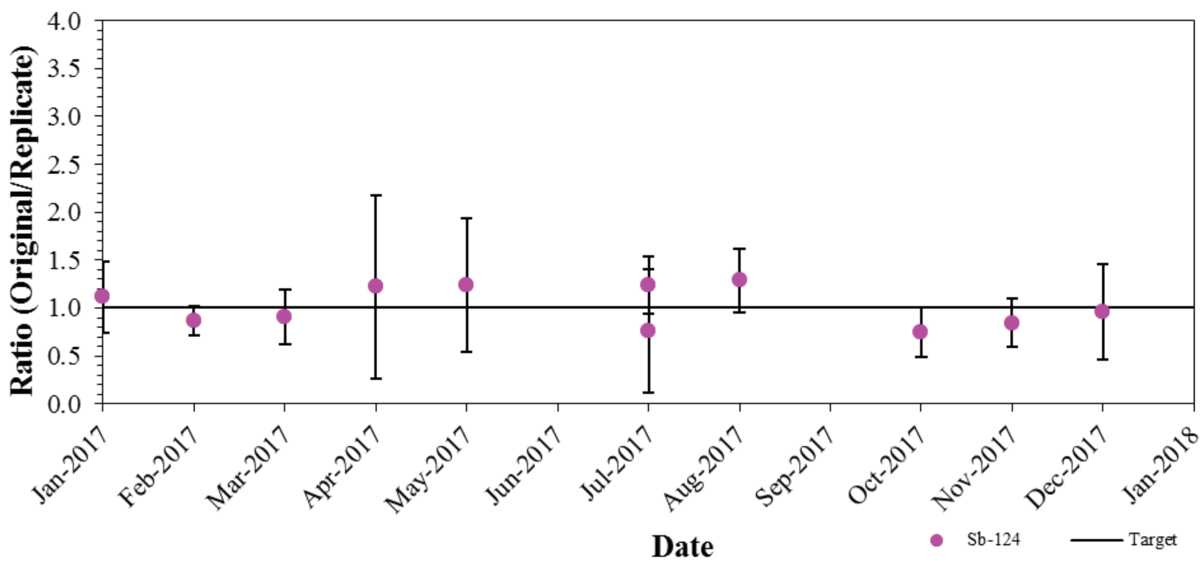


Figure 7.10: Sb-124 Performance (Internal QA – duplicate/replicate)

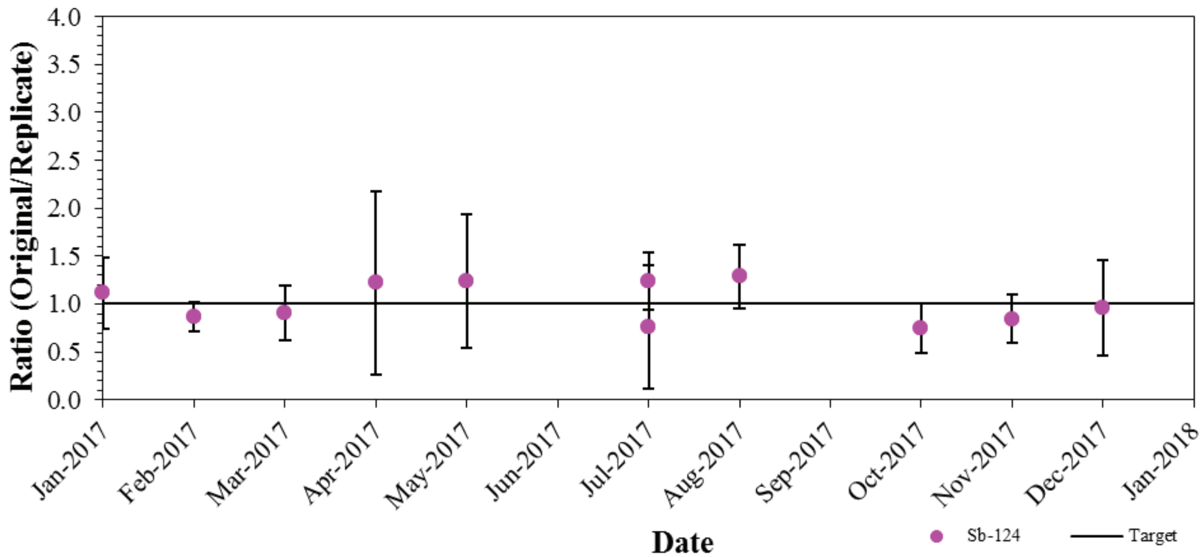


Figure 7.11: Strontium-90 Performance (Internal QA – duplicate/replicate)

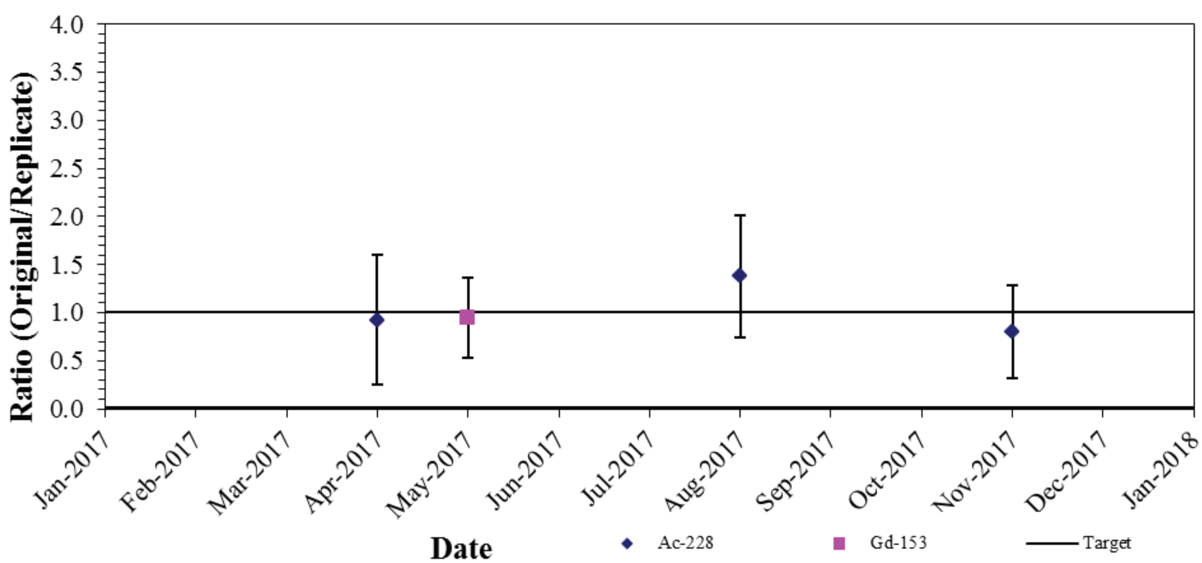


Figure 7.12: Gadolinium-153 and Ac-228 Performance (Internal QA – duplicate/replicate)

Samples that are spiked by laboratory personnel play a minor role in the QA program. It is more desirable to purchase QA samples from an accredited QA laboratory. The only exception is the irradiation of environmental TLDs. Lab staff irradiate the TLDs which are subsequentially analyzed. Results of performance with these samples give an indication of the quality of measurements. Acceptable performance is defined as results within ± 15% of the expected value.

The four separate tests were successful (five TLDs for each test). The results are presented in Figure 7.13.

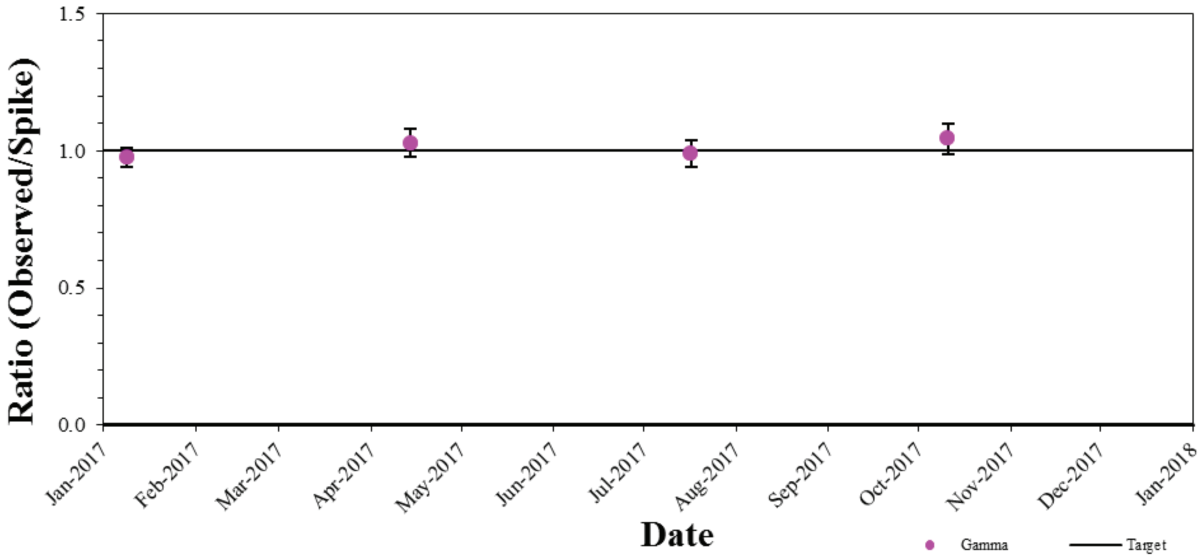


Figure 7.13: Gamma Performance (Internal QA - spikes)

7.04 Program Audit

The REMP audit frequency was changed to once every five years to align with the Canadian Standards Association (CSA) standard. The Nuclear Oversight Group (NOS) at PLNGS is the principal auditor, although other groups from within NB Power, the CNSC, or other utilities may be used.

As part of its overall Management System, Point Lepreau has an Environmental Management System (EMS) in place that is registered to ISO 14001. Radiological releases to water and air are part of this system. There were two audits relating to the EMS during 2017.

7.05 Annual Review

The Radiation Environmental Monitoring Program (REMP) was aligned to the 2010 CSA standard *N288.4-10, Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills* in 2017. The new Environmental Monitoring Program was implemented January 1, 2018.

8 Non-Radiological Monitoring and Reporting

8.01 Ozone Depleting Substance

In Canada, the federal government has legislation in place for the protection of the ozone layer and management of ozone-depleting substances and their halocarbon alternatives. The use and handling of these substances are regulated through the Federal Halocarbon Regulation, 2003 for refrigeration, air-conditioning, fire extinguishing, and solvent systems under federal jurisdiction. Point Lepreau Nuclear Generating Station is governed by the federal regulations.

In 2017, there were no releases that required reporting to Environment Canada.

Letters submitted to Environment Canada are sent to the CNSC staff as per *Guidance* in REGDOC 3.1.1 *Section 3.5*.

8.02 Domestic Waste Water Treatment (Sewage) (Approval to Operate S-2696)

The domestic waste water is regulated by the provinces and territories in their jurisdictions, and through the Federal Wastewater System Effluent Regulations. Point Lepreau Nuclear Generating Station is governed federally and administered provincially.

At Point Lepreau Nuclear Generating Station, an electronic report via Effluent Regulation Reporting Information System (ERRIS) is completed. The electronic submission frequency is determined on daily discharge flow of the facility. PLNGS electronic report was completed January 15th, 2018. Based on the 2017 daily discharge flow, it was required to be completed electronically once during the year, at the end of the calendar year. Also, a letter is submitted to New Brunswick Department of Environment and Local Government describing any discharge to an Overflow Points and Environmental Emergency that occurred during the year. This was submitted on January 31st, 2018. The letter is required to be submitted within 45 days of the end of each year. This letter was submitted to the CNSC staff as per *Guidance* in REGDOC 3.1.1 *Section 3.5*.

The approval required to sample (grab or composite) on a quarterly basis but at least 60 days after any other samples. PLNGS collects and analyzes the effluent on a weekly basis to verify the performance of the facility.

The sample collection and analysis is performed by Saint John Laboratory Services Ltd. They are accredited to Canadian Association for Laboratory Accreditation Inc. (CALA).

Table 8.01: Electronic Data Submission to ERRIS

Owner	New Brunswick Power Corporation
Wastewater System:	Point Lepreau Generating Station
Approval State:	Approved
Reporting year:	2017 — **Reporting Period**: January to December
System Type:	Continuous — **Average Daily Effluent Volume (m^3):** 121.6
Reporting Frequency:	Annually — **Averaging Period:** Annually

Effluent Monitoring Data

Month	Effluent Deposited?
January	Yes
February	Yes
March	Yes
April	Yes
May	Yes
June	Yes
July	Yes
August	Yes
September	Yes
October	Yes
November	Yes
December	Yes

Number of days that effluent was deposited	Total volume of effluent deposited (m^3)	Average CBOD (mg/L) Limit: 25 mg/L	Average concentration of suspended solids(mg/L) Limit: 25 mg/L
365	44918.0	1.3	1.6

Acute Lethality Test Results

Does your waste water system have Acute Lethality test sample (s) to report in this reporting period? **(Required)** No

8.03 Waste Water Compliance (Approval to Operate I-9693)

The wastewater compliance reports for PLNGS are submitted to New Brunswick Department of Environment and Local Government, based on the reporting Conditions of the Approval to Operate, as follows:

The operation of the Industrial Wastewater Treatment System at PLNGS has an Approval to Operate (#I-9693) issued under the Water Quality Regulation – Clean Environment Act. It is valid from March 17, 2017 until April 30, 2021. Condition 44 states that "Within 60 days of the end of each year, The Approval Holder shall submit an Annual Environmental Report to the Department."

Samples are collected and analyzed daily for pH, suspended solids and hydrazine. From the daily samples, a monthly composite is prepared and analyzed for heavy metals (arsenic, barium, cadmium, chromium, copper, iron, lead, mercury, nickel, vanadium and zinc) and Total Petroleum Hydrocarbons (TPH).

The daily sample analysis is performed by the Chemistry Department using procedures:
- CAP-78200-PH1; *pH Measurement by Glass Combination Electrode*
- CLIP-78200-74; *Accumet Excel Model 25 pH/Millivolt Meter*
- CAP-78200-SU2; *Suspended Solid*
- CAP-78200-HY1; *Hydrazine by P-Dimethylaminobenzaldehyde*
- CLIP-78200-22; *Varian Cary 50 UV/VIS Spectrometer*
- CMP-78200-03; *Varian UV/VIS Spectrometer Model Cary*

The heavy metals and the TPH analysis are performed by Saint John Laboratory Services Ltd. They are accredited to Canadian Association for Laboratory Accreditation Inc. (CALA).

The annual report is sent to the CNSC staff as required by *Section 3.5* of CNSC *REGDOC 3.1.1, Reporting Requirements for Nuclear Power Plants*.

8.04 Air Emission (NPRI)

Site conventional air emissions are controlled to meet regulatory requirements, prevent pollution, reduce emissions, and to minimize environmental impacts.

Point Lepreau Nuclear Generating Station no longer requires an air quality approval to operate the Auxiliary Volcano Boiler and Diesel Generators. The fuel consumption and emissions for 2017 were tracked and calculated for possible reporting purposes to the National Pollutant Release Inventory (NPRI) should emissions meet reporting thresholds. We do not need to report the emissions to the Department of Environment and Local Government.

During the year 155 bbls (24 645 liters) (dramatically different from 1915 bbls, 304485 L last year) of Type 2 Light Oil and 2287 barrels (363 633 liters) of Type B Diesel Fuel were consumed at the station. The preliminary analysis indicate the light fuel oil had an average energy content of 5.74 million BTUs per barrel, an average ash content of 0.0003 percent, and an average sulphur content of 0.0342 percent. The preliminary analysis indicate the diesel fuel oil had an average energy content of 5.58 million BTUs per barrel, an average ash content of 0.0005 percent, and an average sulphur content of 0.0013 percent. Fuel analysis results are obtained from the AmSpec Services analysis results sent to the Chemistry Department at PLNGS while fuel consumption figures are provided by the NB Power Fuels Group.

During the year the annual emissions were calculated and are shown in Table 8.02.

Table 8.02: Annual Emissions (2017)

Parameter	Tonnes
Carbon Dioxide	1146
Sulphur Dioxide	0.02
Nitrogen Dioxide	3.10
Particulate Matter	0.16

8.05 Chlorine

There is currently no chlorine disinfection on site at the Point Lepreau Nuclear Generating Station. There is a sodium hypochlorite system utilized during maintenance of specific sections of the domestic waste water works.

8.06 Ammonia

There is currently no requirement to measure ammonia in the effluent at Point Lepreau Nuclear Generating Station.

8.07 Hydrazine

Hydrazine is reported with the Inactive Waste Water approval to Operate I-9693. Samples are collected and analyzed daily at the lagoon discharge, and the Ditch.

8.08 EMS Program Audit

The Point Lepreau Nuclear Generating Station has been successfully upgraded from the ISO 14001:2004 standard to the ISO 14001:2015 standard. The certification cycle is a period of three years; therefore the next registration will be 2019. During the audit, the auditor identified two (2) minor nonconformities with ten (10) opportunities for improvement and one (1) observation.

All findings were minor in nature and are being tracked through PLNGS's internal Corrective Action Program.

8.09 Self-Assessments

In 2017, the environmental group performed one self-assessment for environment on the BSI Pre audit on upgrade to ISO14001:2015 standard. The proposed actions were documented as part of continuous improvement.

9 Reports and Studies

A gap analysis for alignment to the *CSA Standard N288.4-10, Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills* was conducted in 2012. Implementation plans were made in 2013. Alignment to the Canadian Standards Association (CSA) standards *N288.4-10, Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills* and *N288.5-11, Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills* was progressed in 2017. The following were completed or updated in 2017:

- *PRR-00660-SU-2 Provide Environmental Services*
- *SI-01365-P101 Developing and Maintaining the Environmental Management System*
- *SI-01365-P108 Developing and Implementing the Environmental Monitoring Program*
- *IR-07600-01 Environmental Monitoring Program*
- *IR-07600-03 Environmental Monitoring Plan*
- *PRR-00660-OP-3 Control Effluents*
- *SI-01365-P107 Establishing and Implementing the Effluent Monitoring Program*
- *SDP-01368-P077 Monitor and Control Effluents*

Canadian Nuclear Laboratories (CNL) continued their work to assist the station to close the gaps and implement the standards for PLNGS. The newly aligned program was implemented January 1, 2018.

Appendix A: Statistics, Detection Limits, and Dose at Detection Limits

A1 Statistics

The following statistical conventions are applied in the analysis of each sample:

- Detection limits are defined following the method described by Lochamy in *NBS Special Publication 456, Measurements for the Safe Use of Radiation (US Department of Commerce, 1976).* The lower limit of detection (LLD) at the 99% confidence level is defined as 6.58 S_b, where S_b is the standard deviation of the appropriate radiation background measurement. This LLD corresponds to that amount of activity in a sample that will yield a net count greater than 3.29 S_b, or the so-called critical level (CL), with 99% probability. Thus, the LLD specifies the theoretical capability of the system to detect a given amount of radioactivity, whereas the CL is used to determine whether an actual activity measurement should be considered detected. Any net measurement greater than 3.29 S_b is considered detected at the 99% confidence level. This also implies a one percent probability of stating that activity is present when it is not (false positive). If activity is present at the LLD level (6.58 S_b), there is a one percent probability of stating that activity is not present when it is (false negative).

- The CL of 3.29 S_b and LLD of 6.58 S_b apply in those analytical systems where the background levels are either not well defined, or where there is a relationship between the background levels and the detected signal above background, as in Ge gamma spectroscopy. Where the background readings are well defined and are independent of sample readings, as in the TLD data, the CL is 2.33 S_b and the LLD is 4.66 S_b.

- In most of the tables of data (*Section 4.0*), it is this Critical Level that appears in column 2.

- Unless otherwise indicated, the precision of the measurements reported here is given as $\pm$ 1.96 S_a (95% confidence level), where S_a is the standard deviation of the activity measurement.

- The value and standard deviation are reported with two significant figures using modified scientific notation, for example 0.032 is expressed as 3.2E-02.

The lower limits of detection (LLD) of all radionuclides in the various sample media are shown in Tables A.01 to A.11. The Annual Dose is to the Representative Person. The LLDs are based on typical data. Decay of radionuclides is accounted for in the LLD calculations except for H-3 and C-14 (long half-lives). The major assumptions are that the sample is taken at one kilometre from the point of releases and that the level is maintained for the year. Milk is assumed to be from a cow pastured at 1.5 km, fish and lobster are caught at the Condenser Cooling Water (CCW) outlet and sediment, dulse, seawater and clams are collected at Dipper Harbour.

The CSA recommends, where technically feasible, that all measurements achieve LLDs less than that which would result in a dose of 5 µSv to the Representative Person. Most radionuclides pass this criterion. The major exceptions are noble gases. Detection of this group is through TLD measurements (20 μSv dose to the Representative Person at the LLD). However, the noble gas spectrometer on the GEM allows for a much smaller LLD calculation. Other exceptions are Ba-140 in soil, food, water and sediment (5 to 39 μSv); Ru-106 in water, food and seafood (6 to 22 μSv); Ce-144 in water and food (6 to 17 μSv); La-140 in sediment and soil (12 to 15 μSv); Zr-95 in sediment (5 μSv); I-131 in food, water, sediment and seafood (8 to 15 μSv) and 5 to 11 μSv in water (Co-60, Cs-134, Zn-65 and Cs-137). Effluent analyses show these radionuclides are not major components of releases. Part of the QA process identifies those LLDs or activities that do not meet this target.

A1.01 Air

A1.01.01 Airborne Particulates

Typical LLDs are given for a 2400 m^3 sample that is counted for 5000 s. The LLDs are decay corrected to the midpoint between the start and end of sampling, except for the gross alpha/beta results which represent the long-lived activity present a few days after sample collection. Gross alpha/beta is for trending only.

A1.01.02 Airborne Radioiodines

A typical LLD for I-131 is approximately 9E-05 $Bq \cdot m^{-3}$ (for a 2400 m^3 sample, counted for 50 000 s), which is decay corrected to the midpoint between the start and end of sampling.

A1.01.03 Airborne Tritium

The LLD is approximately 1E-01 $Bq \cdot m^{-3}$ of air for a typical sample of 10 to 70 m^3 (counted for 100 min). Due to the long half-life and relatively short period of time between sampling and analysis, decay correction is not applied.

A1.01.04 Airborne Carbon-14

A typical LLD is approximately 4E-02 $Bq \cdot m^{-3}$ of air for a 30 m^3 sample (counted for 100 min). Due to the long half-life and relatively short period of time between sampling and analysis, decay correction is not applied.

A1.01.05 TLD

The LLD is about 20 μSv. For typical quarterly measurements in the region of 150-200 μSv, measurements can be made to ± 10% at the 95% confidence level.

Table A.01 Annual Dose at the LLD for Air

Nuclide	*LLD ($Bq \cdot m^{-3}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq \cdot m^{-3}$)*
H-3	9.6E-02	4.8E-02	9.9E+00
C-14	4.0E-02	1.9E+00	1.0E-01
Cr-51	5.8E-04	3.2E-03	9.2E-01
Mn-54	7.8E-05	9.2E-02	4.3E-03
Fe-59	1.7E-04	6.1E-02	1.4E-02
Co-58	8.0E-05	3.5E-02	1.2E-02
Co-60	8.2E-05	1.7E+00	2.4E-04
Zn-65	1.9E-04	3.3E-01	2.9E-03
Kr-85	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Kr-85m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Kr-87	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Kr-88	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Zr-95	1.3E-04	1.1E-01	6.2E-03
Nb-95	9.4E-05	9.9E-02	4.7E-03
Ru-103	7.4E-05	8.1E-03	4.5E-02
Ru-106	6.0E-04	1.0E+00	2.9E-03
Ag-110m	6.2E-05	2.2E-01	1.4E-03
I-131	8.4E-05	1.6E-01	2.5E-03
Xe-131m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-133	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-133m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-135	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-135m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-138	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Cs-134	6.4E-05	4.3E-01	7.4E-04
Cs-137	6.6E-05	1.6E+00	2.0E-04
Ba-140	4.8E-04	8.9E-02	2.7E-02
La-140	2.0E-04	2.5E-03	4.1E-01
Ce-141	7.6E-05	4.8E-03	7.9E-02
Ce-144	2.2E-04	2.7E-01	4.0E-03

A1.02 Milk

The LLDs in Table A.02 apply to the midpoint between the start and end of sampling for a 3.6 L sample counted for 50 000 s for gamma and a 6 mL sampled counted for 100 min for tritium.

Table A.02 Annual Dose at the LLD for Milk

Nuclide	*LLD ($Bq·L^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq·L^{-1}$)*
H-3	2.4E+01	3.1E-01	3.9E+02
Cr-51	6.4E-01	1.0E-02	3.1E+02
Mn-54	9.2E-02	1.9E-02	2.5E+01
Fe-59	2.2E-01	2.2E-01	5.1E+00
Co-58	9.0E-02	7.5E-02	6.0E+00
Co-60	1.1E-01	9.0E-01	6.1E-01
Zn-65	2.4E-01	5.3E-01	2.3E+00
Zr-95	1.6E-01	4.3E-02	1.8E+01
Nb-95	9.2E-02	1.2E-01	3.8E+00
Ru-103	8.4E-02	1.9E-02	2.2E+01
Ru-106	7.8E-01	2.7E+00	1.4E+00
Ag-110m	8.2E-02	5.5E-02	7.4E+00
I-131	9.4E-02	1.8E+00	2.6E-01
Cs-134	7.8E-02	3.1E-01	1.3E+00
Cs-137	9.8E-02	3.1E-01	1.6E+00
Ba-140	3.4E-01	2.1E-01	8.1E+00
La-140	1.1E-01	8.9E-02	6.1E+00
Ce-141	1.2E-01	3.0E-02	2.1E+01
Ce-144	5.0E-01	9.5E-01	2.6E+00

A1.03 Water

The LLDs in Table A.03 apply to the midpoint between the start and end of sampling for a 3.6 L sample counted for 5000 s for gamma and a 6 mL sampled counted for 100 min for tritium. Alpha/beta results (a 100-500 mL sample counted for 100 min) represent the long-lived activity present several days after sample collection.

The LLDs are based on typical data for precipitation water. Since decay of radionuclides is accounted for in the LLD calculations, well water and other water sample types will have lower LLDs. The major assumptions are that the sample is taken at one kilometre from the point of releases, that the level is maintained for the year and the sample type is the major source of drinking water. Obviously, this is not the case but it gives a simple "worst case" that is easy to monitor and calculate.

Table A.03 Annual Dose at the LLD for Water

Nuclide	*LLD ($Bq \cdot L^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq \cdot L^{-1}$)*
H-3	2.4E+01	3.4E-01	3.6E+02
Cr-51	5.4E+01	7.4E-02	3.7E+03
Mn-54	5.0E-01	1.7E-01	1.4E+01
Fe-59	1.3E+00	9.1E-01	7.1E+00
Co-58	5.6E-01	3.7E-01	7.5E+00
Co-60	4.6E-01	4.5E+00	5.1E-01
Zn-65	1.1E+00	2.3E+00	2.4E+00
Zr-95	9.8E-01	4.0E-01	1.2E+01
Nb-95	6.8E-01	4.0E-01	8.5E+00
Ru-103	6.4E-01	1.8E-01	1.8E+01
Ru-106	4.6E+00	1.7E+01	1.4E+00
Ag-110m	4.6E-01	6.2E-01	3.7E+00
I-131	2.4E+00	3.9E+00	3.1E+00
Cs-134	4.4E-01	4.8E+00	4.6E-01
Cs-137	5.2E-01	3.9E+00	6.6E-01
Ba-140	5.4E+00	2.7E+00	1.0E+01
La-140	2.2E+00	9.1E-01	1.2E+01
Ce-141	8.4E-01	3.4E-01	1.2E+01
Ce-144	2.4E+00	1.1E+01	1.1E+00

A1.04 Food

The LLDs in Table A.04 apply to the time of sample collection. Samples vary in size and are counted for 5000 s. The LLDs are based on typical data for garden vegetables.

Table A.04 Annual Dose at the LLD for Food

Nuclide	*LLD ($Bq \cdot kg^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq \cdot kg^{-1}$)*
Cr-51	3.0E+01	5.9E-02	2.5E+03
Mn-54	3.4E+00	1.3E-01	1.3E+02
Fe-59	7.8E+00	8.4E-01	4.6E+01
Co-58	3.6E+00	3.0E-01	6.0E+01
Co-60	3.8E+00	3.9E+00	4.9E+00
Zn-65	9.0E+00	2.2E+00	2.1E+01
Zr-95	6.2E+00	3.3E-01	9.4E+01
Nb-95	4.0E+00	3.6E-01	5.6E+01
Ru-103	3.8E+00	1.7E-01	1.1E+02
Ru-106	3.0E+01	1.3E+01	1.1E+01
Ag-110m	3.0E+00	4.7E-01	3.2E+01
I-131	1.0E+01	6.9E+00	7.6E+00
Cs-134	3.0E+00	3.6E+00	4.2E+00
Cs-137	3.4E+00	2.9E+00	6.0E+00
Ba-140	2.4E+01	3.5E+00	3.5E+01
La-140	9.4E+00	1.2E+00	4.0E+01
Ce-141	4.2E+00	1.9E-01	1.1E+02
Ce-144	1.4E+01	4.9E+00	1.4E+01

A**1.05 Soil**

The LLDs in Table A.05 apply to the time of sample collection. Samples of approximately 200 g are counted for 5000 s.

Table A.05 Annual Dose at the LLD for Soil

Nuclide	*LLD ($Bq \cdot kg^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq \cdot kg^{-1}$)*
Cr-51	4.0E+01	2.5E-01	7.9E+02
Mn-54	5.8E+00	1.2E+00	2.5E+01
Fe-59	1.2E+01	3.1E+00	1.9E+01
Co-58	5.0E+00	1.1E+00	2.2E+01
Co-60	5.8E+00	3.2E+00	9.1E+00
Zn-65	1.3E+01	1.7E+00	3.9E+01
Zr-95	1.0E+01	5.1E+00	9.9E+00
Nb-95	6.0E+00	9.9E-01	3.0E+01
Ru-103	4.8E+00	5.1E-01	4.7E+01
Ru-106	4.6E+01	1.9E+00	1.2E+02
Ag-110m	5.2E+00	2.7E+00	9.7E+00
I-131	6.8E+00	5.2E-01	6.6E+01
Cs-134	5.2E+00	1.5E+00	1.7E+01
Cs-137	5.6E+00	7.1E-01	3.9E+01
Ba-140	2.2E+01	1.1E+01	9.6E+00
La-140	7.2E+00	*	*
Ce-141	6.8E+00	1.2E-01	2.8E+02
Ce-144	2.4E+01	2.9E-01	4.2E+02
TLD	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
*Dose for Ba-140 assumes equilibrium with La-140 (contribution from both)			

A1.06 Seawater

The LLDs in Table A.06 apply to the time of sample collection for a 3.6 L sample counted for 5000 s for gamma; and a 6 mL sampled counted for 100 min for tritium. The dose is small due to the simple facts that the frigid waters of the Bay of Fundy discourage immersion and salt water is not consumable.

Table A.06 Annual Dose at the LLD for Seawater

Nuclide	*LLD ($Bq \cdot L^{-1}$)*	*Dose at LLD (μSv)*	*Concentration That Gives 5 μSv ($Bq \cdot L^{-1}$)*
H-3	2.4E+01	9.2E-11	1.3E+12
Cr-51	2.2E+00	2.6E-10	4.3E+10
Mn-54	2.8E-01	7.9E-10	1.8E+09
Fe-59	6.2E-01	2.6E-09	1.2E+09
Co-58	2.8E-01	9.1E-10	1.5E+09
Co-60	3.2E-01	2.4E-09	6.8E+08
Zn-65	6.8E-01	1.3E-09	2.6E+09
Zr-95	5.2E-01	1.2E-09	2.2E+09
Nb-95	3.0E-01	9.3E-10	1.6E+09
Ru-103	2.8E-01	4.4E-10	3.2E+09
Ru-106	2.6E+00	1.6E-09	8.3E+09
Ag-110m	2.6E-01	2.3E-09	5.7E+08
I-131	3.6E-01	2.3E-09	8.0E+08
Cs-134	2.6E-01	1.3E-09	1.0E+09
Cs-137	3.0E-01	5.2E-10	2.9E+09
Ba-140	1.2E+00	2.6E-08	2.4E+08
La-140	4.6E-01	*	*
Ce-141	4.0E-01	1.1E-10	1.8E+10
Ce-144	1.6E+00	2.7E-10	3.0E+10
* Dose for Ba-140 assumes equilibrium with La-140 (contribution from both)			

A1.07 Clams

Typical LLDs are given in Table A.07 for the edible portions of clams, decay corrected to the time of sample collection. Samples of varying size are counted for 5000 s. The major assumptions are that the sample is taken at Dipper Harbour and that the level is maintained for the year.

Table A.07 Annual Dose at the LLD for Clams

Nuclide	*LLD ($Bq \cdot kg^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq \cdot kg^{-1}$)*
Cr-51	5.0E+01	2.0E-02	1.3E+04
Mn-54	7.0E+00	6.5E-02	5.4E+02
Fe-59	1.4E+01	3.1E-01	2.3E+02
Co-58	7.2E+00	1.3E-01	2.7E+02
Co-60	6.4E+00	1.8E+00	1.8E+01
Zn-65	1.4E+01	8.8E-01	7.8E+01
Zr-95	1.2E+01	1.5E-01	3.7E+02
Nb-95	6.6E+00	1.4E-01	2.3E+02
Ru-103	6.0E+00	5.5E-02	5.5E+02
Ru-106	5.8E+01	6.5E+00	4.5E+01
Ag-110m	5.8E+00	2.2E-01	1.3E+02
I-131	7.2E+00	9.5E-01	3.8E+01
Cs-134	6.6E+00	1.6E+00	2.1E+01
Cs-137	6.8E+00	1.5E+00	2.2E+01
Ba-140	2.4E+01	7.7E-01	1.6E+02
La-140	9.4E+00	2.2E-01	2.1E+02
Ce-141	7.4E+00	8.0E-02	4.6E+02
Ce-144	3.2E+01	2.6E+00	6.3E+01

A1.08 Fish

Typical LLDs are given in Table A.08 for the edible portions of fish, decay corrected to the time of sample collection. Samples of varying size are counted for 5000 s.

Table A.08 Annual Dose at the LLD for Fish

Nuclide	*LLD ($Bq·kg^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq·kg^{-1}$)*
Cr-51	1.3E+01	1.6E-02	4.0E+03
Mn-54	1.5E+00	5.1E-02	1.5E+02
Fe-59	3.8E+00	2.8E-01	6.8E+01
Co-58	1.5E+00	9.2E-02	8.0E+01
Co-60	1.4E+00	1.3E+00	5.4E+00
Zn-65	3.0E+00	7.0E-01	2.2E+01
Zr-95	2.2E+00	1.1E-01	1.0E+02
Nb-95	1.4E+00	1.1E-01	6.6E+01
Ru-103	1.5E+00	4.9E-02	1.5E+02
Ru-106	1.1E+01	4.4E+00	1.2E+01
Ag-110m	1.2E+00	1.7E-01	3.5E+01
I-131	7.8E+00	1.3E+00	3.1E+01
Cs-134	1.0E+00	1.2E+00	4.5E+00
Cs-137	1.4E+00	1.0E+00	7.1E+00
Ba-140	1.0E+01	7.8E-01	6.4E+01
La-140	4.6E+00	2.4E-01	9.6E+01
Ce-141	1.8E+00	6.0E-02	1.5E+02
Ce-144	5.8E+00	1.6E+00	1.8E+01

A1.09 Lobster

Typical LLDs are given in Table A.09 for the edible portions of lobster, decay corrected to the time of sample collection. Samples of varying size are counted for 5000 s.

Table A.09 Annual Dose at the LLD for Lobster

Nuclide	*LLD ($Bq \cdot kg^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq \cdot kg^{-1}$)*
Cr-51	3.0E+01	1.3E-02	1.2E+04
Mn-54	2.8E+00	2.1E-02	6.7E+02
Fe-59	9.0E+00	1.5E-01	2.9E+02
Co-58	3.2E+00	6.7E-02	2.4E+02
Co-60	3.8E+00	5.4E-01	3.5E+01
Zn-65	7.8E+00	3.4E-01	1.2E+02
Zr-95	5.4E+00	6.8E-02	4.0E+02
Nb-95	4.4E+00	9.0E-02	2.4E+02
Ru-103	4.0E+00	3.1E-02	6.4E+02
Ru-106	3.0E+01	2.4E+00	6.3E+01
Ag-110m	3.4E+00	8.8E-02	1.9E+02
I-131	1.7E+01	3.3E+00	2.6E+01
Cs-134	2.8E+00	6.4E-01	2.2E+01
Cs-137	3.4E+00	4.5E-01	3.8E+01
Ba-140	3.4E+01	1.2E+00	1.4E+02
La-140	1.2E+01	4.2E-01	1.4E+02
Ce-141	4.4E+00	4.3E-02	5.1E+02
Ce-144	1.3E+01	8.7E-01	7.4E+01

A1.10 Dulse

Typical LLDs are given in Table A.10 for dulse, decay corrected to the time of sample collection. Samples of varying size are counted for 5000 s. The major assumptions are that the sample is taken at Dipper Harbour and that the level is maintained for the year.

Table A.10 Annual Dose at the LLD for Dulse

Nuclide	*LLD (Bq·kg^{-1})*	*Dose at LLD (μSv)*	*Concentration That Gives 5 μSv (Bq·kg^{-1})*
Cr-51	2.0E+01	2.4E-03	4.2E+04
Mn-54	3.4E+00	7.4E-03	2.3E+03
Fe-59	8.0E+00	4.4E-02	9.0E+02
Co-58	3.4E+00	1.5E-02	1.1E+03
Co-60	3.4E+00	2.1E-01	7.9E+01
Zn-65	8.2E+00	1.1E-01	3.9E+02
Zr-95	6.6E+00	1.6E-02	2.1E+03
Nb-95	3.6E+00	1.9E-02	9.5E+02
Ru-103	2.8E+00	7.1E-03	2.0E+03
Ru-106	2.6E+01	6.7E-01	2.0E+02
Ag-110m	3.0E+00	2.3E-02	6.4E+02
I-131	5.4E+00	3.0E-01	9.1E+01
Cs-134	2.8E+00	1.9E-01	7.3E+01
Cs-137	3.2E+00	1.3E-01	1.2E+02
Ba-140	1.6E+01	1.6E-01	4.9E+02
La-140	5.4E+00	2.8E-02	9.7E+02
Ce-141	3.4E+00	8.8E-03	1.9E+03
Ce-144	1.4E+01	2.4E-01	2.9E+02

A1.11 Sediment

The LLDs in Table A.11 apply to the time of sample collection. Samples weighing approximately 200 g are counted for 5000 s. The major assumptions are that the sample is taken at Dipper Harbour and that the level is maintained for the year.

Table A.11 Annual Dose at the LLD for Sediment

Nuclide	*LLD ($Bq \cdot kg^{-1}$)*	*Dose at LLD (µSv)*	*Concentration That Gives 5 µSv ($Bq \cdot kg^{-1}$)*
Cr-51	1.7E+01	2.1E-01	4.2E+02
Mn-54	2.8E+00	7.9E-01	1.8E+01
Fe-59	6.2E+00	2.3E+00	1.3E+01
Co-58	2.6E+00	8.4E-01	1.5E+01
Co-60	2.8E+00	2.3E+00	6.1E+00
Zn-65	6.8E+00	1.3E+00	2.7E+01
Zr-95	4.8E+00	3.9E+00	6.1E+00
Nb-95	3.0E+00	7.2E-01	2.1E+01
Ru-103	2.4E+00	3.9E-01	3.1E+01
Ru-106	2.0E+01	1.5E+00	6.6E+01
Ag-110m	2.2E+00	2.1E+00	5.3E+00
I-131	3.4E+00	4.7E-01	3.6E+01
Cs-134	2.0E+00	1.2E+00	8.7E+00
Cs-137	2.8E+00	6.2E-01	2.3E+01
Ba-140	1.2E+01	1.0E+01	5.8E+00
La-140	3.8E+00	*	*
Ce-141	3.0E+00	8.9E-02	1.7E+02
Ce-144	1.1E+01	2.1E-01	2.7E+02
gamma meter	0.01 $\mu Sv \cdot h^{-1}$	3.0E+00	1.7E-02
* Dose for Ba-140 assumes equilibrium with La-140 (contribution from both)			

Appendix B: Sample Collection and Analytical Techniques

B1 Analytical Techniques

All environmental samples are analysed at the Health Physics Fredericton Laboratory. The following pages provide a general summary of the analytical techniques used in the laboratory. Sample collection, preparation and analysis are briefly described, but can be found in detail in the laboratory procedures.

The major analytical techniques and the instruments used in routine environmental analyses are summarised in the Table B.01.

Table B.01 Summary of Analytical Techniques

Analytical Technique	Instrumentation
Gamma Spectroscopy	Canberra 24% efficient* intrinsic, Ge detector in an Applied Physical Technology 10 cm graded lead cave; Canberra S-100 MCA
Liquid Scintillation (tritium and C-14)	Beckman LS 6000TA Liquid Scintillation Counter
Gross Alpha/Beta (Wet Chemical Analysis for Sr-89 and Sr-90)	Tennelec LB-5100 Alpha/Beta Counting System and Protean WPC 9550 Counting System
Gamma Surveys	Eberline Model FH 40G-10 low range gamma survey meter (range 10 $nSv \cdot h^{-1}$ to 1 $Sv \cdot h^{-1}$ for 30 keV to 3 MeV photons).
Thermoluminescent Dosimetry	Panasonic UD-7900U and UD-716AGL TLD Readers and UD-804A1 ($CaSO_4$) dosimeters

*relative to a 3x3 inch sodium iodide detector

In gamma spectroscopy analysis, all statistically significant peaks in the spectrum are identified either by reference to a database library of about 150 radionuclides, or by manual reference to compilations of all known radionuclides. In addition, approximately 20 selected radionuclides are specifically searched for in every sample with the exception of Air Iodine samples in which only I-131 is selected. The selected radionuclides include those that are produced in PLNGS, and which would be readily detectable because of their abundance (high fission yield) and high branching ratios for gamma releases. Naturally occurring gamma emitters, with the exception of Be-7, K-40 and Ac-228, are not included in this report. These excepted radionuclides are sometimes useful as general indicators of the consistency of the analytical techniques.

The peak search and analysis program SAMPO is used to process spectra. The library of radionuclides uses data of the Oak Ridge Laboratory. There are three categories of radionuclides evaluated:

1) selected nuclides of key fission and activation products
2) all other identified radionuclides, including natural radionuclides
3) detected energy peaks for which no identification can be readily made.

The three categories cover all possible eventualities in a spectral analysis and ensure that no significant radionuclides or photon energies will be overlooked.

The usefulness of gross alpha/beta analysis lies primarily in showing trends and determining whether more detailed analyses should be done. The reported alpha and beta values are assessed with respect to Am-241 and Sr-Y-90 calibration sources, respectively.

Wet chemical analysis for Sr-89,90 on GEM and LEM samples follows a method developed by Eichrom Industries Inc.(20) using a strontium specific chromatography resin. This method is similar to test method 05811-95 issued by the American Society of Tests and Materials (ASTM).

Liquid samples, other than milk, are acidified upon receipt to keep radionuclides from plating out on the container walls. Perishable samples are refrigerated or frozen.

B2 Sample Collection and Analysis

B2.01 Airborne Particulates

Airborne particulates are collected on a 47 mm diameter Gelman Type A glass fibre filter, through which air is drawn at about 60 $L \cdot min^{-1}$ for a 28 day continuous sample. The volume of air sampled (approximately 2400 m^3) is measured with an in-line integrating dry gas meter. Every month the filters are replaced and the used ones are returned to the laboratory for analysis. Sampling is, therefore, continuous throughout the year.

Air particulate filters are analysed by gamma spectroscopy as soon as possible after collection to ensure the detection of any short lived gamma emitters that may be present, and to minimise any decay corrections. Samples are counted for 5000 s on the Ge detector.

Approximately three days after the end of the sample collection interval, each filter is counted on one of the alpha beta counters for 100 minutes for the simultaneous determination of gross alpha and gross beta activities. Counting is delayed to allow for the decay of the short-lived radon progeny that would otherwise complicate the analysis.

If alpha/beta levels are detected at twice the normal level, further investigation is initiated by longer gamma counts or radiostrontium determinations.

If levels of Sr-89,90, indicating one percent of the weekly DRL, are detected in the chemical analysis of GEM filters, then the air monitoring station particulate filters are also to be analysed for these radionuclides.

B2.02 Airborne Radioiodines

Airborne radioiodines are collected in an activated charcoal cartridge placed downstream of the particulate filter. The cartridges are from F&J Specialty Products (TE3C 20x40 mesh TEDA). Approximately 2400 m^3 of air is sampled continuously over 28 days at a flow rate of about 60 $L \cdot min^{-1}$. The volume of air sampled is measured with an in-line integrating dry gas meter.

Iodine-131 is the major nuclide of interest on the charcoal cartridges. The cartridges are counted in groups of four for 50 000 s on the gamma spectrometer. Counts are performed as soon as possible after collection because of the relatively short-half life of I-131 (8 days). If radioiodines, believed to have originated from PLNGS, are detected, then the cartridges are re-analysed individually. Fission product radioiodines other than I-131, with much shorter half-lives (minutes to hours), decay before they reach the sample location or during the time the sample is being collected. If an elevated release of radioiodines were noted from the station in this interval, the samples would be changed and analysed earlier to minimise errors from decay corrections.

B2.03 Airborne Tritium

Air is passed through a molecular sieve container (Advanced Specialty Gas Equipment type 13X sieve material) to extract water vapour from the sampled air. Sample volume is measured with a mass flow controller (MFC) (Alicat Scientific Inc. MC-1SLPM-0).

Sampling is continuous at each location throughout the year. Since the amount of water absorbed by the molecular sieve from a given volume of air depends upon absolute humidity, flow rates are adjusted with a MFC to avoid saturation of the sieve material and to ensure adequate sample collection.

For tritium analysis by liquid scintillation counting, 6 mL of water taken from the molecular sieve condensate is counted for 100 minutes.

B2.04 Airborne Carbon-14

An aquarium pump bubbles air through 2N NaOH (1 L), into which carbon dioxide and its C-14 component is absorbed. Carbon dioxide is regenerated from the resulting sodium carbonate by acidification of the 2N NaOH solution and then analysed for the determination of C-14 activity. The carbon dioxide is passed through a silica gel trap to remove moisture and tritium and then absorbed into the chemical Carbo-sorb® E until saturation is reached. After the addition of the scintillation cocktail Permafluor® E^+, the sample is analysed for 100 minutes by liquid scintillation counting.

B2.05 Environmental Gamma Radiation (TLD)

The environmental TLD is composed of three elements of calcium sulphate with lead filtration of 700 $mg \cdot cm^{-2}$. The badge is sealed in plastic, placed in a screw cap plastic container and suspended approximately 1 m above the ground for a period of three months. This arrangement measures the ambient gamma dose, whether it is from activity in the air, from the ground or cosmic in origin.

Readout is by a Panasonic Automatic Reader. For typical quarterly measurements in the region of 150-200 μSv, measurements can be made to ±10% at the 95% confidence level.

B2.06 Soil

Soil samples are collected in undisturbed locations away from nearby buildings or trees. Level areas with some vegetation are preferred. A representative sample (approximately 1.6 kg) of the top 25 mm of a 20 cm by 20 cm area of soil is placed in a disposable plastic bag.

The soil is air dried overnight. If excessive moisture is present, the sample is dried on a disposable aluminum tray (at 100 °C). Composed organic matter and stones are removed. Approximately 0.25 kg of dry soil is counted by gamma spectroscopy for 5000 s.

B2.07 Food

Garden produce and berries, which are either collected or purchased, require no special preparation. The edible portion is put in a calibrated container and weighed. The sample is counted by gamma spectroscopy for 5000 s.

B2.08 Milk

A 4L sample is purchased and placed in a clean polyethylene container.

For gamma spectroscopy, a 3.6 L portion is measured into a marinelli beaker. Approximately 100 mL is distilled, and a 6 mL aliquot of the distillate is analysed for H-3 by liquid scintillation counting. Count times are 50 000 s for gamma spectroscopy and 100 min for tritium analysis.

B2.09 Water

A 4L sample of well water, pond water, lake water or surface runoff is collected in a clean polyethylene container.

A portion is removed for tritium analysis, and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). Of this, 3.6 L is measured into a marinelli beaker for gamma spectroscopy. After gamma analysis, well water samples (125-500 mL, depending upon the historical content of dissolved solids) are evaporated until dry on stainless steel planchets for gross alpha/beta analysis. For tritium analysis, a 6 mL aliquot is analysed by liquid scintillation counting. For gamma spectroscopy, the sample is counted for 5000 s. For tritium and gross alpha/beta analyses, samples are counted for 100 min. A level twice the normal level for alpha/beta will initiate further investigation by longer gamma counts and/or Sr-89,90 analyses.

Measurements of gross alpha and beta are made approximately two weeks after sample collection. This delay avoids analytical interference from radon progeny, which decay with a half-life of about 3.8 days. Naturally occurring radon and radon progeny are present in well waters everywhere and are known to reach elevated concentrations in many New Brunswick locations.

B2.10 Vegetation

The only vegetation types routinely collected and analysed are tree lichen (Spanish moss) and various ground mosses such as Cladonia and Lycopodium. They concentrate a wide range of radionuclides, both natural and anthropogenic. This makes vegetation a sensitive indicator of radionuclides in the environment even though they are not identified in the pathway to humans.

About 25 g or more of each of the samples is collected and air-dried before analysis. No special preparation is required. The sample is placed in a calibrated container, weighed and counted by gamma spectroscopy for 5000 s.

B2.11 Precipitation

Various forms of precipitation are collected continuously throughout the year.

A portion is removed for tritium analysis and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). For gamma spectroscopy, 3.6 L is measured into a marinelli beaker and counted for 5000 s. For tritium analysis by liquid scintillation techniques, 6 mL is counted for 100 min.

B2.12 Sediment and Beach Surveys

Beach sediment samples are collected near the low tide mark, with preference being given to the top 10 mm of the fine sediment characteristic of tidal mud flats. A disposable plastic bag is used to collect about 1 kg of sample. In addition, direct gamma radiation dose rate measurements are made at each sediment site using a FAG FH 40F2 low range gamma survey meter. The meter is held for one minute at a point one metre above the intertidal surface. After the sediment sample has been collected, this is repeated.

The sample is transferred to a disposable aluminum tray for drying at 80 °C. Dried, caked samples are broken into their original free granular form with a porcelain mortar and pestle and sieved through a 0.5 mm mesh to collect the fines for analysis (a 1 mm sieve is used for coarse sediments). Approximately 0.25 kg of dried sediment is counted by gamma spectroscopy for 5000 s.

B2.13 Seafood

The inshore fishery throughout the Maritimes has declined since the OERMP was started in 1982. Some of it has been closed to any kind of harvesting. However, species of local seafood are collected when available from local fishermen. Sampling focuses on fish, lobsters, aquaculture salmon and clams. Some of the areas where clam harvesting is prohibited are sampled with the permission of the Department of Fisheries and Ocean. Other seafood species are more mobile and can sometimes be found throughout the area: crab, periwinkles, scallops, herring, mackerel, dogfish, cod, haddock, sea urchin, mussels, and flounder. The severe restrictions placed on the inshore fishery as well as the depletion of stocks make many of these samples unavailable for periods of time sometimes spanning years. However, whenever they are available an effort is made to collect as many samples as possible. Approximately 0.5 kg of fresh seafood is collected per sample.

Approximately 0.25 kg of each sample is prepared for gamma spectroscopy. Lobsters are cooked first, and the edible meat is removed for analysis. Clams, periwinkles, and crab are analysed whole, with a yield factor applied to account for the mass of the inedible shell. Usually the edible portion of fish is analysed, although sometimes the whole fish is analysed. Samples are counted for 5000 s.

B2.14 Aquatic Plants

Dulse (*Rhodymenia palmata*), an edible seaweed which is commercially harvested in the area, is collected monthly when available. Other species of seaweed concentrate a wide range of radionuclides, both natural and man-made. This makes them sensitive indicators of radionuclides in the environment even though they are not identified in the pathway to humans.

A portion of the seaweed or dulse is put in a calibrated container and weighed. This is counted by gamma spectroscopy for 5000 s.

B2.15 Seawater

A 4 L sample is collected in a clean polyethylene container.

A portion is removed for tritium analysis and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). For gamma spectroscopy, 3.6 L is measured into a marinelli beaker and counted for 5000 s. For tritium analysis by liquid scintillation techniques, 6 mL is counted for 100 min.

If levels of Sr-89,90, indicating one percent of the monthly DRL, are detected in the chemical analysis of the LEM composite, then the seawater is also to be analysed for these radionuclides.

B2.16 Miscellaneous Samples

This category encompasses all of those samples collected that do not fall within the other categories. It is a mechanism by which the lab can track and evaluate media for potential inclusion in the program. It gives the program flexibility and freedom and encourages the scientific curiosity of laboratory staff. A few of the media types started out this way. As many as 50 samples per year are analysed, including deer liver, mud puddles, snow, sea urchin and mussels.

B2.17 Bore Holes

A 4 L sample of water is pumped out of the bore hole into a clean polyethylene container.

A portion is removed for tritium analysis and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). For gamma spectroscopy, 3.6 L is measured into a marinelli beaker and counted for 5000 s. For tritium analysis by liquid scintillation techniques, 6 mL is counted for 100 min.

B2.18 Parshall Flume

PLNGS staff collect a 4 L sample of water from the Parshall flume systems.

A portion is removed for tritium analysis, and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). Of this, 3.6 L is measured into a marinelli beaker for gamma spectroscopy. For tritium analysis, a 6 mL sample of water is counted for 100 min by liquid scintillation techniques. For gamma spectroscopy, the sample is counted for 5000 s.

B2.19 Hemlock Knoll Regional Sanitary Landfill

In December 1999, PLNGS began disposing of its non-active waste at the public landfill facility. A monitoring program was established prior to the first shipment. It includes sampling of water from the leachate, bore holes and various holding ponds; and dosimeter placement at key locations.

Although some extra precautions are observed due to the potential biohazard of some of these samples, they are analysed according to established procedures previously described.

Appendix C: Location Codes

A 5m	PLNGS Dry Fuel Storage Facility - 5 m NNE from perimeter fence
A 10m	PLNGS Dry Fuel Storage Facility - 10 m NNE from perimeter fence
A 15m	PLNGS Dry Fuel Storage Facility - 15 m NNE from perimeter fence
A 20m	PLNGS Dry Fuel Storage Facility – 20 m NNE from perimeter fence
A 25m	PLNGS Dry Fuel Storage Facility – 25 m NNE from perimeter fence
A 50m	PLNGS Dry Fuel Storage Facility – 50 m NNE from perimeter fence
A 75m	PLNGS Dry Fuel Storage Facility – 75 m NNE from perimeter fence
A 100m	PLNGS Dry Fuel Storage Facility – 100 m NNE from perimeter fence
A 118m	PLNGS Dry Fuel Storage Facility – 118 m NNE from perimeter fence
A01R	Bocabec – GPS Reading – L 45˚ 10.111N, Lo 67˚ 0.378 W
A02R	Bocabec – field across from A01R
A03R	Bocabec – inter-tidal zone
A04	Bayside – Farm
A05R	Letete
A06	Digdeguash
A07	Beaver Harbour
A08	Back Bay
A09	Chamcook
A10R	Grand Manan
A11	Oak Bay / Waweig

A12	St. Andrews
A13R	St. Andrews environmental monitoring station
A15	Deer Island
A20	Campobello Island
AECL	Atomic Energy of Canada Ltd., Chalk River (QA)
ANA	Eckert & Ziegler Analytics (QA)
B 5m	PLNGS Dry Fuel Storage Facility – 5 m WNW from perimeter fence
B 10m	PLNGS Dry Fuel Storage Facility – 10 m WNW from perimeter fence
B 15m	PLNGS Dry Fuel Storage Facility – 15 m WNW from perimeter fence
B 20m	PLNGS Dry Fuel Storage Facility – 20 m WNW from perimeter fence
B 25m	PLNGS Dry Fuel Storage Facility – 25 m WNW from perimeter fence
B 50m	PLNGS Dry Fuel Storage Facility – 50 m WNW from perimeter fence
B 75m	PLNGS Dry Fuel Storage Facility – 75 m WNW from perimeter fence
B 100m	PLNGS Dry Fuel Storage Facility – 100 m WNW from perimeter fence
B 150m	PLNGS Dry Fuel Storage Facility – 150 m WNW from perimeter fence
B 200m	PLNGS Dry Fuel Storage Facility – 200 m WNW from perimeter fence
B01	New River Beach - inter-tidal zone
B02	Pocologan
B03	New River Beach - park
B04	New River Harbour to Pocologan Harbour

B10	Pennfield
BAXR	Baxter's Dairy
BB	PLNGS – Boiler Blow-down
BD	Belledune GS
C01	Lepreau Harbour – intertidal zone
C03	Lepreau
CC	Coleson Cove GS
CCW	PLNGS – Condenser Cooling Water Duct
CH	Chatham GS
COG	Kinectrics (CANDU Owners Group)
D01	Little Lepreau Basin - inter-tidal zone (remnants of clam shack)
D02	Little Lepreau
D03	Little Lepreau – GPS Reading – L 45˚ 08.030 N , Lo 66˚ 27.686 W
D04	Little Lepreau Basin – inter-tidal zone (remnants of boat wreck)
DH	Dalhousie GS
DOE	US Department of Energy (QA)
DUMP	PLNGS – onsite landfill
DWC	PLNGS – drinking water fountains
E01	Maces Bay –GPS Reading–L 45˚ 06.306 N, Lo 66˚ 28.651 W
E02	Maces Bay – Fundy Senior Citizens Centre
E03	Maces Bay – inter-tidal zone

E04	Maces Bay Cemetery
E05	Fundy Shores Elementary School – outside (Thompson/Trynor's Field)
E06	Fundy Shores Elementary School – inside
E07	Near intersection of route 790, Maces Bay Rd. and County Line Rd.
E11	28 Ridge Rd., Dipper Harbour
E12	22 Ridge Rd., Dipper Harbour
E13	16 Ridge Rd., Dipper Harbour
E14	10 Ridge Rd., Dipper Harbour
E15	4 Ridge Rd., Dipper Harbour
EDU	Edutech Enterprises
EPA	US Environmental Protection Agency (QA)
ERA	Environmental Resource Associates
F01	Welch Cove–GPS Reading–L 45˚ 04.782N, Lo 66˚ 27.986 W
F02	Welch Cove – inter-tidal zone
F03	190 Welch Cove Rd., Maces Bay
F04	195 Welch Cove Rd., Maces Bay
F05	181 Ridge Rd., Maces Bay
F06	132 Ridge Rd., Maces Bay
F07	68 Ridge Rd., Maces Bay
G01	Indian Cove – inter-tidal zone
G02	Point Lepreau – lighthouse

G03	offshore – within 2 km of Point Lepreau lighthouse
G04	PLNGS – inter-tidal zone 1 km south of CCW out-fall
GEM	PLNGS – Gaseous Effluent Monitor
GL	Grand Lake GS
H01	Duck Cove – duck pond
H02	offshore – close to PLNGS condenser cooling water out-fall
H03	Duck Cove - inter-tidal zone
H04	PLNGS – across the road from old site of Information Centre building
H05	PLNGS - start of nature trail near old site of Information Centre trailers
HS	Hanson Stream Reservoir
I00	PLNGS SRWMF Phase 1– general site area
I01	PLNGS SRWMF Phase 1
I02	PLNGS SRWMF Phase 2
I03	PLNGS SRWMF Phase 2 – general site area
I04	SRWMF Phase 3
I05	SRWMF Phase 3, General Site Area
I10A	PLNGS SRWMF Phase 1 Bore Hole A (BHA)
I10B	PLNGS SRWMF Phase 1 Bore Hole B (BHB)
I10C	PLNGS SRWMF Phase 1 Bore Hole C (BHC)
I10D	PLNGS SRWMF Phase 1 at I01 Barn (Shallow Bore Hole)
I10E	PLNGS SRWMF Phase 1 at I01 Barn (Deep Bore Hole)

I10F	PLNGS SRWMF Phase 1 Bore Hole southeast from C structure
I10G	FUTURE BORE HOLE
I10H	FUTURE BORE HOLE
I10I	FUTURE BORE HOLE
I11A	PLNGS SRWMF Phase 1 - south fence (east side)
I11B	PLNGS SRWMF Phase 1 - south fence (centre)
I11C	PLNGS SRWMF Phase 1 - south fence (west side)
I11D	PLNGS SRWMF Phase 1 - west fence (south side)
I11E	PLNGS SRWMF Phase 1- west fence (centre)
I11F	PLNGS SRWMF Phase 1 - west fence (north side)
I11G	PLNGS SRWMF Phase 1 - north fence (west side)
I11H	PLNGS SRWMF Phase 1 - north fence (centre)
I11I	PLNGS SRWMF Phase 1 - north fence (east side)
I11J	PLNGS SRWMF Phase 1 - east fence (north side)
I11K	PLNGS SRWMF Phase 1 - east fence (centre)
I11L	PLNGS SRWMF Phase 1 - east fence (south side)
I11M	SRWMF Phase 1 ext, Fence W-N
I11N	SRWMF Phase 1 ext, Fence W-NN
I11O	SRWMF Phase 1 ext, Fence N-W
I11P	SRWMF Phase 1 ext, Fence N-C
I11Q	SRWMF Phase 1 ext, Fence N-E

I11S	SRWMF Phase 1 ext, Fence E-NN
I11T	SRWMF Phase 1 ext, Fence E-N
I1A1	PLNGS SRWMF Phase 1 – Cell 1A1
I1A2	PLNGS SRWMF Phase 1 – Cell 1A2
I20A	PLNGS SRWMF Phase 2 – well #4 (shallow) BH4
I20B	PLNGS SRWMF Phase 2 – well #4 (deep) BH4
I20C	PLNGS SRWMF Phase 2 - well #7 (shallow) BH7
I20D	PLNGS SRWMF Phase 2 - well #7 (deep) BH7
I20E	PLNGS SRWMF Phase 2 – well #6 (shallow) BH6
I20F	PLNGS SRWMF Phase 2 - well #6 (deep) BH6
I20G	PLNGS SRWMF Phase 2 – well #5 (shallow) BH5
I20H	PLNGS SRWMF Phase 2 – well #5 (deep) BH5
I20I	PLNGS SRWMF Phase 2 – well #2 (shallow) BH2
I20J	PLNGS SRWMF Phase 2 - well #2 (deep) BH2
I20K	PLNGS SRWMF Phase 2 - well #3 (shallow) BH3
I20L	PLNGS SRWMF Phase 2 – well #3 (deep) BH3
I20M	PLNGS SRWMF Phase 2 – well #1 (shallow) BH1
I20N	PLNGS SRWMF Phase 2 – well #1 (deep) BH1
I20P	PLNGS SRWMF Phase 2 – north from bore hole 1
I20Q	PLNGS SRWMF Phase 2 – south from bore hole 2 (shallow)
I20S	PLNGS SRWMF Phase 2 – south from bore hole 2 (deep)

I20T	PLNGS SRWMF Phase 2 – north from bore hole 2
I20U	PLNGS SRWMF Phase 2 – well #8 shallow (BH8)
I20V	PLNGS SRWMF Phase 2 – well #8 deep (BH8)
I20W	SRWMF Phase 2, Middle NE Shallow
I21A	PLNGS SRWMF Phase 2 – Periphery – south fence (east side)
I21B	PLNGS SRWMF Phase 2 - Periphery – south fence (centre)
I21C	PLNGS SRWMF Phase 2 - Periphery – south fence (west side)
I21D	PLNGS SRWMF Phase 2 - Periphery – west fence (south side)
I21E	PLNGS SRWMF Phase 2- Periphery - west fence (centre)
I21F	PLNGS SRWMF Phase 2 - Periphery - west fence (north side)
I21G	PLNGS SRWMF Phase 2 – Periphery – north fence (west side)
I21H	PLNGS SRWMF Phase 2 - Periphery – north fence (centre)
I21I	PLNGS SRWMF Phase 2 - Periphery – north fence (east side)
I21J	PLNGS SRWMF Phase 2 – Periphery – east fence (north side)
I21K	PLNGS SRWMF Phase 2 – Periphery – east fence (centre)
I21L	PLNGS SRWMF Phase 2 - Periphery – east fence (south side)
I30A	SRWMF Phase 3, Well 1
I30B	SRWMF Phase 3, Well 2 Shallow
I30C	SRWMF Phase 3, Well 2 Deep
I30D	SRWMF Phase 3, Well 3
I30E	SRWMF Phase 3, Well 4

I30F	SRWMF Phase 3, Well 5 Shallow
I30G	SRWMF Phase 3, Well 5 Deep
I30H	SRWMF Phase 3, Well 6
I30I	SRWMF Phase 3, Well 7
I30J	SRWMF Phase 3, Well 8 Shallow
I30K	SRWMF Phase 3, Well 8 Deep
I31A	SRWMF Phase 3, Fence S-E
I31B	SRWMF Phase 3, Fence S–C
I31C	SRWMF Phase 3, Fence S-W
I31D	SRWMF Phase 3, Fence W-SS
I31E	SRWMF Phase 3, Fence W-S
I31F	SRWMF Phase 3, Fence W-SC
I31G	SRWMF Phase 3, Fence W-NC
I31H	SRWMF Phase 3, Fence W-N
I31I	SRWMF Phase 3, Fence W-NN
I31J	SRWMF Phase 3, Fence N-W
I31K	SRWMF Phase 3, Fence N-E
I31L	SRWMF Phase 3, Fence N-C
I31M	SRWMF Phase 3, Fence E-NN
I31N	SRWMF Phase 3, Fence E-N
I31P	SRWMF Phase 3, Fence E-NC

I31Q	SRWMF Phase 3, Fence E-WC
I31S	SRWMF Phase 3, Fence E-W
I31T	SRWMF Phase 3, Fence E-WW
I70	PLNGS – woods between plant & SRWMF
I71	PLNGS - Near Plant Monitoring Well MW01-10, northeast from RB
I75	PLNGS – north 73° east, 85 m from the stack (on pole)
I86	PLNGS – 2nd pole from SRWMF driveway heading toward outer gate
I87	PLNGS –3rd pole from SRWMF driveway heading toward outer gate
I88	PLNGS – 4th pole from SRWMF driveway heading toward outer gate
I89	PLNGS -5th pole from SRWMF driveway heading toward outer gate
I90	At distribution line on west side of Point Lepreau Rd.
I91	100 m north of distribution line on west side of Point Lepreau Rd.
I92	200 m north of distribution line on west side of Point Lepreau Rd.
I93	300 m north of distribution line on west side of Point Lepreau Rd.
I94	400 m north of distribution line on west side of Point Lepreau Rd.
I95	500 m north of distribution line on west side of Point Lepreau Rd.
I96	on the old Dupont warning sign at the end of the old “dynamite road”
I97	on the west side of the clearing at the end of the old “dynamite road”
I98	PLNGS – north of SRWMF PHASE 2 (200 m north of transmission line)
I99	PLNGS – north of SRWMF PHASE 2 – (100 m north of transmission
IAEA	International Atomic Energy Agency (QA)

J00	PLNGS – south, 180 m from the stack (on fence)
J01	PLNGS - Near Plant Monitoring Well MW01-1, near surge shaft
J02A	PLNGS - Near Plant Monitoring Well MW01-2 (shallow), SSE from
J02B	PLNGS - Near Plant Monitoring Well MW01-2 (deep), SSE from RB
J20	PLNGS – south 19° east, 115 m from the stack (on fence)
J35	PLNGS – south 34° east, 135 m from the stack (on sign)
J70	PLNGS – south 69° east, 70 m from the stack (on pole)
K00	PLNGS - Near Plant Monitoring Well MW01-3 south from RB
K01	PLNGS – 95 m west of south gate leading to the lighthouse
K02	PLNGS Cooling Water Pump-house – east fence near surge shaft
K03	PLNGS - Near Plant Monitoring Well MW01-4 SSW from RB
K03C	PLNGS sewage lagoon (chlorine contact tank)
K03E	PLNGS inactive drainage (east lagoon)
K03W	PLNGS inactive drainage (west lagoon)
K04	PLNGS - Near Plant Monitoring Well MW01-5, WSW from RB
K10	Firing Range
KDRP	KD Radpro
L01	PLNGS – site of old cement plant
L02	PLNGS – switchyard
L03	PLNGS – outer security building (main gate)
L04	PLNGS – construction stores

L05	PLNGS - Near Plant Monitoring Well MW01-6, WNW from RB
L06	PLNGS - Near Plant Monitoring Well MW01-7, paved staff parking
L07	PLNGS - Near Plant Monitoring Well MW01-8, construction parking
L08	PLNGS - Near Plant Monitoring Well MW01-9, N beyond fire
L09A	MW05-1, fire fighter training area
L09B	MW05-2, fire fighter training area
L09C	MW05-3, fire fighter training area
L09D	MW05-4, fire fighter training area
L09E	MW05-5, fire fighter training area
L10A	Landfill SW05-1
L10B	Landfill SW05-2
L10C	Landfill SW05-3
L10D	Landfill SW05-4
L10E	Landfill SW05-5
L10F	Landfill SW05-6
L10G	Landfill Seep
L11A	Landfill MW6
L11B	Landfill MW7
L11C	Landfill MW8
L11D	Landfill MW9
L11E	Landfill MW10

L11F	Landfill MW11
L11G	Landfill MW12
L11H	Landfill MW13
LAB	Fredericton – Health Physics Laboratory
LEM	PLNGS – Liquid Effluent Monitor
M02	PLNGS – Administration Building (2nd floor)
MISC	Miscellaneous locations
MQ	Mactaquac GS
N01	Dipper Harbour – GPS Reading – L 45˚ 05.399 N, Lo 66˚ 25.154 W
N02	Dipper Harbour – GPS Reading – L 45˚ 06.106 N, Lo 66˚ 24.949 W
N03	Dipper Harbour – GPS Reading – L 45˚ 05.551 N, Lo 66˚ 25.449 W
N04	Dipper Harbour – intertidal zone
N05	Dipper Harbour – beach behind restaurant
N06	Dipper Harbour – offshore
NTS	Nuclear Technology Services Inc. (QA)
P01	Chance Harbour – GPS Reading – L 45˚ 07.494 N, Lo 66˚ 21.456 W
P02	Little Dipper Harbour
P03	Liberty Hill – GPS Reading – L 45˚ 07.043 N, Lo 66˚ 21.498
P04	Round Meadow Farm
P05	Chance Harbour – 2 km offshore
PLNGS	PLNGS – general

Q01R	Lorneville
RPB	Radiation Protection Bureau, Health Canada (QA)
RPC	Research and Productivity Council
S00	Saint John and surrounding area
S10	Hammond River
SPL	Spruce Lake reservoir
TAYR	Taymouth
X03R	Fredericton - Chestnut Complex lab
X04R	Fredericton – reference seafood
X05R	Fredericton – reference milk test
X06R	West of Fredericton (Silverwood)
X10	Fredericton Junction – Atlantic Dairy Institute
X12	York Mills
X20	Lincoln
Y#####	Hemlock Knoll Regional Sanitary Landfill

Appendix D: Abbreviations

CCW	Condenser Cooling Water
CL	Critical Level
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
CSA	Canadian Standards Association
DRL	Derived Release Limit
FWHM	Full Width Half Maxima
GEM	Gaseous Effluent Monitor
IAEA	International Atomic Energy Agency
ISO	International Organization for Standardization
LEM	Liquid Effluent Monitor
LLD	Lower Limit of Detection
LSC	Liquid Scintillation Counter
MFC	Mass Flow Controller
NBEMO	New Brunswick Emergency Measures Organization
NIST	National Institute of Standards and Technology
NRC	National Research Council
NTS	Nuclear Technology Services
OERMP	Operational Environmental Radiation Monitoring Program
PICA	Problem Identification and Corrective Action
PLNGS	Point Lepreau Nuclear Generating Station
QA	Quality Assurance
QC	Quality Control
REPD	Radiation and Environmental Protection Division
RPB	Radiation Protection Bureau
SEA	Significant Environmental Aspect
SRWMF	Solid Radioactive Waste Management Facility
TLD	Thermoluminescent Dosimeter
USDOE	United States Department of Energy