

INVENTORY OF RADIOACTIVE WASTE IN CANADA

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Abstract

Since 1999, the Government of Canada has been gathering and compiling Canada's radioactive waste inventory and projection data from waste owners and making it available to the public in the form of a triennial Inventory Summary Report. The goal of this data collection exercise has been to support federal policy development, support the Canadian Nuclear Safety Commission's activities, provide consolidated radioactive waste information for industry, promote transparency, and meet Canada's international commitments and growing demands internationally for radioactive waste data.

Since the coming into force of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* in June 2001, the data collection and reporting cycle has been aligned to provide the waste inventory data required for Canada's triennial National Report to the Joint Convention. To date, the inventory summary reports have been published by Canadian Nuclear Laboratories' (CNL) Low-level Radioactive Waste Management Office (LLRWMO) and made available on its website. Going forward, this data collection and reporting project will be undertaken by Natural Resources Canada (NRCan).

For the 2013 reporting year, Canada modernized the format of the Inventory Summary Report. Employees from NRCan worked closely with staff from CNL and their contractors to revise the text and update the graphics of the report. In addition to the report, Canada developed a Historic Waste Infographic to explain what historic waste is and how it has been managed in Canada.

This paper presents Canada's radioactive waste inventory and projection data and summarizes key findings from the analysis of the data. It also describes some of the uses that are made of the information provided in the inventory. To support Canada's Sixth National Report to the Joint Convention in fall 2017, the national waste inventory will be updated in spring 2017.

1.0 Introduction

Since 1999, the Government of Canada has been gathering and compiling Canada's radioactive waste inventory and projection data from waste owners and making it available to the public in the form of a triennial *Inventory of Radioactive Waste in Canada*, also known as the *Inventory Summary Report*. The goal of this data collection exercise has been to support federal policy development, support the Canadian Nuclear Safety Commission's activities, provide consolidated radioactive waste information for industry, promote transparency, and meet Canada's international commitments and growing demands internationally for radioactive waste data.

2.0 International Requirements for Waste Inventory Reporting

There is an increasing interest within the international community for Canada's radioactive waste data, and Canada made specific commitments to report on its inventory of radioactive waste when it ratified and became a Contracting Party to the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* in 2001. The *Joint Convention* is an international agreement governing all aspects of spent fuel and radioactive waste management, and was the first legally binding international treaty on safety in these areas. The *Joint Convention* represents the Contracting Parties' commitment to achieving and maintaining a consistently high level of safety in these areas. There are now 69 Contracting Parties that have ratified the *Joint Convention*. Contracting Parties meet at triennial review meetings to share information on national policies, practices, and inventories for spent fuel and radioactive waste.

Prior to each triennial review meeting, Contracting Parties are required to submit a National Report. The report must address each Contracting Party's spent fuel management policy and practices, radioactive waste management policy and practices, and criteria used to define and categorize radioactive waste. The report also must include a list of spent fuel and radioactive waste management facilities, an inventory of spent fuel and radioactive waste, and a list of nuclear facilities in the process of being decommissioned. The publication of the *Inventory Summary Report* is aligned with the triennial data collection and reporting cycle for Canada's National Report to *Joint Convention* review meetings.

Besides the triennial submission of data to the *Joint Convention*, Canada regularly submits waste inventory data to support other international projects and initiatives led by the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA), and other international organizations. Two examples are the *IAEA Net-Enabled Radioactive Waste Management Database* (NEWMDB), the *Status and Trends Report*.

Canada submits data to the NEWMDB which contains information on national radioactive waste management programmes, radioactive waste inventories, radioactive waste disposal, relevant laws and regulations, waste management policies, and plans and activities. The NEWMDB's objectives are to improve access to radioactive waste management data and provide a system for maintaining the international "memory" of such information, readily accessible reference material for IAEA Member States, a means to research and assess the development and implementation of national systems for radioactive waste management within IAEA Member States, and a tool that supports the reporting requirements of the *Joint Convention*.

The IAEA *Status and Trends Report*, which is expected to be published in late 2016 or early 2017, will provide a detailed compilation and analysis of the status and trends in radioactive waste management in IAEA Member States.

3.0 Inventory Summary Report

The *Inventory Summary Report* is the definitive inventory of all radioactive waste in Canada. The most recent report provides data current to December 31, 2013. It provides an overview of the production, accumulation and projections of radioactive waste in Canada. Information and data on Canada's radioactive waste inventory is compiled from reports provided by the waste owners on their waste management facilities.

For the 2013 reporting year, Canada modernized the format of the *Inventory Summary Report*. Employees from NRCan worked closely with staff from Canadian Nuclear Laboratories' (CNL) Low-level Radioactive Waste Management Office (LLRWMO) and their contractors to revise the text and update the graphics of the report. In addition to the *Inventory Summary Report*, Canada developed a *Historic Waste Infographic* to explain what historic waste is and how it has been managed in Canada.

3.1 Target audience

The data from the *Inventory Summary Report* is typically used by policy and scientific advisors as well as decision-makers in nuclear-related government and industry roles. For the 2013 reporting year, however, the format and graphics of the report were improved to broaden the target audience. The intention was to create a product that the average member of the public would find to be visually appealing, informative, and easier to follow.

As historic waste is sometimes present within urban environments and on public lands, the project team decided to develop a separate document to explain what historic waste is and how it is managed in a concise and visually-appealing format for the public. During the data collection stage the team reviewed a variety of presentations of scientific data and information in media to identify approaches and techniques to achieve this goal. A historic waste-specific fact sheet/infographic hybrid was eventually chosen for the design. The final product is called the *Historic Waste Infographic* and can be viewed as a companion product to the *Inventory Summary Report*.

3.2 Methodology

The data collection methodology for the 2013 reporting year remained largely the same as in previous years. NRCan contacted waste owners and informed them that a representative from the Government of Canada would be contacting them shortly for their inventory data. The data was then collected and processed by an engineering and environmental consulting services contractor for use in both the *Joint Convention* and the *Inventory Summary Report*.

While not required under the *Joint Convention*, Canada has always collected and disseminated future projections of waste inventory data in addition to current inventory data. This projection data is reported for the next triennial reporting year, for 2050, and in the case of decommissioning waste, for the year 2100. The rationale for providing projection data up until

the year 2100 for decommissioning waste is that it is expected, by that time, that all currently-operating Canadian reactors will have been closed and fully decommissioned.

4.0 Data Summary and Analysis

The following section summarizes Canada's radioactive waste inventory data from the *Inventory Summary Report* under the three categories: High-Level Radioactive Waste (HLRW), consisting in Canada of nuclear fuel waste¹, Low- and Intermediate-Level Radioactive Waste (LILRW), and Uranium Mine and Mill Tailings.

4.1 High-Level Radioactive Waste

In the *Inventory Summary Report*, all HLRW listed is in fact nuclear fuel waste. The federal *Nuclear Fuel Waste Act* defines nuclear fuel waste as irradiated fuel bundles removed from a commercial or research nuclear fission reactor. While most nuclear fuel waste is in the form of a CANDU fuel bundle, nuclear fuel waste from research reactors can be in the form of fuel rods or fuel assemblies. HLRW is generated when nuclear fuel is removed from a reactor during operations, or prior to decommissioning activities.

As of December 31, 2013, the total inventory of HLRW in Canada was 10,021 m³. The total HLRW inventory to the end of 2013 for power reactors was approximately 9,758 m³ or 2,437,770 bundles. As of December 31, 2013, the HLRW from the three shutdown prototype/demonstration reactors (Douglas Point, Gentilly-1, and Nuclear Power Demonstration) remained at 122 m³ (30,355 bundles). The balance of the inventory consists of 141 m³ of HLRW (bundles, rods, assemblies, units and items) from research reactors at Atomic Energy of Canada Limited's (AECL) Chalk River and Whiteshell Laboratories, as well as the McMaster Nuclear Reactor (MNR).

In Canada, there are 22 power reactors owned by three provincial utilities. Ontario Power Generation (OPG) owns 20 reactors while Hydro-Québec and New Brunswick Power (NB Power) each own one reactor. Hydro-Québec's Gentilly-2 reactor and two reactors at OPG's Pickering nuclear generating station are now in safe shutdown. The 19 operating reactors have a total generation capacity of 15,000 megawatts of electricity. Nuclear fuel waste from power generation is currently safely managed in facilities licensed for interim storage at the nuclear reactor sites in Ontario, Quebec and New Brunswick, and is destined for future management in a deep geologic repository that will be sited and constructed by the Nuclear Waste Management Organization (NWMO).

As shown in Figure 1, OPG currently owns 87% of Canada's nuclear fuel waste. Hydro-Québec (5%), NB Power (5%), and AECL (3%) collectively own the remaining 13%. McMaster University also produces a small amount of nuclear fuel waste from research activities and has about 1 m³ of waste in storage.

¹Nuclear Fuel Waste can also be referred to as spent fuel, used fuel or irradiated fuel. It is included in the larger category of "High-Level Radioactive Waste" (HLRW) for the purposes of the Summary Report.

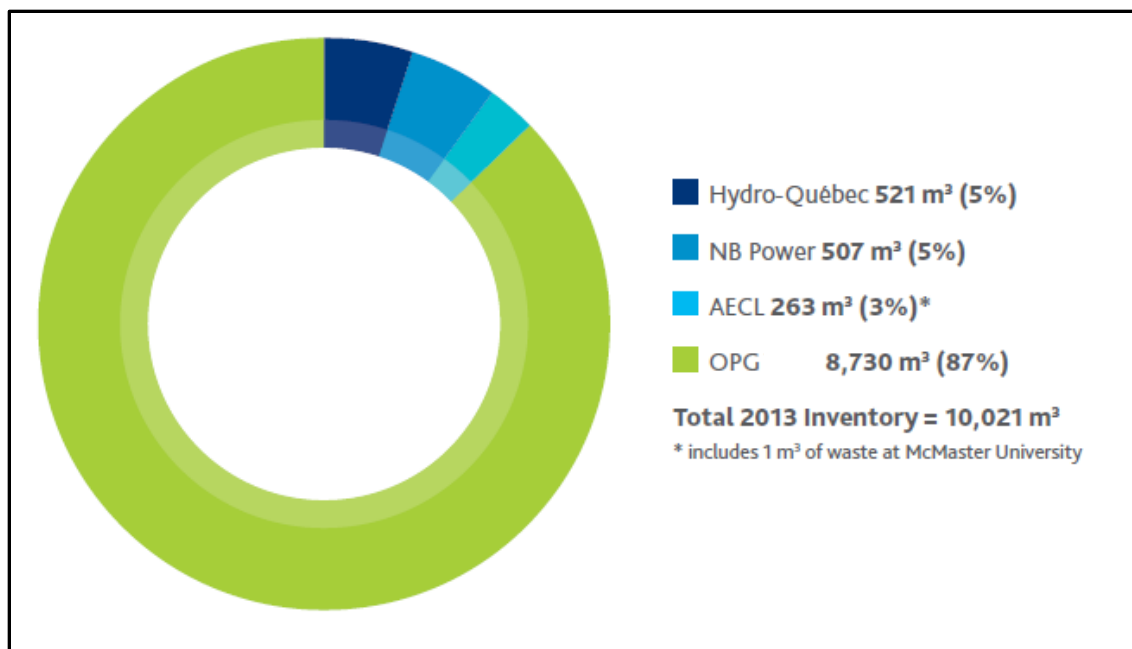


Figure 1– 2013 HLRW Inventory by Waste Owner

Currently, CNL operates two nuclear research reactors at Chalk River Laboratories (CRL) in Chalk River, Ontario. These are the Zero Energy Deuterium 200-Watt Reactor (ZED-2) and the National Research Universal 135-Megawatt Reactor (NRU). Operational HLRW generated at these two reactors is safely managed on site. Nuclear fuel waste from previously shutdown research reactors at CRL and the Nuclear Power Demonstration (NPD) prototype reactor in Rolphton, Ontario is also stored at the Chalk River site. Additional nuclear fuel waste is in storage at Whiteshell Laboratories from the WR-1 reactor, which was shut down in 1985, and at the Gentilly-1 and Douglas Point prototype reactor sites.

From 2010 to 2013, the total inventory of HLRW in Canada increased by 942 m³ (10%). The NWMO has accounted for the projected waste generation from future operations of power and research reactors in developing plans for the long-term management of nuclear fuel waste.

For a map of HLRW locations in Canada, please refer to Appendix 2 – HLRW Inventory Location Map.

4.2 Low- and Intermediate-Level Radioactive Waste

LILRW includes all non-fuel waste arising from activities associated with nuclear power generation and nuclear research and development, as well as waste from the production and use of radioisotopes in medicine, education, research, agriculture and industry. As shown in Figure 2 below, at the end of 2013, there was about 2.39 million m³ of LILRW stored in Canada.

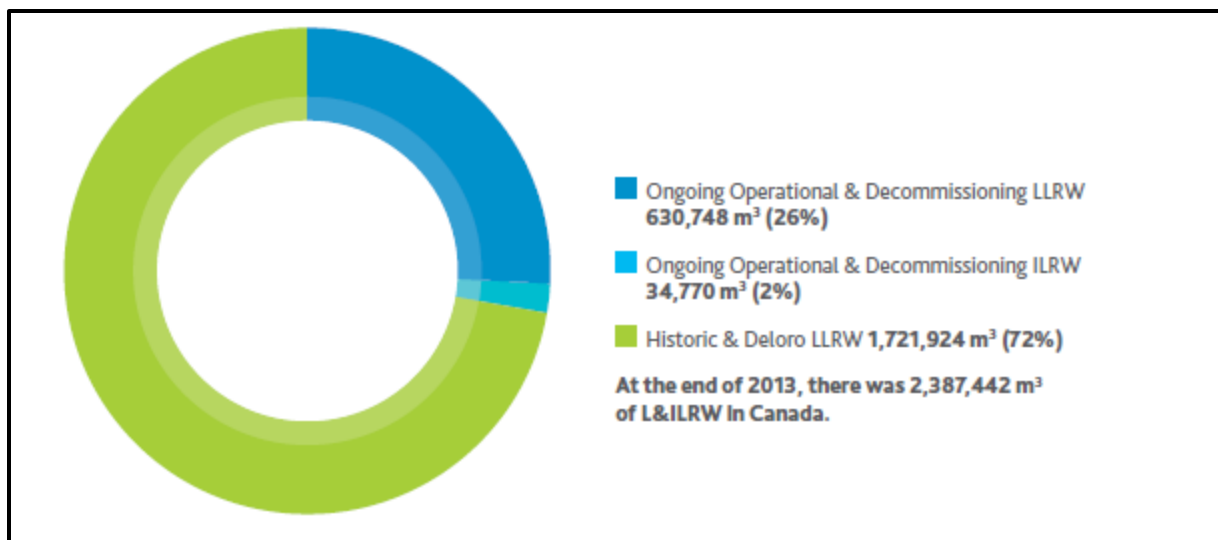


Figure 2 – 2013 Total LILRW Inventory

Approximately 2.35 million m³ (98%) of the overall waste volume is considered low-level radioactive waste (LLRW) from historic, ongoing, or decommissioning sources. LLRW is typically made up of contaminated soils, protective shoe covers and clothing, rags, mop heads, equipment and tools.

The remainder (2%) of Canada's LILRW is intermediate-level radioactive waste (ILRW), which is typically comprised of reactor refurbishment waste, ion-exchange resins and some radioactive sources used in radiation therapy.

As shown by Figure 2, historic waste represents the majority of LILRW in Canada, consisting of roughly 1.72 million m³ or 72% of the total volume. Historic waste is defined as LLRW that has resulted from past practices, is managed in a way that is no longer considered acceptable by today's standards, for which the owner cannot reasonably be held responsible, and for which the Government of Canada has taken responsibility. Most historic waste (approximately 1.6 million m³) is contaminated soil located in the Port Hope area (waste materials from refining operators) with an additional 68,000 m³ of soil which was inadvertently contaminated with uranium ore along the Northern Transportation Route from Port Radium, Northwest Territories to Fort McMurray, Alberta during transport. The total for historic waste also includes 38,000 m³ of waste from the Deloro mine site in Deloro, Ontario, which is the responsibility of the Government of Ontario. This waste resulted from the reprocessing of uranium mine and mill tailings to extract cobalt.

Figure 3 below provides a breakdown by owner of ongoing and decommissioning LILRW in Canada which, as shown in Figure 2, accounts for 28% of the total volume of LILRW in Canada. AECL owns the majority (82%) of Canada's ongoing and decommissioning LILRW. However, this volume includes about 382,800 m³ of contaminated soils, much of which is the result of previous cleanups of historic waste across Canada that is now stored at CRL. OPG owns the second largest inventory (14.8%) of LILRW, and is planning to construct a deep geologic repository at the Bruce Nuclear Site to manage the waste over the long-term. The proposed project is currently undergoing a federal environmental assessment. Cameco owns 2% while

Hydro-Québec and NB Power each own less than 1%. When considering only non-federal sources, OPG owns 84% of the LILRW in Canada.

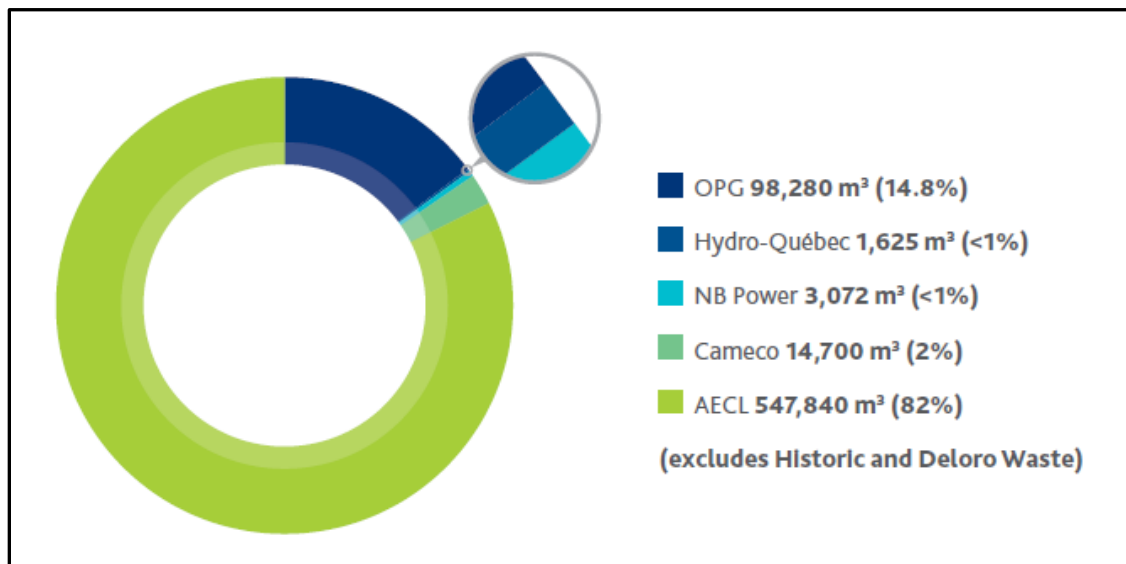


Figure 3 – 2013 Ongoing Operational and Decommissioning LILRW Inventory by Waste Owner

At present, all LILRW is safely stored in the interim awaiting the implementation of long-term management solutions. From 2010 to 2013, the total inventory of ongoing and decommissioning LILRW increased by 16,352 m³ (2.5%). Waste owners are taking into account projected waste generation from future operations in developing their plans for the long-term management of their waste.

For a map of LILRW locations in Canada, please refer to Appendix 3 – LILRW Inventory Location Map.

4.3 Uranium Mine and Mill Tailings

Uranium mine and mill tailings are a specific type of LLRW that is generated during the mining and milling (processing) of uranium ore to produce uranium concentrate. Uranium concentrate, once refined and converted, is used to make fuel for Canadian and foreign power reactors. Today, tailings are placed in mined-out, open pits converted to tailings management facilities (TMFs). However, this was not always the case. Historically, tailings were placed in natural containment areas such as lakes or valleys, or disposed as backfill in underground mines, or placed in engineered surface containment areas.

The total inventory of tailings in Canada is 216,111,650 tonnes. As of December 31, 2013, the inventory of tailings at closed/decommissioned sites was about 201 million tonnes with the vast majority existing in Ontario. About 15 million tonnes was from sites that are currently operating.

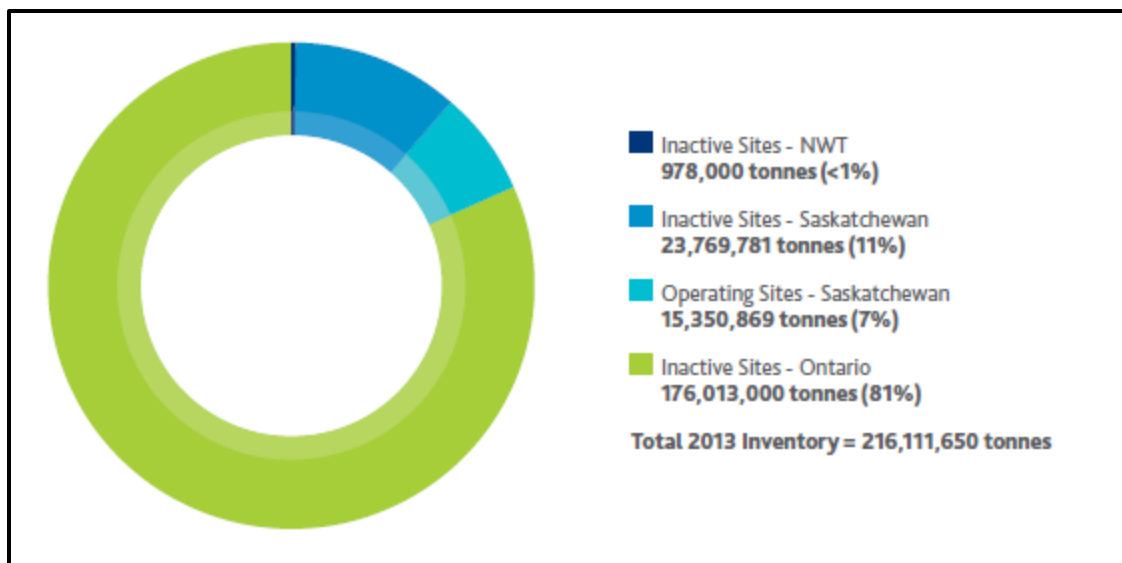


Figure 4- 2013 Uranium Mine and Mill Tailings Inventory

Uranium mine sites are decommissioned in place due to the large volumes and low activity levels of the mine and mill tailings. Decommissioning of surface tailings sites usually includes improvement or construction of dams to provide long-term containment, flooding or covering of tailings to reduce acid generation and the release of gamma radiation and radon gas, and management/monitoring of tailings and effluent.

For a map of uranium mine and mill tailings locations in Canada, please refer to Appendix 4 – Uranium Mine Tailings Inventory Location Map.

4.4 Findings and Conclusions

All nuclear fuel waste is currently held in interim wet or dry storage at the nuclear generating station or research laboratory where it is/was produced, with the exception of the nuclear fuel waste produced at the now-closed NPD prototype nuclear reactor, which is stored at AECL's CRL. All high-level waste is destined for future management in a deep geologic repository that will be sited and constructed by the NWMO.

Canadian waste owners make use of a variety of above-ground and in-ground storage structures and facilities to store LILRW. All structures and facilities that receive waste on an on-going basis provide for complete containment of the LILRW, and prevent the release of contaminants to the environment. OPG, Canada's largest producer of ongoing radioactive waste, has a centralized storage facility, the Western Waste Management Facility (WWMF), for LILRW at the Bruce Nuclear Site, whereas other waste owners generally store their LILRW at the site where the waste was generated. Waste owners are taking into account projected waste generation from future operations in developing their plans for the long-term management of their waste.

Uranium mine and mill tailings are generally managed in place due to the large volumes and low activity levels associated with the waste.

5.0 Finished Products

Canada's National Report to the May 2015 review meeting of the Joint Convention was made available on the Canadian Nuclear Safety Commission (CNSC) website in May 2015. Canada's *Radioactive Waste Inventory Summary Report* was published in November 2015.

The most recent versions of final products are available at the following websites:

1. Canada's National Report to the May 2015 review meeting of the Joint Convention
http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/joint-convention-fifth-national-report-2014-eng.pdf
2. Canada's Inventory of Radioactive Waste in Canada Summary Report
http://www.cnl.ca/site/media/Parent/2013-CNL_LLRW-Summary-Report-Eng.pdf

Appendix 1 – List of Accronyms

AECL	Atomic Energy of Canada Limited
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
CRL	Chalk River Laboratories
HLRW	High-Level Radioactive Waste
IAEA	International Atomic Energy Agency
ILRW	Intermediate-Level Radioactive Waste
LILRW	Low- and Intermediate-Level Radioactive Waste
LLRW	Low-Level Radioactive Waste
LLRWMO	Low-Level Radioactive Waste Management Office
MNR	McMaster Nuclear Reactor
NB Power	New Brunswick Power
NEA	Nuclear Energy Agency
NEWMDB	Net-Enabled Radioactive Waste Management Database
NPD	Nuclear Power Demonstration (shutdown prototype reactor)
NRCan	Natural Resources Canada
NRU	National Research Universal 135-Megawatt Reactor
NWMO	Nuclear Waste Management Organization
OPG	Ontario Power Generation
TMF	Tailings Management Facility
WWMF	Western Waste Management Facility
ZED-2	Zero Energy Deuterium 200-Watt Reactor

Appendix 2 – HLRW Inventory Location Map



Appendix 3 – LILRW Inventory Location Map



Appendix 4 – Uranium Mine and Mill Tailings Inventory Location Map

