Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

Annual Compliance Monitoring Report Environmental Monitoring in 2020 at Chalk River Laboratories

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Date

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Revision History

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SUMMARY

Overview

This report reviews and summarizes the results of the Chalk River Laboratories (CRL) Environmental Monitoring Program (EMP) for the 2020 calendar year. Canadian Nuclear Laboratories (CNL) reports the monitoring results annually to the Canadian Nuclear Safety Commission (CNSC) as a condition of the *Nuclear Research and Test Establishment Operating Licence* [1] and as per the compliance verification criteria in the *Licence Conditions Handbook for Chalk River Laboratories* [2], issued by the CNSC.

In 2020, based on the results of environmental monitoring, the total estimated dose to the public for all air effluent exposure pathways represented 0.59% of the regulatory public dose limit of 1 millisievert (mSv), and all liquid effluent pathways represented 0.15%, as summarized in Table 1. The assessment of measured dose from CRL operations in 2020, via the Effluent Verification Monitoring Program (EVMP), showed (as in previous years) that the dose to critical groups for any consecutive 12-month period, ending in 2020, was well below 0.3 mSv (Table 2). There is a notable decrease in the rolling 12 consecutive month dose that may be due to the reduced operations at CRL during the COVID-19 pandemic.

CNL maintains a comprehensive EMP for CRL to verify that radiation doses to members of the public as a result of radioactive releases from the CRL site remain as low as reasonably achievable, taking into account both social and economic factors. The program demonstrates that the radiation dose to the most exposed members of the public (i.e., critical groups) due to CRL operations does not exceed regulatory limits, and also serves to verify that non-radiological releases do not pose hazards to human health, and that neither radiological nor non-radiological releases pose hazards to the environment.

The EMP encompasses three integrated components: (1) environmental monitoring, (2) effluent verification monitoring, and (3) groundwater monitoring. Together, these three components provide data for the CRL's site contaminant pathways monitoring, enabling the monitoring of contaminant levels in abiotic and biotic compartments in the environment. Monitoring is conducted through the routine collection and analysis of environmental samples from numerous locations at the CRL site and in surrounding communities, in order to measure the concentrations of contaminants in every significant environmental compartment involved in the migration of contaminants throughout the environment. Monitored media include ambient air, groundwater, Ottawa River water and other surface waters, both on and off site, and foodstuff (e.g., fish, garden produce, large game, and farm animals). Monitoring of beach sand, ground surfaces, local vegetation, small animals and meteorological conditions is also performed.

Results for 2020 verified that environmental monitoring trends at off-site locations were consistent with radioactive releases from the CRL site. The dose from both liquid and air effluent pathways continues to be a low percentage of the public dose limit. Since the shutdown of NRU in March 2018, Argon-41 (^{41}Ar) and any other potential gamma emissions from the site are indistinguishable from natural background radiation levels, as evidenced by thermoluminescent dosimeter (TLD) monitoring and Gamma TRACER monitoring on-site and

off-site. The main contributors to dose from air effluent pathways now include tritium inhalation and immersion, and garden produce and game animal ingestion.

For on-site monitoring in the last five years, Strontium-90 (^{90}Sr) was the only radionuclide in the surface waters of the Perch Lake basin that was considered to be of moderate impact[1], with all other contaminants having a low environmental impact. In the last five years, and continuing in 2020, concentrations of ^{90}Sr appear to have stabilized and, at the outlet of the drainage system into the Ottawa River, gross beta[2] levels dropped to less than 6 Bq/L in 2020, which is well below the benchmark value (183 Bq/L [3]), i.e., the level above which ecological effects could potentially occur. These releases to the Ottawa River continued to represent a small fraction of the derived release limit (DRL) as well. The impacts of ^{90}Sr migration in the Perch Lake basin are mitigated by the continuing operation of three groundwater treatment systems located at the Liquid Dispersal Area (LDA) and Waste Management Areas (WMAs) A and B.

Overall, the 2020 radioactive environmental monitoring results indicate stability in the performance of facilities and operations at CRL, and that the control of releases of nuclear and hazardous substances currently in place for CRL continues to provide protection of the environment.

[1] Moderate impact is defined by CNL as the increasing contaminant concentration in the environment that exceeds the ecologically based benchmark value in localized regions of the drainage basin.

[2] Gross beta in the Perch Lake drainage basin is representative of Strontium-90 and its daughter Yttrium-90 in equilibrium.

Table 1: Total dose to critical groups outside the Chalk River Laboratories boundaries based on Environmental Monitoring results

Pathway	Airborne Effluent Pathway	Liquid Effluent Pathway
Bounding Age Group	Adult	Adult
2020 Total Effective Dose (mSv/a)	0.0059 ±0.001	0.00152 ± 0.0003
Total Dose (as % of annual public dose limit, 1 mSv)	0.59 ± 0.1	0.152 ± 0.03
Total Dose (as % of typical average background radiation dose in Canada, 3.3 mSv)	0.18 ± 0.04	0.046 ± 0.01
2019 Total Effective Dose (mSv/a)	0.0029 ±0.007 (A)	0.00097 ± 0.0004 (A)
2018 Total Effective Dose (mSv/a)	0.036 ± 0.026 (A)	0.00016 ± 0.00051 (I)
2017 Total Effective Dose (mSv/a)	0.086 ± 0.039 (A)	0.00042 ± 0.0003 (A)
2016 Total Effective Dose (mSv/a)	0.077 ± 0.047 (I)	0.00052 ± 0.00025 (A)
2015 Total Effective Dose (mSv/a)	0.082 ± 0.028 (I)	0.001 ± 0.00009 (A)

Note: The total dose to off-site members of the public was not calculated based on a single critical group, rather the dose to the most sensitive critical group was selected for each given exposure pathway resulting in a dose to a hypothetical individual living off-site.

Note: In 2016 the CNL EMP moved from reporting a ±1 sigma uncertainty to a method (described in the CSA N288.4 [4]) that more accurately represents the uncertainty associated with the measured value. This has, in general, resulted in a higher reported uncertainty than what has been seen in previous years.

Note: Each year the most restrictive of the bounding age groups is selected, Adult (A), Child (C) or Infant (I). The Child (C) grouping was added in 2019 due to an update of the DRL model.

Table 2: Rolling 12 consecutive month dose to critical groups based on Effluent Verification Monitoring results

12-month Period	Dose Constraint (mSv)	Dose to Critical Groups (mSv)	
2019-Feb-1 to 2020-Jan 31	0.300	0.0019	
2019-Mar-1 to 2020-Feb 28	0.300	0.0018	
2019-Apr-1 to 2020-Mar-31	0.300	0.0017	
2019-May-1 to 2020-Apr-30	0.300	0.0015	
2019-Jun-1 to 2020-May-31	0.300	0.0013	
2019-Jul-1 to 2020-Jun-30	0.300	0.0012	
2019-Aug-1 to 2020-Jul-31	0.300	0.0011	
2019-Sep-1 to 2020-Aug-31	0.300	0.0011	
2019-Oct-1 to 2020-Sep-30	0.300	0.0010	
2019-Nov-1 to 2020-Oct-31	0.300	0.0011	
2019-Dec-1 to 2020-Nov-30	0.300	0.0009	
2020-Jan-1 to 2020-Dec-31	0.300	0.0015*	

(green)	The total dose for the period is below the dose constraint.
(red)	The total dose for the period is above the dose constraint.

* This value is based on Effluent Verification Monitoring Results in 2020; results of Environmental Monitoring estimated a total effective dose of 0.0074 mSv in 2020 (see Table 1), still well below the dose constraint of 0.3 mSv per year.

Introduction

At CNL's CRL site, nuclear facilities include the WMAs, the Tritium Laboratory Facility, and the Waste Treatment Centre (WTC) and its associated facilities. The main source of radioactive emissions, the National Research Universal (NRU) reactor, was placed in a Safe Shutdown / Standby State (SSS) in 2018 March. The CRL site also houses a variety of research, development, and analytical laboratories, and most of these activities are conducted within the built-up portions of the CRL site. The CRL site includes several permanently closed down facilities that are at various stages of decommissioning, including the National Research Experimental (NRX) reactor.

The CRL site, with a total area of about 40 km^2, is located in Renfrew County, Ontario, on the south shore of the Ottawa River, about 200 km northwest of Ottawa. Nearby communities include the Town of Laurentian Hills (includes the community of Chalk River), the Town of Deep River, the Town of Petawawa and Garrison Petawawa, and the City of Pembroke. The portion of Pontiac County, in the Province of Québec, that lies north of the river and opposite the CRL site is normally uninhabited except during the summer months, when a few cottage dwellers may be present.

The primary objectives for the EMP are to achieve the following:

- Assess the level of risk on human health and safety, and the potential biological effects in the environment from the contaminants and physical stressors of concern arising from CRL;
- Demonstrate compliance with limits of the concentration and intensity of contaminants, and physical stressors in the environment or their effect on the environment;
- Check, independently of effluent monitoring, on the effectiveness of containment and effluent control, and provide public assurance of the effectiveness of containment and effluent control;
- Provide an early indication of unusual or unforeseen conditions that might require corrective action or additional monitoring; and
- Verify the predictions made by the Environmental Risk Assessment (ERA), Derived Release Limit (DRL) model, and Environmental Assessments (EA), refine the models used, and reduce the uncertainty in the predictions made by these assessments and models.

The EMP is also designed to provide data required to support site restoration programs, site operations, and to plan for future stages of a facility's lifecycle (e.g., decommissioning). Additionally, the EMP provides resources and data that can be of value during the response to an accident or upset and in the recovery from such an event, to demonstrate due diligence, and to meet stakeholder commitments. The design of the EMP takes into account the facilities and processes at the site, actual emissions from the site at present and in the past, the environmental pathways leading to radiation dose to the critical groups as identified by the DRL calculations, as well as various other scientific, historic and public considerations.

The EMP operates under the direction of CNL's Environmental Protection (EnvP) Program. Analysis of samples is conducted by both CNL and external laboratories. Results, including identified non-conformances, are reported to EnvP Program staff as well as staff and management associated with the facilities subject to the monitoring. The evaluation of results is performed by EnvP Program staff within the Environmental Services division.

Sampling and Analysis

Monitoring is conducted through the routine collection and analysis of environmental samples from numerous locations at the CRL site and in surrounding communities. Releases from CRL facilities and operations may be to the atmosphere or to water. Atmospheric releases arise from stacks and vents associated with operations and facilities in the built-up portion of the site, as well as WMA facilities. Waterborne releases can be from a number of sources; effluent discharges to the Ottawa River, direct groundwater discharge to the Ottawa River, or surface water drainage from facilities in the site's Outer Area. Release points that meet the criteria for routine monitoring as determined in CNL's *Management and Monitoring Emissions* [5] and *Environmental Monitoring Program* documents [6] are monitored as part of the EMP or EVMP, respectively. For a number of CRL facilities, contaminant releases may also occur to groundwater systems, which are monitored as part of the Groundwater Monitoring Program (GWMP) as per CNL's *Protection and Monitoring of Groundwater* [7].

The measurement of groundwater quality around the perimeters of operating areas provides a means of monitoring the conditions and behaviour of CRL's facilities and operations. A significant fraction of the monitoring is carried out around the CRL WMAs. In total, about 192 monitoring wells are subject to routine (annual or twice-yearly) radioactive and non-radioactive monitoring up- and down-gradient of WMAs and facilities. Where groundwater contamination is present, this routine monitoring is augmented by periodic detailed evaluations of subsurface contaminant distributions and movement.

The sampling of water from lakes and streams on the CRL site is an important component of the environmental monitoring network. In total, surface waters on the CRL site are routinely monitored at 27 locations. The selection of parameters for analysis of on-site surface waters is based on the results of groundwater monitoring, information from upstream monitoring points (including groundwater monitoring locations), information on potential source facilities, and results of Environmental Risk Assessment (ERA).

The radiological monitoring of environmental media in communities surrounding the CRL site focuses on exposure pathways for critical groups and populated areas in the vicinity of the CRL site. Monitoring of air effluent exposure pathways includes the measurement and recording of meteorological conditions as well as sampling and analysis of ambient air, garden produce, locally raised farm animals, and large game animals. Monitoring of liquid effluent exposure pathways includes sampling and analysis of Ottawa River surface water, fish, and beach sand. Some aspects of the monitoring program, for example the monitoring of other off-site surface waters, land gamma radiation on roadways, and atmospheric deposition, although not used directly in the calculation of dose to the public, provide valuable information on the fate of airborne effluents on the CRL site and in the surrounding communities.

Quality Assurance

Quality Assurance (QA) is applied to the monitoring program using a range of methods that include performance verification (assessing the quality of sampling and laboratory analysis activities), the application of sampling and analysis procedures, program reviews and audits, and records management. General QA objectives for CNL's EMP are set out in the *Environmental Protection Program Radiological and Non-Radiological Monitoring Services Quality Assurance Plan* [8], which applies to all sampling and analysis with the exception of thermoluminescent dosimeters (TLDs) which are covered by the *CRL Dosimetry Services Quality Assurance Manual* [9].

With regard to laboratory quality verification, typically the evaluation of data quality uses the Quality Control (QC) parameters adopted under the QA programs of the laboratories performing the analyses. These laboratories use QC tools such as blanks, spiked blanks, and replicate samples to address precision, accuracy, sensitivity, and to detect errors in the data. The quality verification data generated at the performing laboratories are evaluated against acceptance criteria. Verification of the quality of sampling activities (field quality verification) is conducted using the results of travelling blanks and duplicate samples. The results of which are used to assess cross-contamination and reproducibility. Data quality verification testing is also inherent in the process of reviewing the monitoring results to evaluate environmental performance and in comparing the monitoring results from year to year (i.e., trending). Any issues related to sampling operations or sample analyses, as reported by staff, are examined and corrective measures developed to address the problems.

In 2019, numerous quality improvements were made to the primary monitoring service used by the EnvP Program including the transition of the Environmental Monitoring Branch (EMB) (the hub for the majority of EnvP data), from a Microsoft Excel/Access compilation used for data storage, calculation and reporting to an official Laboratory Information Management System (LIMS). In 2020, field QC verification was performed as per the monitoring schedule and reported monthly along with the analytical results. No field QC failures were noted for the 2020 radiological parameters.

As per the *Management and Monitoring of Emissions* [5], in the event of a QC non-conformance, the related results may be removed from the data set and replacement data points estimated for the period in which the non-conforming quality verification occurred. Investigations are usually performed to determine the cause of these non-conformances and corrective or remedial actions are assigned, if necessary.

Environmental Monitoring at the Chalk River Laboratories Site

Land on the CRL site, potentially affected by routine and non-routine operations, is subject to routine groundwater, surface water, and ambient air monitoring. Performance in this context was evaluated by characterizing the concentrations of contaminants of potential concern in environmental compartments, comparing the concentrations to available benchmark values (i.e., the levels above which ecological effects could potentially occur), and by reviewing contaminant concentration and loading trends.

Of the five drainage basins at CRL, there are three main drainage basins that are directly affected by CRL operations, including the Ottawa River Direct basin, the Perch Lake basin, and the Maskinonge Lake basin (Figure 1). Within each of the three drainage basins, the facilities of interest have been organized into Management Units (MUs) for ease of remediation planning. Figure 2 is a schematic diagram that relates these CRL facilities of interest into MUs and the drainage basins and paths along which groundwater or surface water contaminants travel on their way to the Ottawa River. For groundwater and surface water contaminants, the environmental performance review is presented on a watershed basis, in consideration of these three major drainage basins.

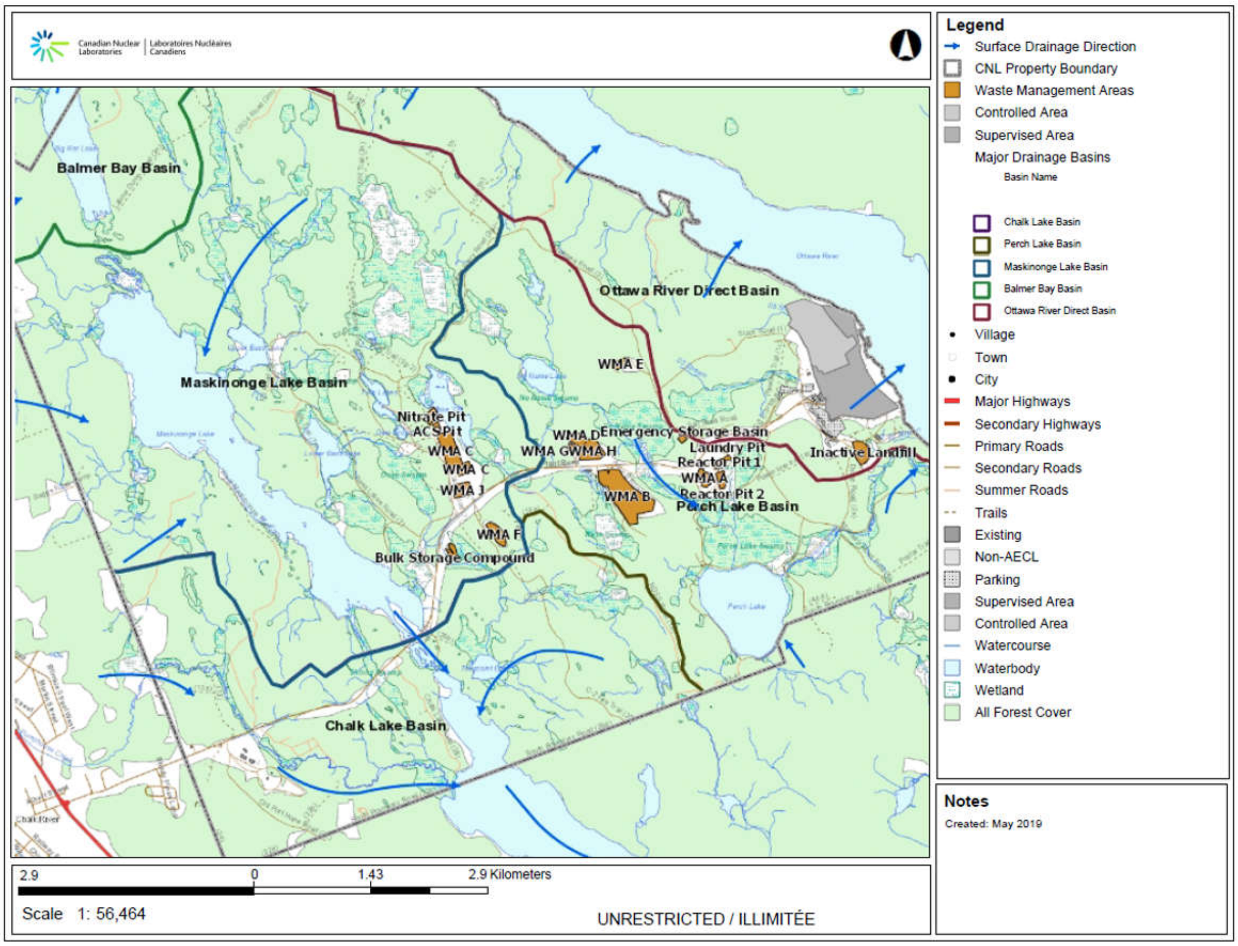

Figure 1 Chalk River Laboratories basin overview

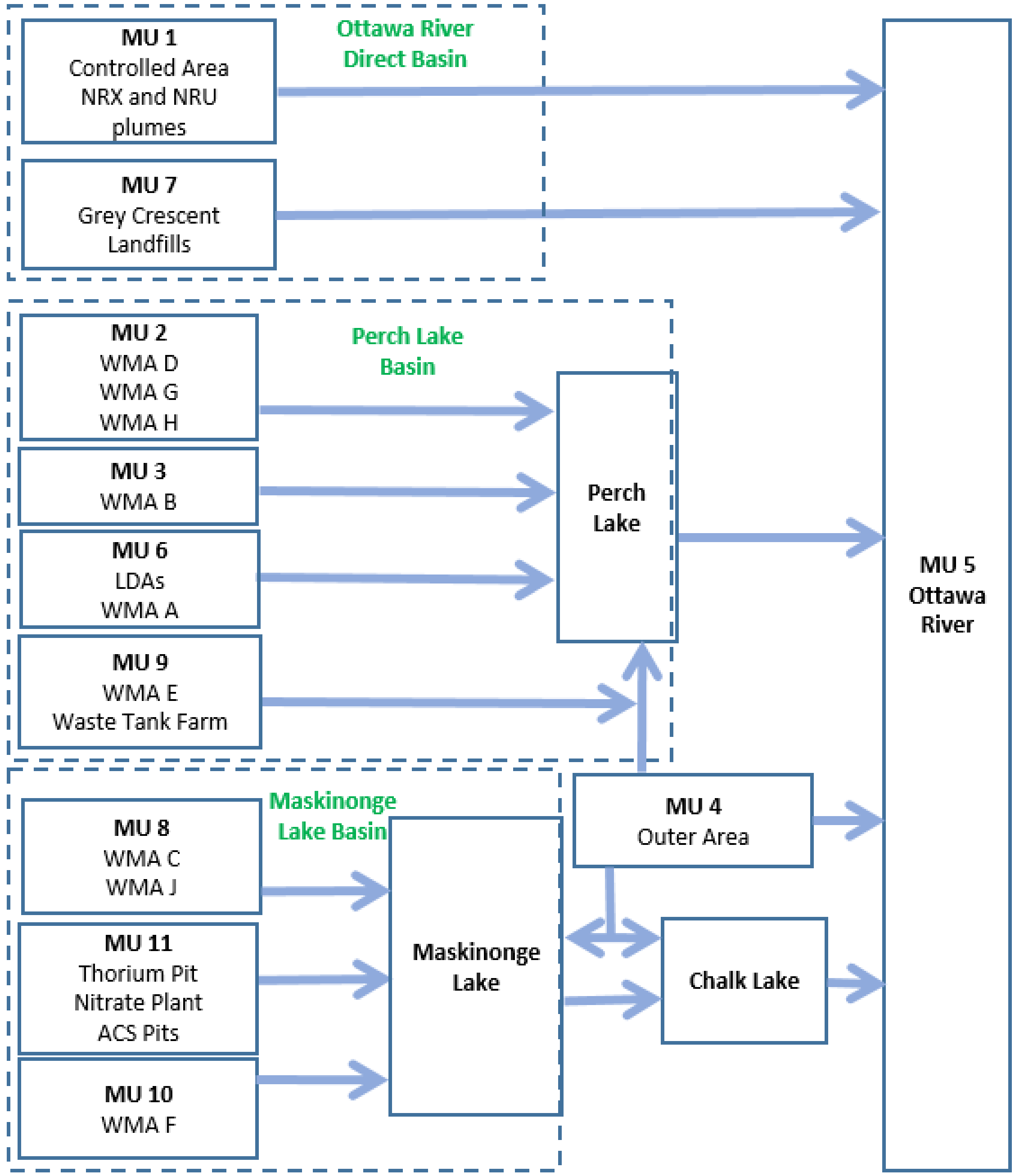

Figure 2 Chalk River Laboratories site model overview

Ottawa River Direct Basin

The Ottawa River Direct basin drains approximately 12% of the water from the CRL site, and includes the built-up area of the site where most of the operational nuclear and industrial facilities are located (MU 1, the controlled area, and MU 7, the supervised area). Most of the air and waterborne effluents resulting from CRL operations are released from this zone, with all liquid effluents being discharged directly to the Ottawa River. This region also includes several landfill facilities and two groundwater contaminant plumes (from the NRX and NRU reactor facilities) that slowly discharge to the Ottawa River through regions of the riverbed (see Figure 2). Within the Ottawa River Direct basin, potential impacts are associated with liquid releases of tritium and gross beta (^{90}Sr in secular equilibrium with its progeny, Yttrium-90 (^{90}Y)) to the Ottawa River.

The main sources of tritium from CRL to the Ottawa River are the Process Outfall (PRO) (associated with NRU secondary cooling and WTC effluents), Perch Creek (associated with the WMAs located in the Perch Lake basin), discharges from Manhole 4F6 and discharges from the Maskinonge Lake basin (discharging to the Ottawa River via Chalk Lake). These four sources represented 97% of the tritium releases to the Ottawa River in 2020. As in previous years, monitoring in 2020 found stable tritium concentrations in the Ottawa River near CRL and further downstream, at Petawawa and Pembroke, which are consistent with effluent releases from the Chalk River site. Tritium concentrations at downstream monitoring locations were less than 5 Bq/L, well below the Canadian Drinking Water Guideline of 7,000 Bq/L [10] and the ecological risk benchmark value of 17.4 MBq/L [3]. While it may appear in Figure 3 that there was a decrease in tritium from 2012 to 2013, concentrations in the Ottawa River were in fact very similar from one year to the next. The apparent decrease stems from a change in the way in which values that fall below the Critical Level (L_C) or Detection Limit (L_D) were used in calculations, whereby the actual numerical measurement result is used, if available. This was changed again in 2020, such that if a value falls below the L_C, the value of the L_C is used in calculations and reported as Not Detected. In addition, in 2015, the Monitoring Services (MS) supporting the EnvP Program began running analysis on a newly acquired High Volume Liquid Scintillation Counter (LSC). This new counter reduced the L_D from 3.0 Bq/L to 0.5 Bq/L, which sequentially increased CRL's confidence in measured results at these low levels, while also decreasing analytical uncertainty associated with the measured results.

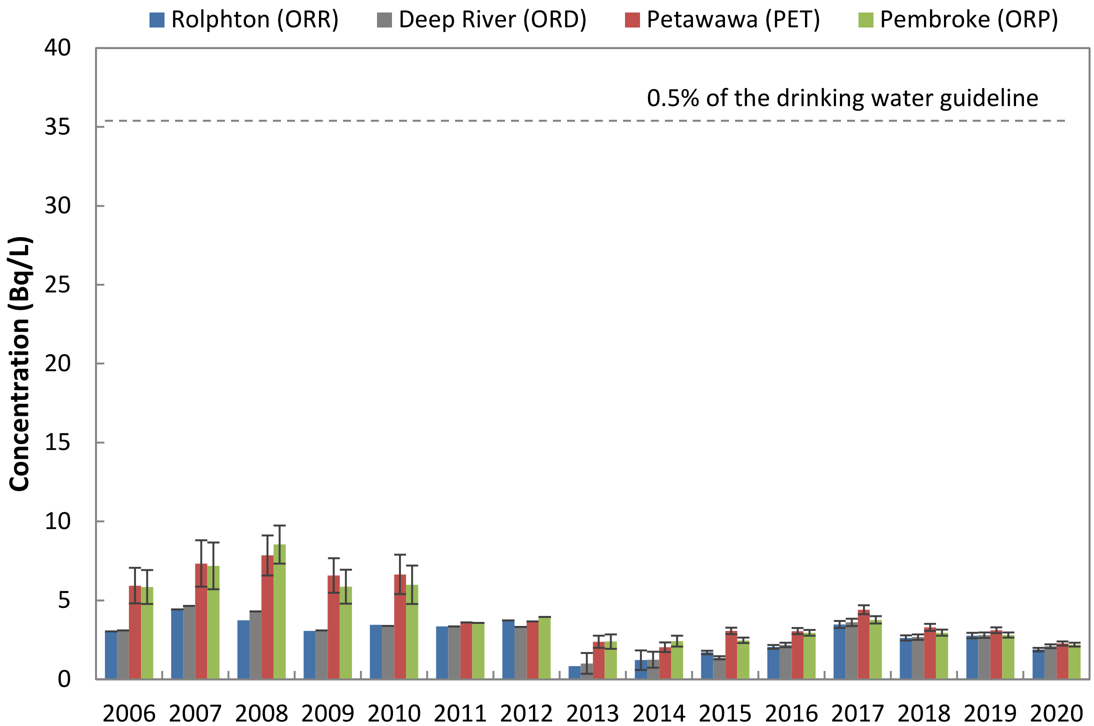

Figure 3 Tritium concentrations in the Ottawa River upstream (ORR, ORD) and downstream (PET, ORP) of the Chalk River Laboratories

The primary sources of waterborne gross beta to the Ottawa River are the Process Outfall (PRO, associated with WTC operations) and Perch Creek (associated with the WMAs located in the Perch Lake basin). These two sources represented 96% of the gross beta releases to the Ottawa River in 2020. In the Ottawa River, concentrations of the anthropogenic gross beta constituents Caesium-137 (^{137}Cs) and ^{90}Sr were only a small fraction of the Canadian Drinking Water Guidelines (10 Bq/L and 5 Bq/L, respectively) [10] and the ecological benchmark values (72.7 Bq/L and 183 Bq/L, respectively) [3]. This is consistent with effluent releases from the Chalk River site in 2020 (i.e., gross beta levels from PRO averaged 0.10 Bq/L and were indistinguishable from concentrations in the Ottawa River upstream of the site).

As previously mentioned, the beta activity concentrations at the shoreline in 2020 were in line with expectations and the levels observed in most recent years. The source of gross beta activity to the Ottawa River includes groundwater migration of gross beta (^{90}Sr and ^{90}Y) from the NRX Rod Bays, which has resulted in a localized groundwater plume extending to the river. Elevated concentrations of gross beta activity continue to be measured in groundwater immediately downgradient of the NRX Rod Bays with lower concentrations (the average being 229 Bq/L) occurring near the discharge zone along the shoreline region. Gross beta activity releases from the plume are expected to gradually decline as inputs to the plume were stopped in 2006 when the NRX Rod Bays were drained. Where the groundwater discharges into the Ottawa River through the riverbed, concentrations of gross beta are also estimated to be lower than the ecological benchmark value of 366 Bq/L (or 183 Bq/L ^{90}Sr) [3]. This is conservative, assuming that the concentrations near the discharge zone in the riverbed (where ecological receptors would reside) are similar to those observed in the shoreline groundwater monitoring.

Overall, the impacts of tritium and gross beta releases to the Ottawa River are very low and the release trends have remained stable with slight declines.

Perch Lake Basin

The Perch Lake basin drains approximately 18% of the CRL site. Drainage from this basin is into Perch Lake, and then through Perch Creek into the Ottawa River. A number of WMAs are located within this basin, including WMAs D, G and H (MU 2), WMA B (MU 3), WMA A and the Liquid Dispersal Area (LDA) (MU 6), and WMA E and Waste Tank Farm (MU 9) (see Figure 2). The LDA includes Reactor Pit 1, Reactor Pit 2, the Chemical Pit and the Laundry Pit.

The main contaminant of concern associated with the Perch Lake basin continues to be gross beta activity, primarily ^{90}Sr. The most significant sources of ^{90}Sr are from WMA A, the LDA, and WMA B. Between 1946 and 1955, WMA A received solid wastes, wastewaters from the NRX, and waste solutions from fuel reprocessing experiments. In 2013, a permeable reactive barrier was installed downgradient of WMA A to remove ^{90}Sr from groundwater that discharges to an adjacent wetland (South Swamp). The LDA, primarily the Chemical Pit (1956-1994) and Reactor Pit 2 (1956-2000), were used to discharge low-radioactivity wastewaters and were designed to promote wastewater infiltration to ground. A portion of the groundwater plume from the Chemical Pit is pumped and treated by a groundwater treatment facility before being discharged to East Swamp Stream. Contaminants are transported from WMA A and the LDA via groundwater to nearby wetlands (South and East Swamp) and from there by overland flow through Main Stream and East Swamp Stream to Perch Lake.

The northwest corner of WMA B is occupied by unlined sand trenches that were used to bury low and intermediate level solid wastes between 1953 and 1963. A plume originating from the trenches has caused the ^{90}Sr contamination in West Swamp. A portion of this plume has been treated by the Spring B Treatment System that has operated since 1993. During 2019, a new Spring B Treatment facility was commissioned, supplementing operations of the older, less efficient system. There is still a small portion of the groundwater from the unlined trenches that goes untreated, therefore the West Swamp continues to receive ^{90}Sr (and small quantities of tritium). Contaminants are transported by surface water from West Swamp to Perch Lake via Perch Lake Inlet 1 (PL1).

The risks associated with the presence of ^{90}Sr in the Perch Lake basin in 2020 are considered to be moderate; that is, contaminant concentrations exceed the benchmark value in localized regions of the drainage basin, with Perch Lake (PL) Inlet 1 and PL Inlet 2 showing stable conditions. Gross beta activity in Perch Creek (Perch Creek Weir (PCW) plotted in Figure 4) before it enters the Ottawa River has ranged from 3 Bq/L to 13 Bq/L over the past 20 years, and averaged 5.7 Bq/L in 2020 (or an average loading of 0.0001 TBq/month), which is a small fraction of the DRL (37.5 TBq/month [11]) and the ecological benchmark value (183 Bq/L for ^{90}Sr [3]), respectively.

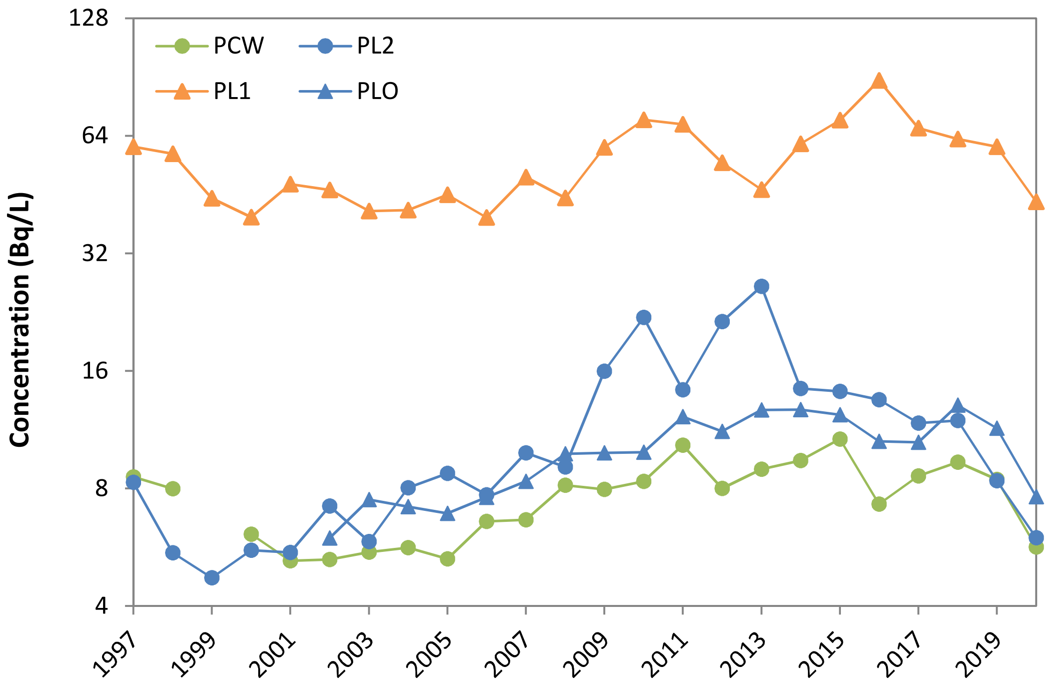

Figure 4 Gross Beta (90Sr and 90Y in Equilibrium) Concentrations at Perch Lake Inlets (PL1 and PL 2) and in Perch Creek (Outlet, PLO and PCW)

Note: Changed to base 2 log scale in 2016.

In addition to ^{90}Sr, tritium contamination remains present in the Perch Lake basin. Ongoing inputs of tritium to groundwater are occurring in WMA B, primarily from some of the cylindrical bunkers located in the southern portion of the compound. These releases are discharged into the wetland that drains through PL1, as well as to Main Stream, which enters Perch Lake at PL2. Most of the tritium passing through Perch Creek, however, arises from the former dispersal of spent fuel bay water in Reactor Pit 2 (RP2). Tritium migration from RP2 has resulted in the development of a groundwater tritium plume that has extended into Perch Lake and Perch Creek. There have been no tritium inputs to RP2 since 2000 and tritium discharges to local surface waters (East Swamp Stream and the South Swamp) ceased within two years of the termination of RP2 inputs. Tritium in the groundwater flow system between the reactor pit and Perch Lake and Perch Creek will continue to discharge to those water bodies for several decades yet.

At PCW, tritium concentrations and loadings have decreased by a factor of three over the period between 1995 and 2011, and have been gradually decreasing since that time. In 2020, the tritium concentration in Perch Creek averaged 2,905 Bq/L, very similar to 2019 (2,934 Bq/L), and on par with the previous 5-year average (Figure 5). A marginal increase has been noted since 2017 when the lowest annual average was reported (2,055 Bq/L), and this may be attributed to a groundwater seepage area with elevated tritium near the outlet of Perch Lake. The Perch Lake basin tritium concentrations are a small fraction of the ecological risk benchmark value of 17.4 MBq/L, and average tritium releases from Perch Creek to the Ottawa

River represent 0.00035 % of the DRL. Tritium in the Perch Lake basin does not represent a significant risk to the environment.

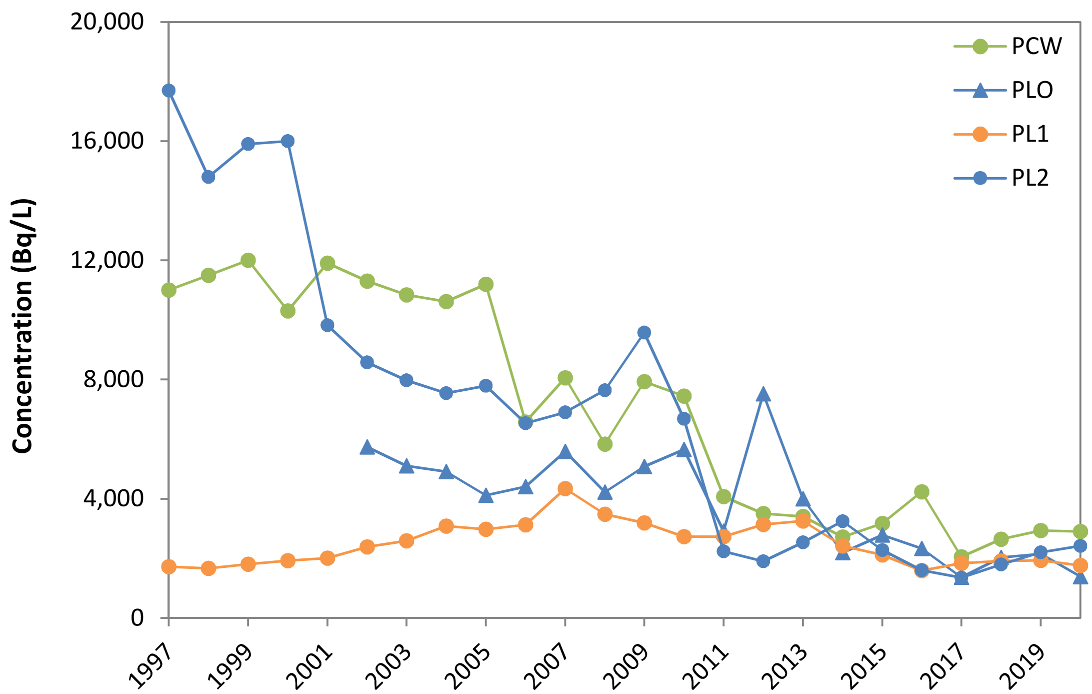

Figure 5 Tritium concentrations at Perch Lake Inlets (PL1 and PL2) and in Perch Creek (outlet, PLO and PCW)

Other contaminants of interest within the Perch Lake basin include mercury and chlorinated solvents, which are present only in small, localized areas of the basin, primarily detected in groundwater.

Mercury concentrations are routinely monitored in groundwater downgradient of many WMAs. Groundwater mercury concentrations exceeding the ecological risk benchmark value of 0.23 µg/L were encountered up until 2016 (a maximum of 8 µg/L) in several areas: downgradient of the Chemical Pit, Electrical Storage Yard Landfill (Landfill 2) in the Grey Crescent Region, WMA F, Concrete Lined Crib No. 3 (CLC-3 facility) in the central region of WMA B, and on the western perimeter of WMA B. In 2020, the fall measurement of mercury at South Swamp (SSW) downgradient of the Chemical Pit (0.04 µg/L) exceeded the surface water screening criterion (0.026 µg/L). This is the first mercury exceedance at this location, and does not indicate that ecological effects are occurring at this location; it will continue to be monitored for changes.

A range of chlorinated volatile organic compounds are detected in the groundwater at the northeast corner of WMA B. These contaminants form a groundwater solvent plume emanating from the eastern section of unlined sand trenches, with the main contaminant of concern being 1,1,1-trichloroethane. This contaminant was undetectable in surface waters downgradient of the solvent plume for many years and was removed from the surface water program in 2020 as the expectation is that upon reaching surface waters the compounds rapidly evaporate, dispersing into the atmosphere and then degrading, and thereby limiting the potential for ecological effects. Sediment in Main Stream at Plant Road, and downstream at PL1 was analyzed for volatile organic compounds in 2020, but most were again below detection levels. The impact of volatile organic compounds in the Perch Lake basin is therefore characterized as being of low risk.

Maskinonge Lake Basin

The Maskinonge Lake basin drains almost 40% of the CRL site. Drainage from this basin is into Chalk Lake, and then into the Ottawa River. A number of WMAs are located within this basin, including WMA C, the Nitrate Plant, and the Thorium Pit (MU 8, MU 10 and MU 11, see Figure 2).

The main contaminant of concern associated with the Maskinonge Lake basin is tritium, associated with WMA C, where low level solid wastes were buried in unlined trenches between 1963 and 2000. The groundwater tritium plume arising from WMA C, discharges to two nearby wetlands, which in turn drain through Duke Stream (DSW), Bulk Storage Stream (BSW), and Lower Bass Creek (LBL) and eventually to Maskinonge Lake (MLO) (Figure 6). Most of the WMA C groundwater plume discharges to the southern portion of Duke Swamp and is transported overland through DSW.

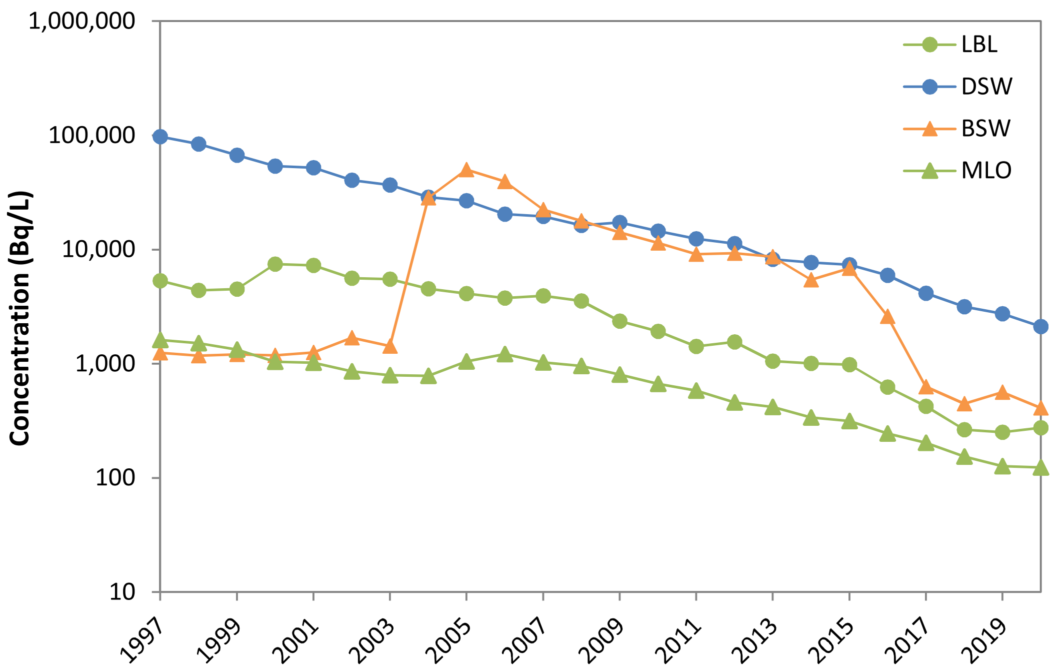

Figure 6 Tritium concentrations in surface water of the Maskinonge Lake basin

Note: Lower Bass Lake (LBL), Duke Swamp Weir (DSW), Bulk Storage Weir (BSW) and Maskinonge Lake Outlet (MLO). Concentrations are displayed on a logarithmic scale

Tritium concentrations and fluxes in Duke Stream peaked in 1983, and have decreased exponentially ever since. Tritium concentrations in BSW increased sharply in 2004 following the failure of waste containers in the WMA C Extension, but since 2005, the concentrations in this watercourse have decreased steadily. In 2013, an impermeable cover was installed over WMA C. The expectation was that the effects of the cover on downgradient groundwater quality would first be evident in the tritium data (expected to be observed in 2017), as tritiated water moves with no retardation. Concentrations continue to decrease at both DSW and BSW after the higher 2016 average values of 5,958 Bq/L and 2,597 Bq/L, which have now decreased to 2,119 Bq/L and 410 Bq/L in 2020, respectively. These declines were also observed downstream in MLO which dropped from 246 Bq/L in 2016 to 124 Bq/L in 2020. Tritium concentrations in Chalk Lake are consistent with the five-year average concentration (30 Bq/L). Concentrations remain a negligible fraction of the ecological risk benchmark value (17.4 MBq/L).

Operations in the Nitrate Plant compound from 1953 to 1954 led to several releases of highly radioactive waste solutions and subsequent migration of ^{90}Sr. Substantially elevated concentrations of gross beta activity (^{90}Sr and ^{90}Y) continued to be measured in groundwater immediately downgradient of the Nitrate Plant (averaging 4.0 kBq/L in 2020). The “Wall and Curtain” passive groundwater treatment facility removes ^{90}Sr from the groundwater downgradient of the monitoring location and the Nitrate Plant. In 2020, water in the treatment system’s effluent, which is discharged to Lower Bass Creek, contained < 1 Bq/L of total beta activity.

Gross beta concentrations at LBL, which receives contributions from the Nitrate Plant and Thorium Pit Plume, averaged 2.8 Bq/L in 2020 (Figure 7), which remains a small fraction of the ecological risk benchmark value (183 Bq/L for ^{90}Sr [3]). A gradual increasing trend was noted from 2011 to 2015 and found to be the result of groundwater by-passing the Wall and Curtain, but it was reconfigured in 2013 and this trend has stabilized as a result of remedial work.

Finally, at the outlet of Maskinonge Lake (MLO), which receives water from Lower Bass Creek, the beta activity concentrations have remained stable over the period from 1996 to 2020, and are close to background (0.21 Bq/L) as displayed in Figure 7.

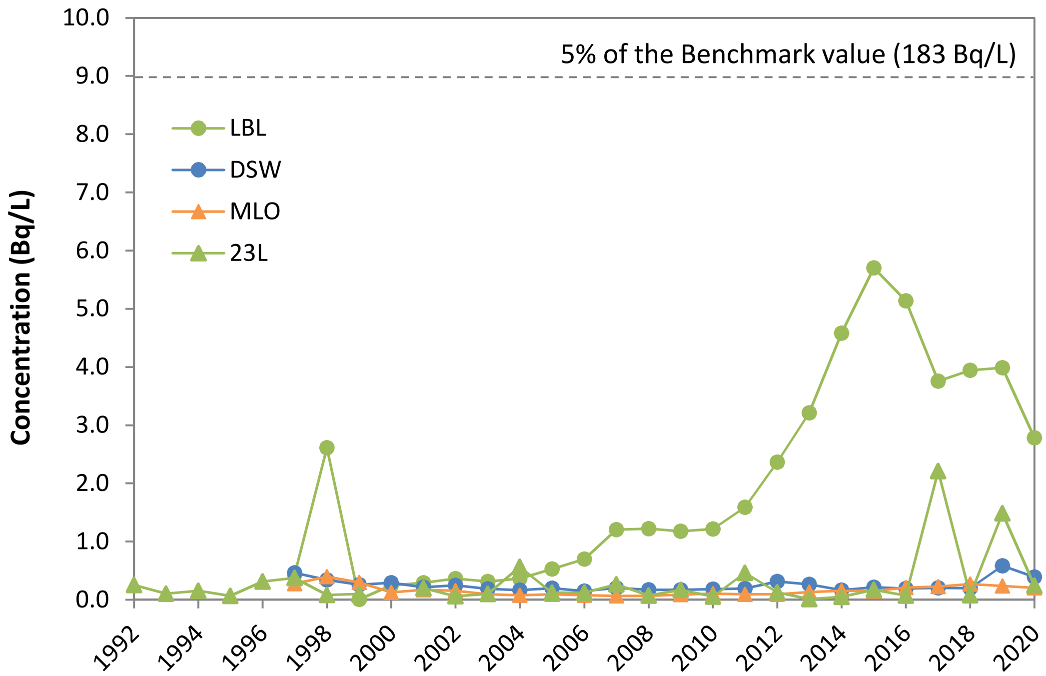

Figure 7 Gross Beta concentrations in surface waters of the Maskinonge Lake basin

Note: Lower Bass Lake (LBL), Duke Swamp Weir (DSW), Maskinonge Lake Outlet (MLO) and Lake 233 (23L).

A number of chlorinated volatile organic compounds, including chloroform, 1,1-dichloroethane, 1,1,1-trichloroethane, and trichloroethylene are detected in the groundwater along both the west and south perimeters of WMA C. The 2020 concentrations of these organic compounds at these and all other sampling locations were, in general, within the historical data range or slightly lower than those observed in previous years, showing overall stability or slight improvement in the degree of this solvent contamination. These compounds were always found to be undetectable in surface waters downgradient of the WMA C solvent plume, and were removed from the program in 2020. Sediment from Duke Swamp Stream was analyzed for these compounds in 2020 and were also found to be below detection. This supports the expectation that, upon reaching the surface water environment, the compounds rapidly volatilize, dispersing into the atmosphere and decomposing, and thereby limiting the potential for ecological effects.

Overall, for all of the contaminants of concern in the Maskinonge Lake basin, risks are judged to be low with stable or improving performance.

Airborne Contaminants

In 2020, the predominant airborne emissions resulting from CRL operations was tritium. In previous years, the primary contaminant was mixed noble gases (^{41}Ar), however, after the NRU reactor was placed in a safe shutdown state on March 31, 2018, ^{41}Ar is no longer being released and monitoring was ceased.

Continued monitoring of ambient gamma confirmed that levels of radiation in the environment from CRL operations were below regulatory limits (i.e., derived release limits) and below levels at which ecological effects could potentially occur.

Processes from the NRU facility continued to be the main source of airborne tritium emissions at the CRL site in 2020, being released from roof vents, fans and fugitive emissions, with 43% of the total coming from the NRU reactor stack. Since the NRU reactor shutdown, tritium releases have continued to decrease. Decreasing trends in measured ambient tritium in air around the CRL site through 2020 were consistent with the decline in emissions observed in 2020. Ambient tritium concentrations dropped considerably with increasing distance from the NRU facility, with many of the stations along the CRL boundary and all off-site stations being at levels comparable to natural background levels, which range from 0.09 Bq/m^3 to 0.26 Bq/m^3 in Ontario [12]. Levels of airborne tritium released into the environment from CRL operations were below release limits and below levels at which ecological effects could potentially occur. The impact of airborne tritium on the environment is therefore characterized as being of low risk.

In 2020, CRL was again required to report annual releases under the *National Pollutant Release Inventory* (NPRI) [13]. Note that this reporting included relevant waterborne, land and waste releases, in addition to airborne releases. Reporting was required for Part 4 Substances - Criteria Air Contaminants (CACs) only, including: NO_x, Particulate Matter 10 microns or less (PM_{10}) and Particulate Matter 2.5 microns or less ($PM_{2.5}$).

Asbestos met the reporting threshold but did not have measurable airborne emissions. Mercury emissions were reported in 2020 due to disposal quantities. Airborne emissions were similar to previous years and are primarily from the burning of Natural Gas on site.

Reporting releases under the Greenhouse Gas (GHG) Emissions Notice [14] is required if CRL emits over the 10,000 tonnes of CO_2 equivalent (CO_2e) within the calendar year. CRL emitted 26,150 CO_2e tonnes in 2020 and was therefore required to report. In 2020, the overall decrease of CO_2e greenhouse gas emissions from CRL compared to 2019 emissions was largely due to: (1) the reduced fuel use requirement at the Powerhouse through the installation of an economizer which recovers energy, and (2) reduced emissions from the Van de Graaff facility.

Assessment of Dose to the Public

The monitoring of environmental pathways conducted as part of the EMP was used to assess the radiation doses due to emissions from CRL during 2020, to the most exposed members of the public (i.e., critical groups). Calculated doses were compared to the regulatory limit for effective dose to members of the public (1 mSv in a year) and, as required by the site licence, were used to verify that doses did not exceed 0.3 mSv in any 12 month period (Table 2).

Doses are based on environmental concentrations of radionuclides measured in the environment near critical group locations. The radionuclides included in the dose assessment are those that are known or expected to be released from CRL and are detectable in the environment, or have the potential to contribute significantly to dose. The pathways included in the dose assessment are those that have the potential to contribute significantly to the dose to any critical group [11]. Other radionuclides and environmental exposure pathways for which the dose contribution is negligible were not included in the dose assessment (e.g., ingestion of well water). The doses to critical groups from both air and liquid effluent pathways for 2020 and the previous five years are summarized in Table 1, Table 2 and Figure 8.

The final dose is broken up into two components:

- The dose from air effluent pathways, which include air inhalation and immersion, consumption of garden produce and terrestrial animal produce (i.e., beef, pork, and wild game), is portrayed in Figure 9.
- The dose from liquid effluent pathways, which include ingestion of water, consumption of fish, and external exposure to beach sand, is portrayed in Figure 10.

In 2020, the total estimated dose to the public for all air effluent exposure pathways, as summarized in Table 1, represented 0.59% of the regulatory public dose limit of 1 mSv, which is a slight increase when compared to the dose reported in 2019 (0.29%). The apparent increase in 2020 can largely be attributed to natural variability of radioactive concentrations in environmental compartments, such as garden produce and animal meat, at both background and indicator locations. Coupled with small sample sizes and, therefore, high uncertainty, fluctuating low dose estimates may become the norm now that the previous major contributors (NRU ^{41}Ar exposure) no longer exist. In 2020, more detailed statistical analyses were done comparing current and historical data from background and critical group locations, and for many parameters, found that results are statistically the same. These could then be excluded from the dose assessment. Furthermore, it is important to note that because the NRU stack was not the main source of airborne tritium in 2020 (contributions from the stack were 43% of the total tritium emissions from site, with the remaining released from roof vents/fans/doors), the assumed critical group used in dose calculations is different than that used in previous years and adjustments were made where required.

The total estimated dose to the public for all liquid effluent exposure pathways in 2020, as summarized in Table 1, represented 0.152% of the regulatory public dose limit of 1 mSv, which is an increase from the dose reported in 2019 (0.097%). The slight increase in the estimated dose in 2020 may be linked to minimal variations in all pathways, including fish ingestion, drinking water and beach sand exposure. When dealing with many results either at or below detection levels in these pathways, any small difference at either background locations or indicator locations can have an impact on the final dose estimates. Overall, the dose from liquid effluent exposure pathways continues to contribute a small percentage of the regulatory public dose limit.

The higher uncertainty associated with the dose values after 2014 can, in part, be attributed to the CNL EMP moving from reporting a ±1 sigma uncertainty to the method outlined in [4] that more accurately represents the uncertainty associated with the measured value. This has, in general, resulted in a higher reported uncertainty than what has been seen in previous years.

Each year, the total radiological releases from the Chalk River site (measured as part of the EVMP) are compared to site-specific Derived Release Limits in order to estimate doses to public from exposure to airborne and liquid emissions [15]. In order to verify the adequacy of effluent monitoring, the doses estimated from effluent monitoring results are compared to the public doses presented in Table 1, which are calculated based on the results of environmental monitoring. Upon comparison, the 2020 estimated doses from airborne emissions monitoring (based on EVMP results) were much lower, with an estimated dose of 0.09% of the DRL compared to a calculated dose of 0.59% of the public dose limit (Table 1) derived from environmental monitoring results. The estimated dose of 0.056% of the DRL for liquid emissions from the EVMP was also lower than the calculated dose of 0.15% of the public dose limit (Table 1). The calculated environmental dose is higher than that estimated with data from the EVMP because of different pathways being considered in the DRL model versus the EMP. The greatest contributor to the calculated airborne pathway dose is game animal ingestion (0.58% of the total air dose of 0.59%). However, it is important to note that the on-site game animals that are included in the assessment could be exposed to contamination unrelated to air effluents; rather any contamination is likely related to the site's WMAs and legacy contamination. This distinction introduces an expected discrepancy between the dose estimate calculated from the EMP data and that estimated through the application of DRLs to data from the EVMP.

Conclusion

During the 2020 calendar year, the EnvP Program and the EMP met its objectives. The combined operation of the EMP, EVMP and GWMP enables the tracking of contaminants through the different environmental compartments of the geosphere and biosphere, allowing conclusions to be drawn on the overall environmental impact of CRL operations.

Based on the discussion of contaminants of concern at source areas, identified by comparison to ecological effects concentrations, only one was deemed of moderate environmental impact (all others were of low environmental impact): ^{90}Sr migration originating from certain WMAs within the Perch Lake basin. However, all of the related source areas were shutdown decades ago, and the elevated concentrations of ^{90}Sr occur over relatively small regions of the basin. Contaminant concentrations at the outlet of the drainage system, although gradually increasing in recent years, are below the benchmark value (183 Bq/L), and releases to the river continued to represent a small fraction of the release limit. The impacts of ^{90}Sr migration in the Perch Lake basin are mitigated by continuing operation of three groundwater treatment systems.

Overall, the environmental impact of CRL operations can be characterized as low risk, in that the potential for human or ecological impacts is low, and overall trending indicates stable performance. The 2020 radiological environmental monitoring results indicated stability in the performance of facilities and operations at CRL, and that the controls for the release of radioactive contaminants currently in place at CRL continue to provide protection to the environment and the public. The information and data presented in this report support the conclusion that safe performance is being achieved at the CRL site, and that continuous improvement efforts are also being implemented to improve that performance.

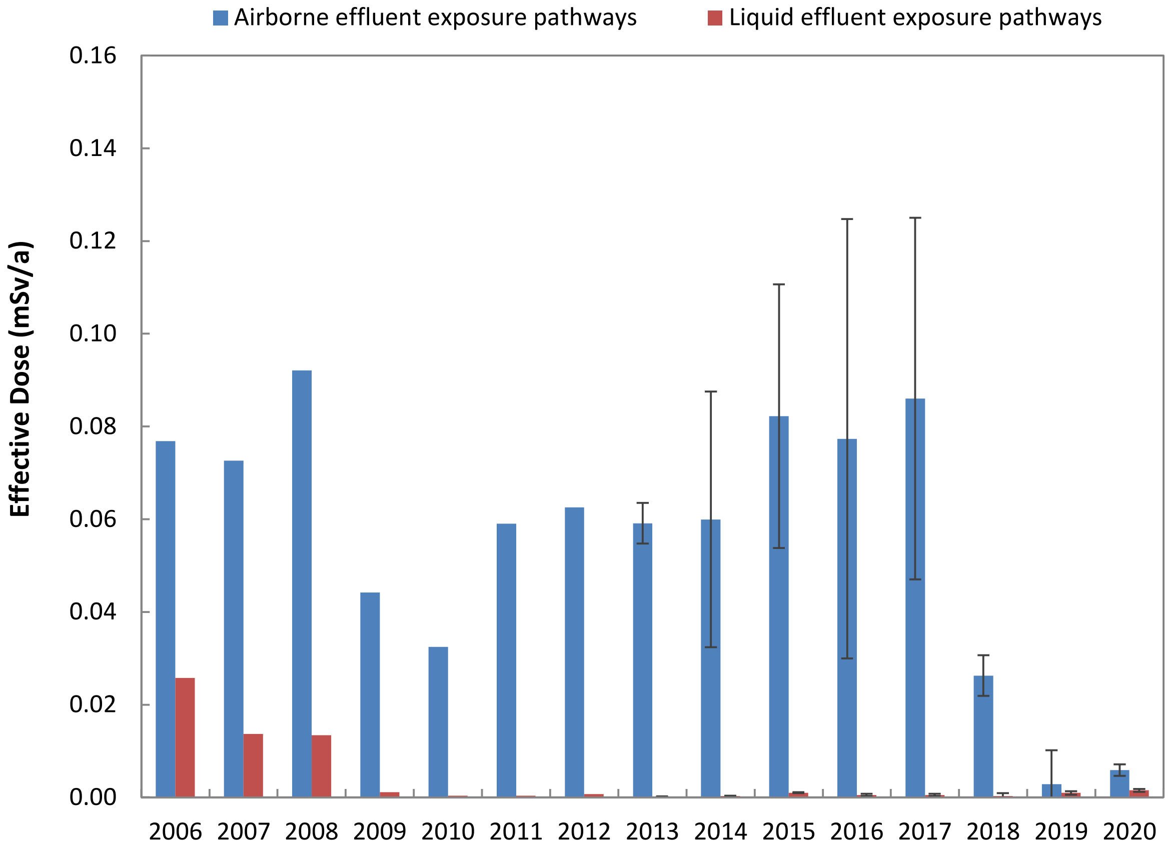

Figure 8 Dose trends to critical groups from 2006 to 2020

As per CSA N288.4 [4], Uncertainty is expressed via ± error bars.

Note: In 2016 the CNL EMP moved from reporting a ±1 sigma uncertainty to a method (described in the CSA N288.4 [4]) that more accurately represents the uncertainty associated with the measured value. This has, in general, resulted in a higher reported uncertainty than what has been seen in previous years.

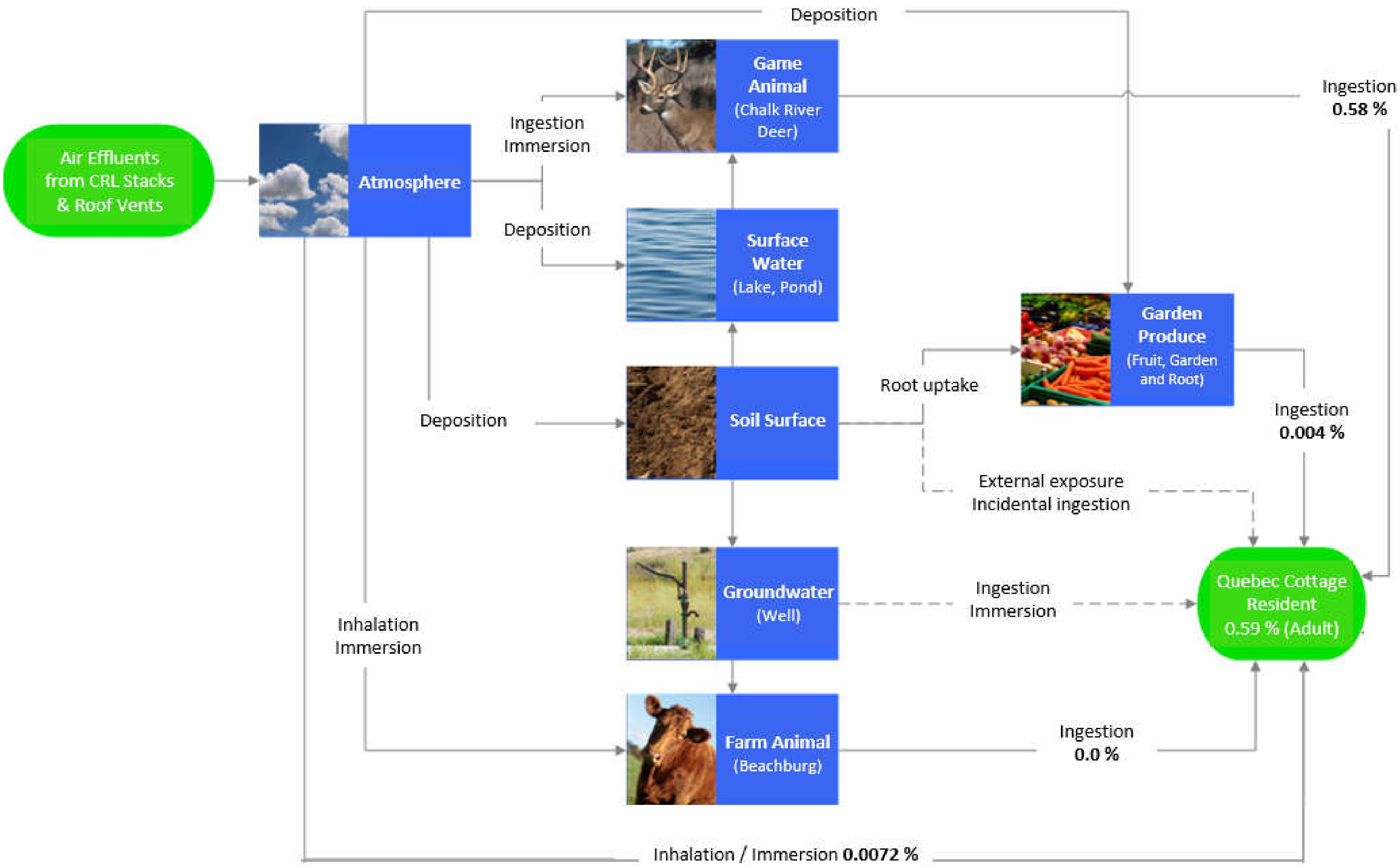

Figure 9 Conceptual diagram of exposure pathways to adults from CRL Airborne Emissions

(Note: Doses are expressed as a Percentage of the Public Dose Limit of 1 mSv per year)

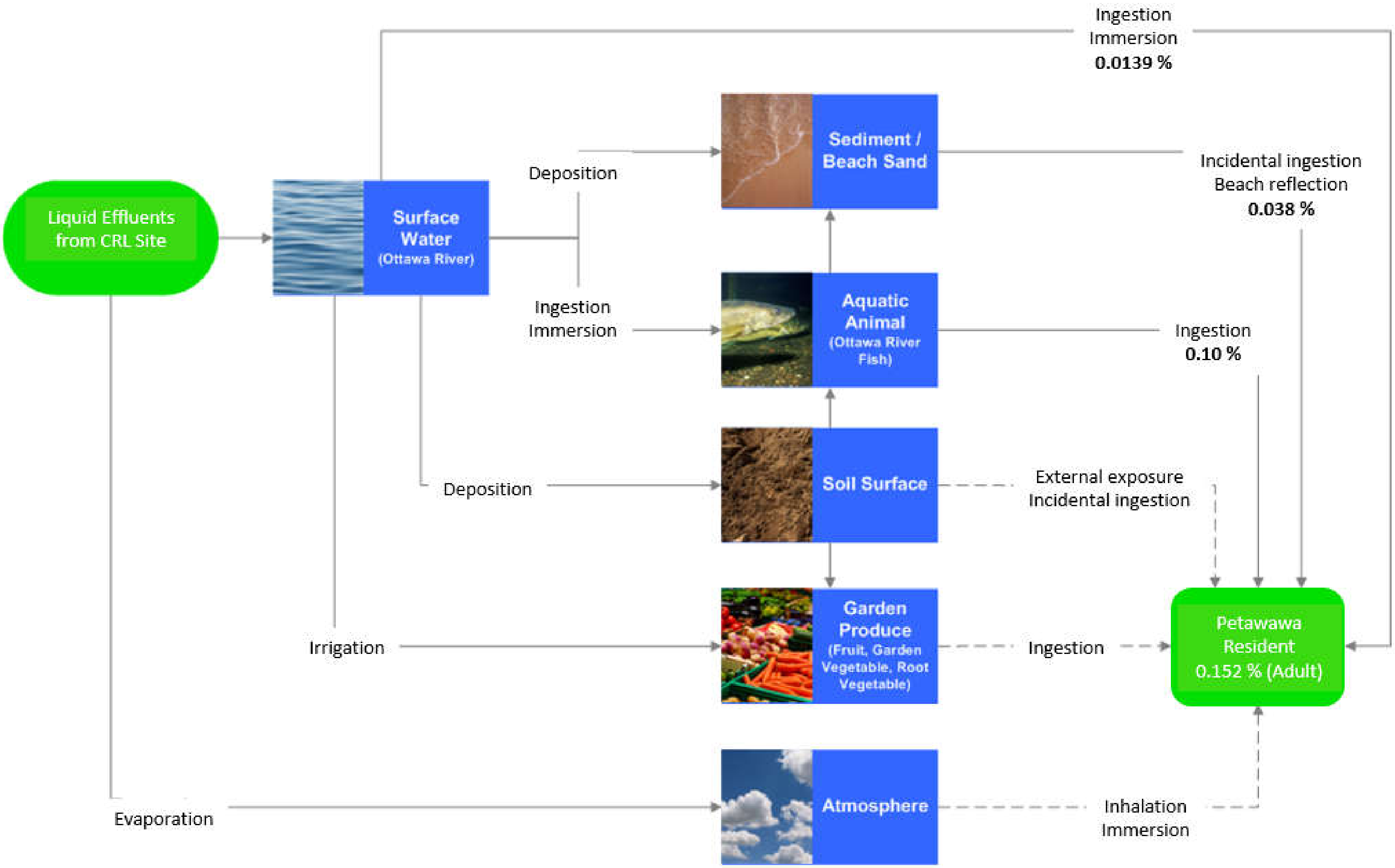

Figure 10 Conceptual diagram of exposure pathways to adults from CRL Liquid Emission

(Note: Doses are expressed as a Percentage of the Public Dose Limit of 1 mSv per year)

Executive Summary References

[1] *Canadian Nuclear Safety Commission, Nuclear Research and Test Establishment Operating Licence, Chalk River Laboratories*, Licence No. NRTEOL-01.00/2028, expires 2028 March 31.

[2] Canadian Nuclear Safety Commission, *Licence Conditions Handbook for Chalk River Laboratories*, NRTEOL-01.00/2028, Revision 1, 2019 February, CRL-508760-HBK-002, 40466302

[3] *CRL Radioactive Environmental Monitoring Plan,* CRL-509200-PLA-005, Revision 1. 20238036

[4] *Canadian Standards Association,* CAN/CSA-N288.4-10, *Environmental Monitoring at Class I Nuclear Facilities and Uranium Mines and Mills*, 2010 May.

[5] *Management and Monitoring Emissions*, 900-509200-STD-009, Revision 0. 35270485.

[6] *Environmental Monitoring Program,* 900-509200-STD-010, Revision 0. 41549534.

[7] *Protection and Monitoring of Groundwater*, 2020, 900-509200-STD-015.

[8] *Environmental Protection Program Radiological and Non-Radiological Monitoring Services Quality Assurance Plan*, ENVP-01913-QAP-001, Revision 2. 20153850.

[9] *Dosimetry Services Quality Assurance Manual*, DSP-508790-QAM-001, Revision 3. 20625113.

[10] Health Canada, *Guidelines for Canadian Drinking Water Quality – Summary Table*, Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment, 2019 June.

[11] *Derived Release Limits (DRLs) for AECL's Chalk River Laboratories*, CRL-509200-RRD-001, Revision 2. 2018. 40450397.

[12] RC-1185, Available Data for Establishing Background Levels in the Vicinity of Canadian CANDU Stations, COG-94-75, 1994 March.

[13] *Canada Gazette*, Part I, *Notice with respect to the substances in the National Pollutant Release Inventory for 2020 and 2021*, Vol 154, No 7, 2020 February 15.

[14] *Canada Gazette*, Part I, *Notice with Respect to Reporting of Greenhouse Gases (GHGs) for 2020*, Volume 155, No 7, 2021 February 13.

[15] *Effluent Verification Monitoring at Chalk River Laboratories in 2020*, CRL-509254-ACMR-2020, 54349113.

Note: The references above only apply to the Summary Section of this ACMR. There is an additional reference section at the end of the main body of this report that applies only to the main report and not this summary section.