McMaster University

Non-Power Operating Licence Renewal Application

April 2023

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EXECUTIVE SUMMARY

The McMaster Nuclear Reactor (MNR) was established in 1959 as the first university-based research reactor in the British Commonwealth. The McMaster Nuclear Reactor (MNR) is Canada's only high-powered nuclear research reactor, and the nation's only major neutron source. As such, MNR enables a broad range of neutron-based research programs in health, materials, energy and environmental sciences that could not otherwise exist in Canada. At present, MNR's specialized facilities, radioisotopes, and radiotracers are used by over 200 unique users per year to conduct research in advanced fuels, biology, chemical engineering, chemistry, engineering physics, science, health physics, materials science, medical physics, medicine, and radiation biology. Areas of particular strength include medical isotopes and radiopharmaceuticals, ecology and earth science, and an expanding portfolio of applications in nuclear energy and advanced materials. The facility provides unique educational experiences for students and the general public. With a reputation for providing a user-focused, agile, and innovative problem-solving environment, MNR attracts national and international companies seeking a partner capable of enhancing their commercial activities.

MNR, together with three co-located nuclear facilities, provides a unique suite of facilities found on no other University campus in the world. The High Level Laboratory Facility (HLLF) provides a 24,000 ft^2 suite of licensed lab space for radioisotope processing and radiotracer production. The Center for Advanced Nuclear Systems (CANS) enables comprehensive testing of highly radioactive components (such as those found in Canada's CANDU reactor fleet) to understand how materials behave inside nuclear power reactors; the McMaster University Cyclotron Facility (MUCF) produces positron-emitting radioisotopes used for imaging disease, complementing the therapeutic isotopes generated at MNR. This cluster of nuclear facilities, anchored by MNR, place the University in an exceptional position to be at the forefront neutron-based discovery and innovation.

During the current licensing period, MNR became Canada's largest neutron source and as such has had to grow its operations to accommodate this new role. Additionally, over the past five years the world has seen an unprecedented expansion of radiopharmaceuticals, clean energy and materials research. In response to these new national and international priories, the University and both the Federal and Provincial governments have all committed significant funding to return the reactor to a 5 MW 24 hour a day operating schedule (currently the reactor operates only sixteen hours a day at 3 MW). These changes will triple to the capacity of the reactor and furnish Canadian researchers with neutron intensities required to respond to the emerging questions facing them.

The purpose of this application to the Canadian Nuclear Safety Commission (CNSC) is to request the renewal of the non-power reactor operating licence for the MNR located on the University's main campus in Hamilton, Ontario. The current ten-year operating licence, NPROL-01/24 will expire on 30 June 2024 and hence the request for renewal. This request is for a twenty-year operating license; valid from 01 July 2024 to 30 June 2044.
The McMaster Nuclear Reactor has operated safely and securely since first criticality; supporting thousands of students and researchers in their pursuit of knowledge and hundreds of industry partners preparing new applications and innovations that address urgent, complex issues facing our global community.

1.0 INTRODUCTION

McMaster University recognizes and acknowledges that the University and our McMaster Nuclear Reactor are located on the traditional territories of the Mississauga of the Credit First Nation (MCFN) and Haudenosaunee Confederacy (HC) nations. The traditional territory of the MCFN upon which McMaster University resides is covered by the Between the Lakes Treaty No. 3. We are guests on the territory where we currently have the privilege to study, learn, live and work.

The activity to be licenced in this application is the renewal of McMaster University's non-power research reactor operating licence NPROL-01. MNR is situated in a stand-alone containment building located on the University's main campus at 1280 Main Street West, Hamilton Ontario.

The University's main campus is located at the western end of the City of Hamilton, west of the community of Westdale and east of the town of Dundas (See **Figure 1.0-1**). The University is situated on lands previously owned and maintained by the Royal Botanical Gardens.

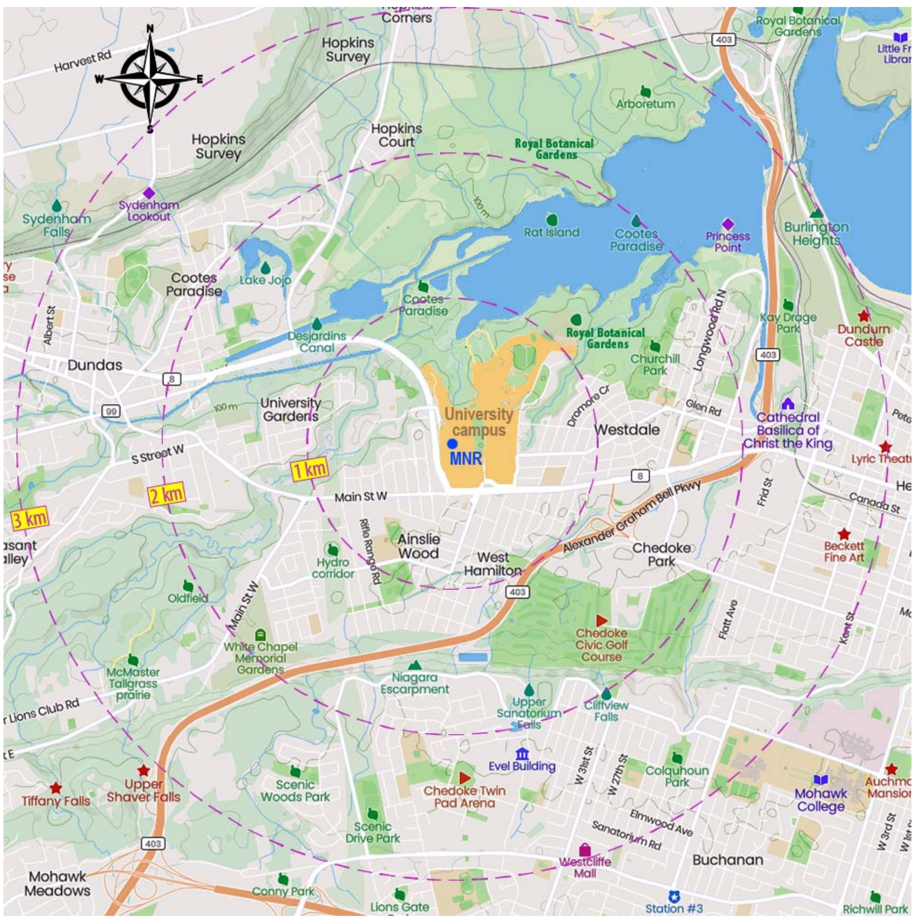


Figure 1.0-1: Site Location

1.1 IDENTIFICATION AND CONTACT INFORMATION

1.1.1 Current Licence Number

Non-Power Reactor Operating Licence: NPROL-01/2024

1.1.2 Applicant Name and Business Address

Applicant Name: McMaster University

Business Address: The Office of the President and Vice-Chancellor
McMaster University
1280 Main Street West
Hamilton Ontario Canada L8S 4K1

1.1.3 Mailing Address

Mailing Address: The Office of the President and Vice-Chancellor
McMaster University
1280 Main Street West
Hamilton, Ontario Canada L8S 4K1

1.1.4 Persons with Authority to Interact with the CNSC on the Application

Licensee Authority: Dr. David Farrar
President and Vice-Chancellor
McMaster University

Licensee
Single Point of Contact: Dr. Derek Cappon
Director Reactor Operations and Maintenance
McMaster University

Application Support: Mr. Chris Heysel
Director Nuclear Operations and Facilities
McMaster University

1.1.5 Proof of Legal Status

McMaster University is corporation established by royal assent through the *McMaster University Act* [1] to unite Toronto Baptist College and Woodstock College under the name of McMaster University by Chapter 95 of the Statutes of Ontario, 1887. The *McMaster University Act* has been amended over time as the University has grown and its governance has evolved. The most recent approval (by royal assent) was April 19, 2016.

1.1.6 Evidence the Applicant is the Owner of the Site

Evidence of site ownership can be found in found in *The McMaster University Act*, 1976 [1].

1.1.7 Identification of persons responsible for the management and control of the licensed activity

The persons with direct licensing responsibilities for MNR are as follows:

Licensee Authority:	Dr. David Farrar President and Vice-Chancellor McMaster University president@mcmaster.ca
Licensee Single Point of Contact:	Dr. Derek Cappon Director, Reactor Operations and Maintenance McMaster University cappond@mcmaster.ca
Day-to-Day Reactor Operations:	Mr. Robert Pasuta Manager, Reactor Operations and Facilities McMaster University pasutar@mcmaster.ca

A complete list of Staff with responsibilities at MNR can be found in AP-1130 Organizational Structure [2] and is described in section 2.1.3 of this application.

1.1.8 Billing Contact Person

Not Applicable.

1.1.9 Legal Signing Authority

Licensee Authority:	Dr. David Farrar President and Vice-Chancellor McMaster University president@mcmaster.ca 1 (905) 525-9140 Ext. 24340

1.2 FACILITY AND ACTIVITIES TO BE LICENCED

The McMaster Nuclear Reactor (MNR) was established in 1959 as the first university-based research reactor in the British Commonwealth. MNR is Canada's most powerful nuclear research reactor and the nation's sole facility capable of supporting world-class, neutron-based research in the areas of *Advanced Materials*, *Energy and the Environment* and *Health and Medicine*. The facility provides unique educational experiences for students and the general public. With a reputation for providing a user-focused, agile, and innovative problem-solving environment, MNR attracts national and international companies seeking a partner capable of enhancing their commercial activities.

1.2.1 Licence period

This application has been prepared to request the renewal of McMaster University's research reactor's non-power operating licence (NPROL-01) for a period of twenty years.

1.2.2 Statement of Main Purpose

The purpose of the application is to renew the NPROL for the McMaster University's research reactor. The reactor is an open pool, materials test reactor (MTR) used to support research and education in a wide range of nuclear and radiation sciences. MNR is available for public tours. Each year, MNR tours thousands of high school and university students through the facility to help demystify the technology for our next generation decision makers. In addition to the meeting the fundamental goals of the University, the facility is used to support analysis services for dozens of Canadian companies and produces medical isotopes employed in the treatment of over 70,000 cancer patients across the world each year.

1.2.3 Description of Site

McMaster University recognizes and acknowledges that it is located on the traditional territories of the Mississauga of the Credit First nation (MCFN) and Haudenosaunee Confederacy (HC). The traditional territory of the MCFN upon with the University resides is covered by the Between the Lakes Treaty No. 3.

The McMaster Nuclear Reactor is located on the University's main campus. The University's main campus is located at the western end of the City of Hamilton, west of the community of Westdale and east of the town of Dundas. The University is situated on lands previously owned and maintained by the Royal Botanical Gardens.

The campus is bounded on the west by Cootes Drive, on the east by Forsythe Avenue, on the south by Main Street, and on the north by Cootes Paradise valley. The site topology is shown in **Figure 1.2.3-1**.

MNR is located on the University's main campus (see **Figure 1.2.3-2**). It is surrounded by the Nuclear Research Building on the north and east, the Central Utilities Building on the north-west, the John Hodgins Engineering Building on the east, and the Arthur Bourns Science Building on the south and east (see **Figure 1.2.3-3**).

The Central Utilities Building is the control and distribution point for the University and supplies water, compressed air, steam, and electricity. The surrounding area is mostly residential with some commercial activity and light industry as illustrated in (see **Figure 1.2.3-4**). Hamilton population in 2022 is estimated at 819,167 residents.

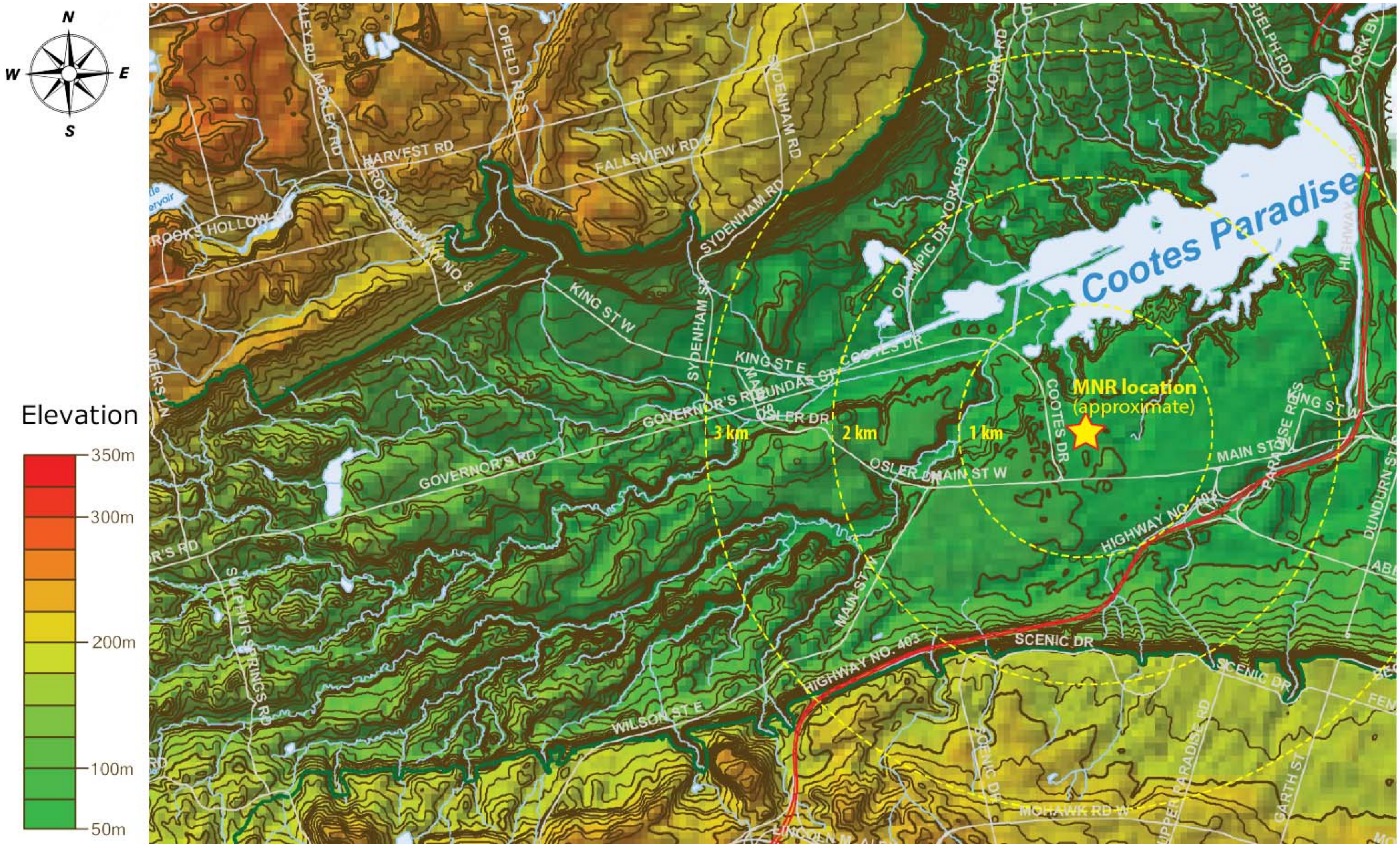


Figure 1.2.3-1: Site Topography

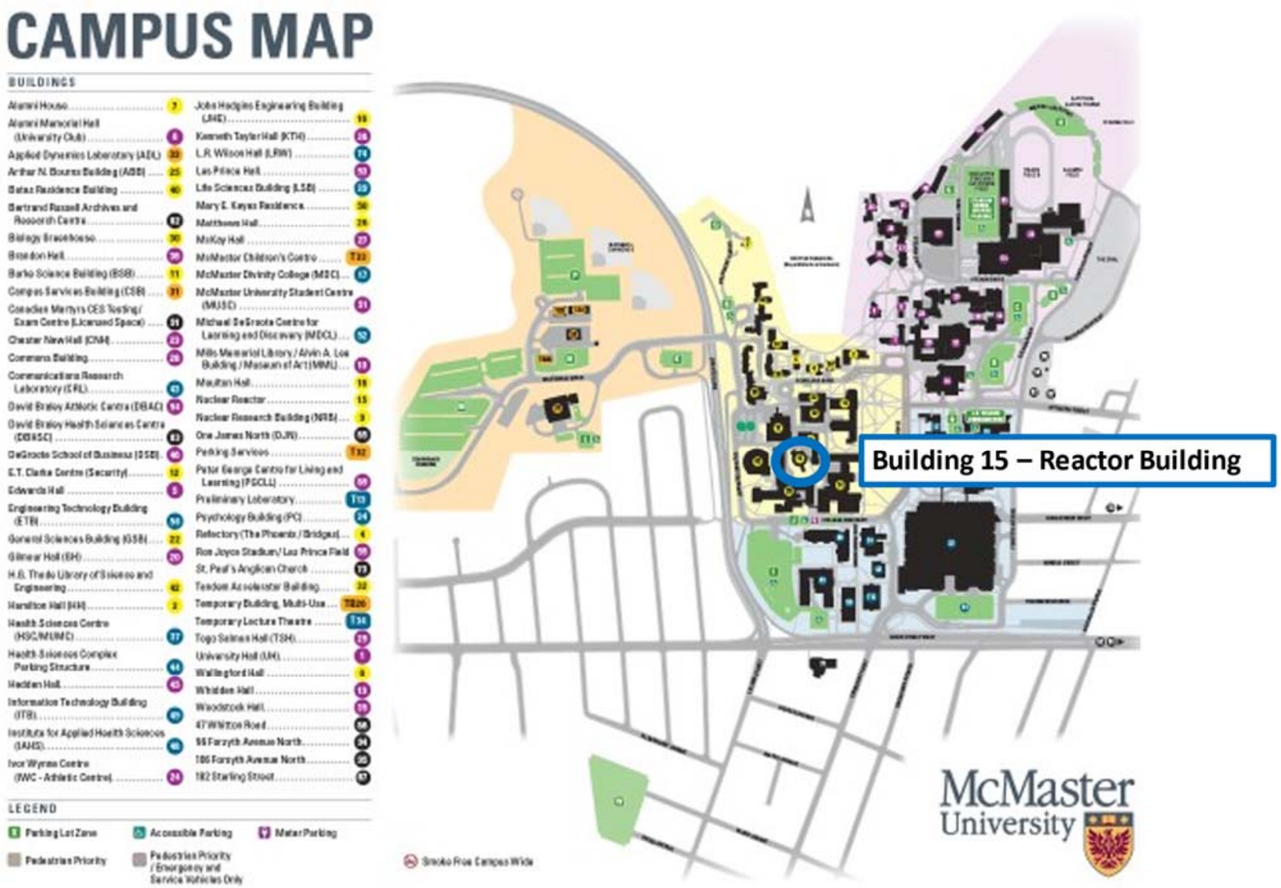


Figure 1.2.3-2: McMaster University Main Campus

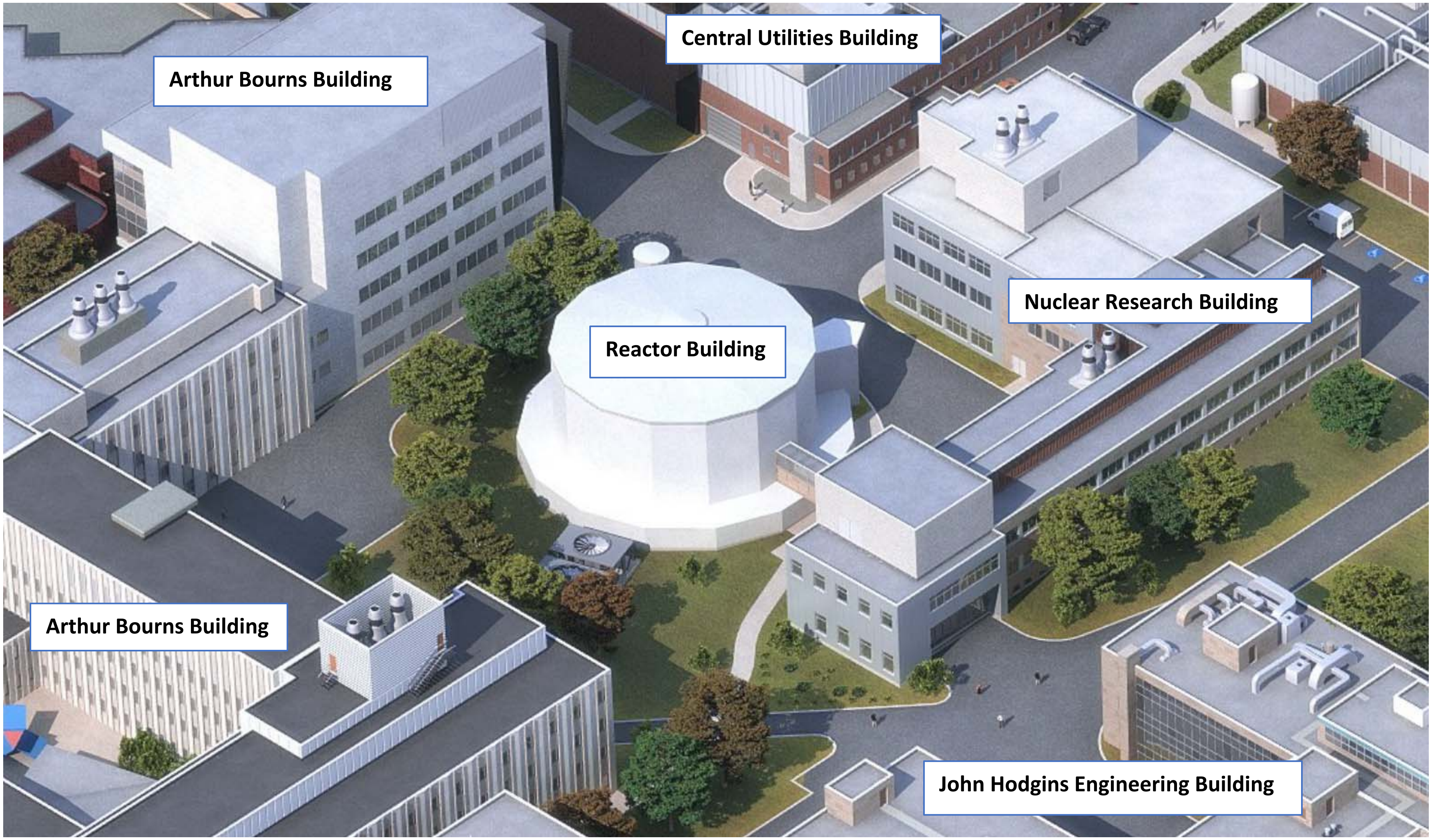


Figure 1.2.3-3: Buildings Surrounding MNR

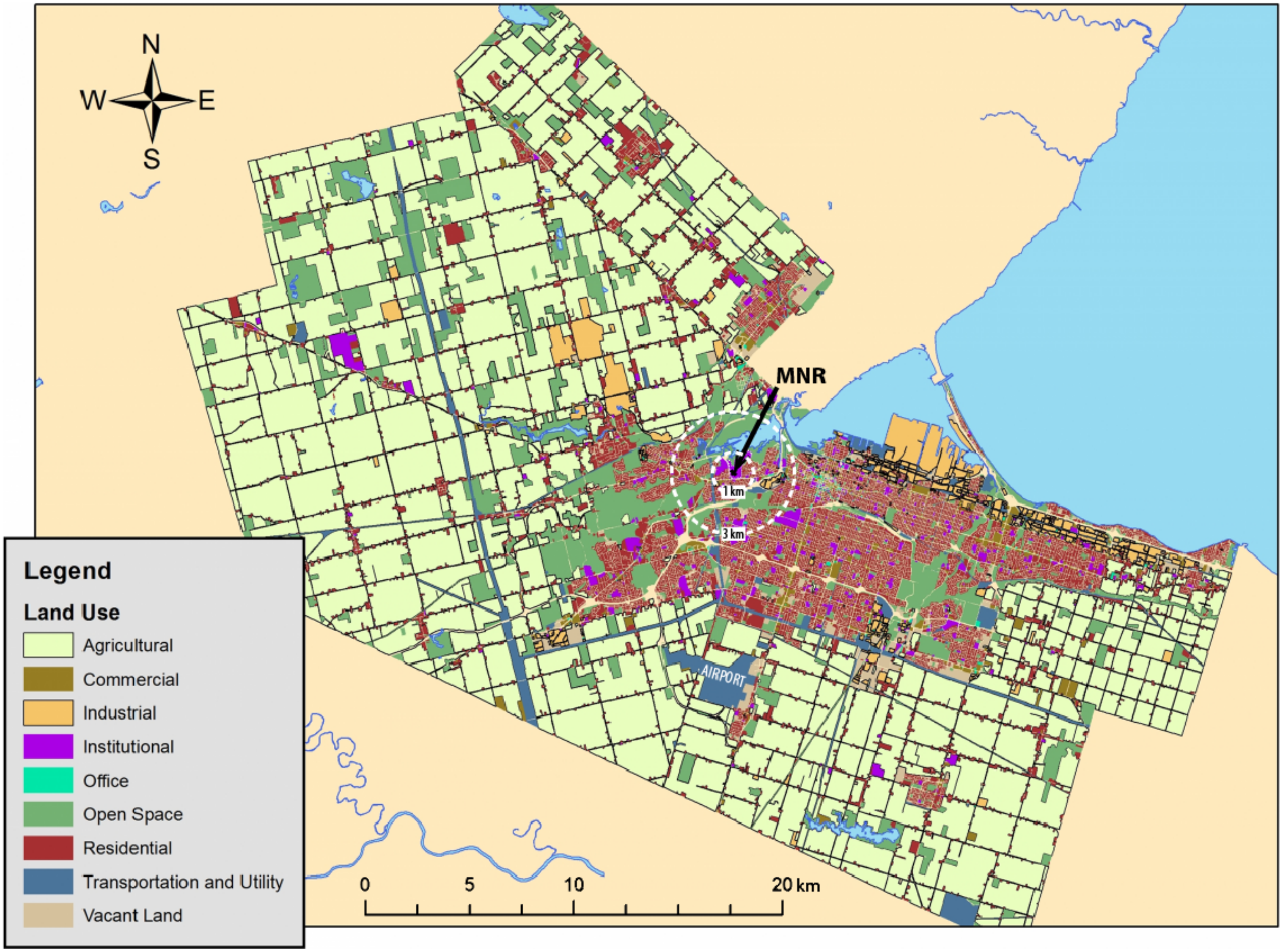


Figure 1.2.3-4: Hamilton land use (2016)

Annotated map from https://uwaterloo.ca/library/geospatial/blog/post/city-hamilton-land-use-2016

1.2.4 Description of Existing Licensing Status

The current licence, NPROL-01/2024 for the facility is valid until June 30, 2024. This application has been prepared for the renewal of NPROL-01.

1.2.5 Nuclear and Hazardous Material

Nuclear hazards are contained within the robust containment building. Waste consists of spent nuclear fuel which is temporarily stored in the reactors pool until it is sent for disposal.

Samples irradiated for analysis in the rabbit systems are stored in secure and controlled spaces within the reactor building until they have decayed to low levels. They are returned to the company or researcher for whom the analysis was being performed or sent to a licensed disposal facility.

Waste generated through the production of medical isotopes is securely stored within the reactor building until the material has decayed to low levels. The waste can then be disposed of as non-active waste.

Other low-level waste which is generated through routine operation and maintenance activities (water purification resins, gloves, disposable lab coats, booties, etc.) is segregated, characterized, packaged and sent to licensed disposal facilities. MNR typically generates on the order of 2-3 m^3 of low-level waste each year.

MNR only uses a small amount of non-nuclear hazardous materials for cleaning and similar purposes. These materials are controlled according to university procedures and when necessary are disposed of through third party hazardous waste handling companies.

1.3 OTHER RELEVANT INFORMATION

1.3.1 Permits, certificates, and other licenses

MNR occasionally applies for import and/or export permits in accordance with applicable requirements un the *Nuclear Safety and Control Act* (NCSA) [3].

1.3.2 Similar Facilities

Not applicable.

2.0 SAFETY AND CONTROL AREAS

2.1 MANAGEMENT SYSTEM

2.1.1 General Considerations

The McMaster Nuclear Reactor (MNR) follows a Quality Management System (QMS) [4] that meets the requirements of CSA N286-12 Management System Requirements for Nuclear Facilities [5] (henceforth referenced as N286). The QMS complies with N286's generic requirements for the management system and the specific requirements for research and isotope processing facilities. The QMS is written and implemented to ensure the best possible outcomes for health, safety, the environment, security, economics, and quality. This is accomplished by adhering to the QMS foundations of purpose, commitment, capability, process definition and control, and continual improvement. See **Figure 2.1.1-1** Quality Management System below.

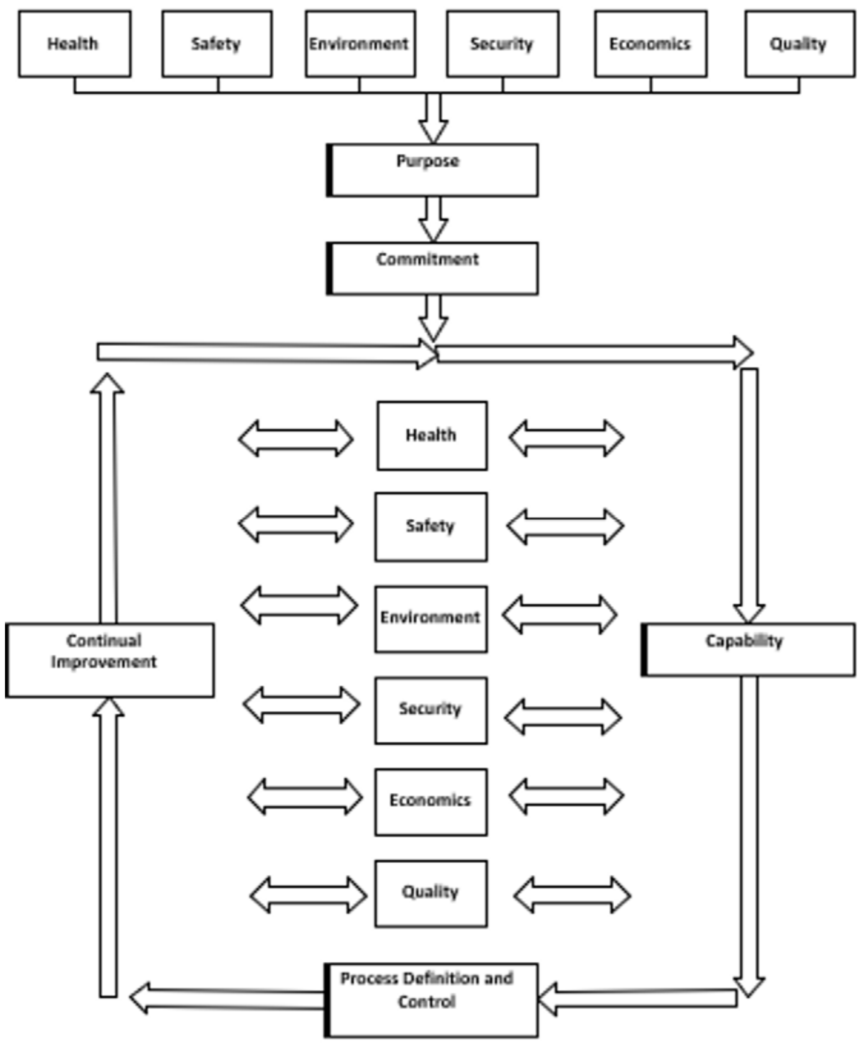


Figure 2.1.1-1 Quality Management System

MNR uses several quality tools that will be referenced in the rest of the document. A brief description of a couple are listed below.

uniPoint Software: A QMS software package that has numerous modules including document control, nonconformance, corrective action, audits, and training. uniPoint serves as a tool to manage these processes as well as a location to store records.

Taproot™ Root Cause Analysis: A proprietary system used for problem solving and root cause analysis.

2.1.2 Management System

The QMS is built within a framework that considers safety as paramount to all other considerations. Safety guides all MNR's decisions and actions. It is a key input to the QMS foundations including purpose, commitment, capability, process definition and control, and continual improvement.

The QMS is built on the following principles:

- Safety is the paramount consideration guiding decisions and actions.
- The business is defined, planned, and controlled.
- The organization is defined and understood.
- Resources are managed.
- Communication is effective.
- Information is managed.
- Work is managed.
- Problems are identified and resolved.
- Changes are controlled.
- Assessments are performed.
- Experience is sought, shared, and used.
- The management system is continually improved.

These principles guide each requirement of N286 and in turn guide all applicable MNR QMS policies, procedures, work instructions, forms, etc.

MNR applies the requirements of N286 and its own QMS requirements using a graded approach. Safety is always considered, along with health, environment, security, economics, and quality as needed in individual situations. What this means is that the more significant the risk to safety and the other factors a process poses, the more rigorous the controls put in place will be. Other factors may also contribute to this decision, such as process control, training and qualification, independent verification, and auditing. Work with elevated levels of complexity requires more complex controls to be put in place. When MNR uses a graded approach, the process is defined including what criteria justify the final decisions.

2.1.3 Organization

The organization structure for MNR is shown below in **Figure 2.1.3-1** and detailed in AP-1130 Organizational Structure [2].

The responsibility and authority of each level in the line organization is defined and documented [2]. It is communicated to individuals by their immediate supervisor. Processes are in place to ensure the understanding and acceptance of these responsibilities. This is generally implemented through the applicable training program for each position.

The organization is established in a manner that allows effective management control. This effectiveness is monitored and corrected through the audit process.

Regarding MNR, the President and Vice-Chancellor of McMaster University, along with the Board of Governors, are responsible for providing the general policy, aims and objectives to be pursued in light of the requirements of the University as a whole. The President and Vice-Chancellor is authorized by the Board of Governors as the formal signing authority for the Non-Power Reactor Operating License (NPROL). In this capacity, formal applications to the CNSC for licensing and authorizations related to the Reactor must be signed by the President and Vice-Chancellor.

The Vice-President, Research is responsible for overseeing all research activities at the University, this includes ensuring that the Reactor is operated in accordance with University policies, monitoring the effectiveness of the Nuclear Facilities Control Committee (NFCC) in executing its delegated authority and responsibilities, and providing necessary financial and human resources for the execution of the NFCC's delegated authority and responsibilities.

The Assistant Vice-President Research (AVPR) Nuclear reports to the Vice-President, Research and has overall administrative and budgeting responsibility for the reactor. The Director Reactor Operations and Maintenance (DROM) reports directly to the AVPR Nuclear.

McMaster University's Nuclear Facilities are operated in a manner that is consistent with public safety and within the terms of the facility licences granted by the CNSC. The NFCC determines if these objectives are being achieved through review and audit of facility operations. The Committee, through its Chair, reports to the Vice-President, Research. The NFCC works with the DROM in assigning priorities for experimental facility access when necessary.

The NFCC is responsible for the following:

- serving as McMaster University's internal oversight body concerning all issues of operational safety in the University's nuclear facilities.
- reviewing the University's nuclear facilities operating practices and management decisions against the requirements of the nuclear facilities licence(s) granted to McMaster University by the CNSC and against industry standards of good operating practices.
- approving all licence applications to be submitted by McMaster University to the CNSC and all changes sought on behalf of the University in existing licenses and supporting documents.
- monitoring the operational procedures within the facilities by periodic audits of logbooks, and by periodic visits to the facilities.
- approving all experiments relating to instructional, research, and commercial use of the facilities, forwarding, at its discretion, items for additional approvals by the Health Physics Advisory Committee.
- monitoring scheduling of experiments with respect to the priorities for access to the facilities and to assure "users" that individual experiments do not infringe on each other.
- advising the DROM on all matters brought to the Committee's attention.
- striking sub-committees of individuals with relevant knowledge and experience as required to accomplish its objectives.

Some of the key Leadership roles for MNR follow.

The Director, Reactor Operations and Maintenance (DROM) reports to the Assistant Vice-President, Nuclear and supervises the Area Managers.

The DROM is responsible for:

- formulating Reactor policy consistent with the aims of the University.
- directing the activities of the Reactor facility in a manner that will best serve the research and academic needs of McMaster University and that will maximize the benefit to Canadian science and the Canadian people.
- preparing the annual operating budget for approval by the AVP Nuclear.
- overseeing the operation of the Reactor facility.
- working in close cooperation with the CNSC to carry out their instructions and ensure compliance with regulations, particularly those pertaining to fuel management, safety, emergency procedures and security.
- working closely with the Senior Health Physicist (SHP) regarding safety and emergency procedures.
- being responsible for program implementation, including responsibility for program review.
- being responsible for staffing decisions, personnel matters, and maintaining an adequate Reactor operations staff.
- sharing with authorized Supervisors, “on-call” duties to assure that competent staff is always available.
- working with the Manager, Reactor Operations to authorize individual experiments of approved research programs.
- acting as a consultant to those planning experiments.
- preparing reports as required.
- negotiating purchase contracts and licence renewal.
- ensuring record-keeping is carried out as outlined in the Operating Limits and Conditions (OLC).

The Manager, Reactor Operations (MRO) reports to the DROM and supervises Reactor Supervisors and the Assistant Supervisor.

The MRO is responsible for the following:

- the overall operation and maintenance of the Reactor and all activities performed within the facility in accordance with facility policies, procedure and the NPROL.
- supervising, along with the DROM, the management of fissile material.
- sharing “on-call” duties.
- working with individual experiments of approved programs.
- advising or assisting experimenters or researchers as required.
- assisting the DROM in the preparation of reports as required.
- maintaining complete records of all experimental work, Reactor operations and maintenance.
- overall responsibility for training all Reactor staff.
- reviewing and approving training programs for operations personnel.
- sharing the responsibility for providing both initial and refresher training to Reactor Operators and Reactor Supervisors in normal operating procedures, maintenance procedures, and emergency procedures.
- reviewing and approving all configuration, systems, structures and equipment changes within the facility.

The Manager, Operations Quality Management and Training (OQMT) reports to the DROM and supervises the OQMT Technician.

The Manager, OQMT is responsible for the following:

- developing, implementing and managing the QMS at MNR.
- ensuring compliance with standard operating procedures through the internal audit program.
- coordinating and leading program review activities, including analysis and interpretation of program review results. The outputs of program review are approved by the DROM, who maintains overall responsibility for program review.
- implementation and oversight of training programs as required.
- preparing reports and assist the DROM in the generation of reports as required.

The Manager, Major Projects reports directly to the AVPR Nuclear and has project management accountabilities for all major projects under the AVPR Nuclear's purview.

The Health Physics Advisory Committee (HPAC) receives its authority from the Office of the President of McMaster University. HPAC is responsible for establishing and reviewing the University's radiation protection program and ensuring that it complies with radiation protection regulations promulgated by federal, provincial, and local authorities. This responsibility in no way pre-empts the requirements of the Canadian Nuclear Safety Regulations or any order issued thereunder. The committee is responsible for the Radiation Protection Program at the Reactor.

The Health Physics group, headed by the Senior Health Physicist (SHP), operates under the authority of the HPAC. The group is thus responsible for implementing the University's radiation protection program. In this regard, Health Physics is responsible for all operations associated with the Reactor from the standpoint of Radiation Protection.

The Health Physics group is responsible for the following:

- personnel monitoring.
- radiation surveys.
- radioactive waste collection and disposal.
- environmental monitoring.
- monitoring of radioactive shipments.
- supervision of radiation emergencies.
- maintenance of radiation protection records.
- development and provision of Radiation Safety Training.
- review of Procedures and Work Plans for radiological work.

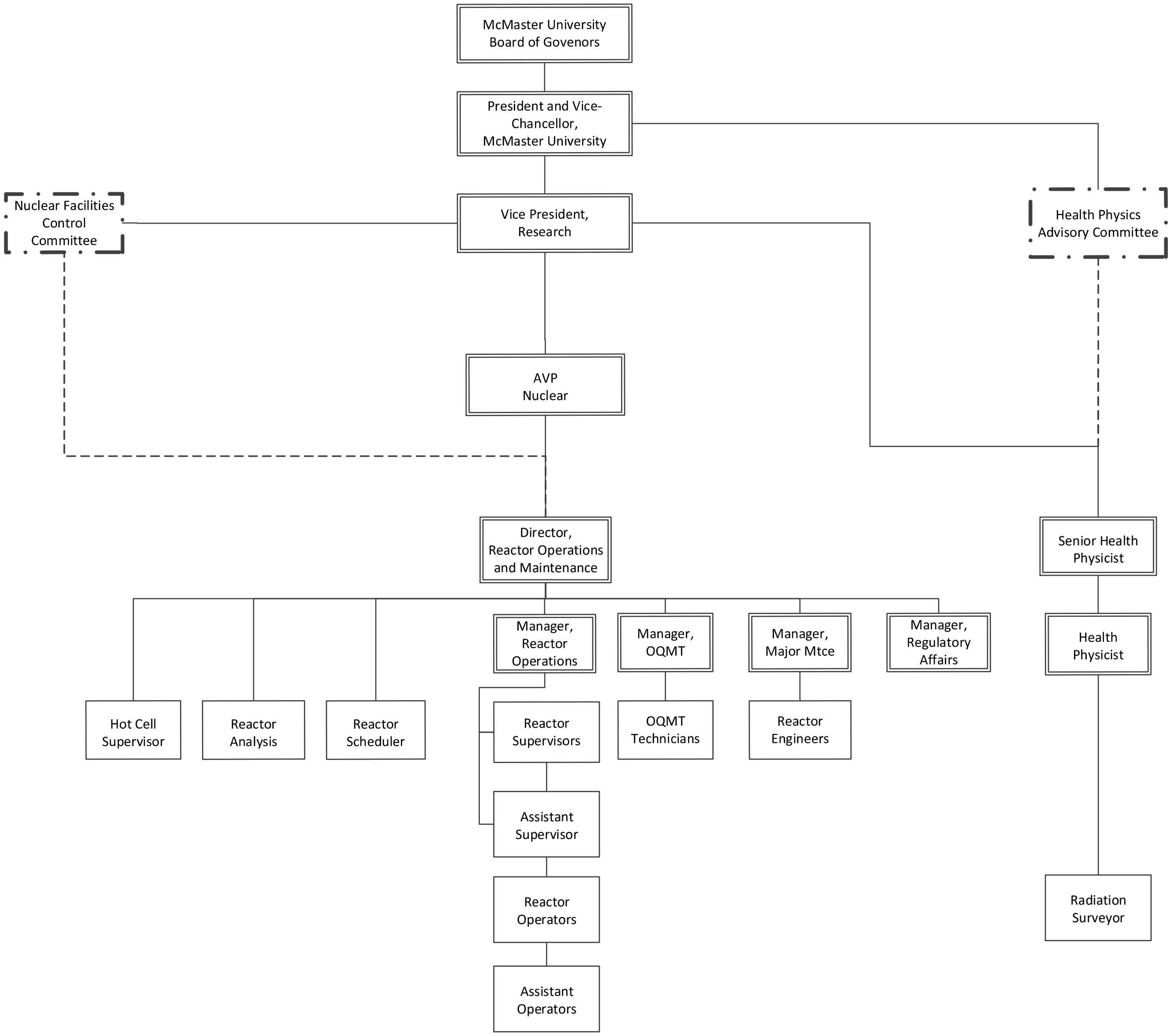


Figure 2.1.3-1. Organizational Chart at the McMaster Nuclear Reactor

2.1.4 Performance Assessment, Improvement and Management Review

Performance assessment, improvement and management review are performed and documented in accordance with MNR programs and procedures.

2.1.4.1 Self Assessment

Management conducts self-assessments of performance to identify opportunities for continual improvement and ensuring outcomes are meeting desired results. A summary of these assessments is presented as part of Program Review [6].

A formal review of the effectiveness of the MNR QMS is carried out at least once a year. In addition, the DROM may call a special review at any time to examine specific concerns about the effectiveness of the program. The program review covers the operating period from January 1st to December 31st and is completed using the inputs to the Annual Compliance Report (ACR) to the CNSC and NFCC.

Information is gathered which assesses the effectiveness of the QMS in meeting program objectives. The collected information is analyzed and the results summarized. Comparisons are made to expected and previous performance.

The review consists of summaries by the responsible persons on the extent to which quality program objectives are satisfied in the following areas:

- Overall facility performance including operation, maintenance, training, safety system testing and performance, radiation and occupational safety, facility changes and modifications, and unplanned events. Actual performance is compared with targets and/or past performance. Trends are identified and discussed. New or revised targets are established if existing targets are no longer appropriate. Specific and appropriate performance targets are determined by the Area Manager and approved by the DROM. In the case of radiological safety targets both the SHP and DROM will approve the targets.

- Reporting, information, and experience tracking including annual compliance reports, annual health physics reports, internal audit reports, operating experience reports, nonconformance reports, corrective action reports, and reports to the CNSC and other jurisdictions. Reports are reviewed. Trends are identified and discussed. Status, timeliness of implementation and effectiveness of corrective actions and any actions arising from previous program reviews. Any overdue actions are reported and reviewed. The degree and effectiveness of implementation of the QMS are reviewed.

The result of the program review meeting is an understanding among the participants of:

- What are the areas identified for improvement?
- Which will be addressed?
- Who will be responsible for addressing them?
- When will the action be completed?

Corrective actions are identified to resolve any deficiencies in the QMS. All concerns and actions arising from the meeting are summarized and reviewed. Responsibility for development and implementation of follow-up actions is assigned. Priorities and schedules are set.

A formal record of the meeting is prepared, including the agenda, reports, minutes of meeting, recommendations, actions, and unresolved issues. The record is approved by the DROM and distributed to all attendees, the NFCC and to the AVP Nuclear and Vice President Research as required.

2.1.4.2 Independent Assessment

Independent assessment at MNR is performed through the internal audit process [7]. The audits are conducted on behalf of top management to confirm that the documented QMS complies with N286 and is effectively implemented.

All independent assessors:

- Have access to the work site, workers, the work, documents, and records.
- Neither have performed, verified, nor supervised the work being assessed.

As planned by MNR management, all the following processes are audited at least every five years:

- Calibration
- Change Control
- Commissioning
- Corrective Action
- Design Control
- Document Control
- Internal Audit
- Maintenance
- MNR Policy Manual
- Nonconformance
- Nuclear Criticality Safety
- Procurement
- Program Review
- Record Control
- Training
- Verification of Work
- Work Planning and Control

All audits consider the principles of the Management System, as well as concepts like Safety Culture that play a role in all the processes.

The extent of audit and choice of program area or facility take into account:

- The maturity of facility operation or program implementation.
- Previous audit results.
- OPEX, nonconformance and corrective action reports.
- Significance and complexity of the processes to be audited.
- Resource demands.

In addition to scheduled audits, an audit may be called at any time by the DROM to examine specific concerns about the effectiveness of the Management System.

All audit results are presented to the Area Manager and the DROM for review. Any deficiencies are addressed through the corrective action system. Records are kept of the auditing process and its results.

2.1.5 Operating Experience

Feedback of experience from the various work areas and relevant external sources are sought out, collected, assessed, and used to improve equipment, performance, and work practices [8]. The Manager/Supervisor in charge of a given process reviews the information on a routine basis and communicates the results of those reviews to appropriate levels of management. The effective use of operational experience is the responsibility of all personnel.

Any employee who discovers or experiences an unsafe condition or event must report it promptly to supervision or area management. Any unplanned event must be reported verbally by Area Management to the DROM as soon as practical and where appropriate followed up by generation of an Operating Experience (OPEX) event in the Nonconformance Module of the uniPoint Quality System Software [9]. OPEX are defined as pertinent internal and external information, gained through practical experience, used to learn about and improve the safety and reliability of nuclear facilities.

OPEX information external sources can be documented using the Nonconformance Module in uniPoint Quality System Software. Information may also be presented in alternate formats such as regulatory body tools, including but not limited to action notices, General Nuclear Safety and Control Regulation (GNSCR) [10] subsection 12(2) requests, and OPEX databases.

Upon receiving notification of an unplanned event or operating experience from any other source including external sources, the DROM assesses the event and initiates further action based on the nature and seriousness of the consequences.

Consideration should be given to the following:

- Decide if the event is reportable to any regulatory body.
- Decide if the NFCC or Line Management should be informed.
- If this event is reportable or merits further investigation, then initiate an investigation.
- Instruct the Investigation Team to document any action(s) arising from the event or the investigation.
- Ensure that the appropriate Area Manager completes the OPEX Report using the NC module in uniPoint as described in the uniPoint: Nonconformance Module Work Instruction [12] and distribute as required.

If the DROM determines that a detailed investigation is required, the event investigation and analysis is carried out by the investigator or investigation team (as determined by the DROM) using appropriate techniques for root cause analysis including TapRoot™ when feasible. The goal of the investigation is accurate identification of root causes of an event, and development of effective corrective actions aimed at preventing recurrence of a similar event at MNR.

In consultation with the Supervisor(s) of the affected work area, the investigation team will recommend corrections and/or corrective actions after analysis of the event is complete. Recommendations will be reviewed and accepted by the DROM and Area Manager(s) who will be responsible for their implementation. The DROM will indicate approval of the action plan by signing the disposition section of the OPEX event in uniPoint. The implementation of corrections is tracked in the Verification section for the OPEX event. Implementation and verification of effectiveness for corrective action is tracked through Corrective Action Reporting process. Once the action plan has been implemented, the effectiveness of corrections and corrective actions is assessed by the Area Manager and Manager, OQMT. Details of the verification of effectiveness for the action plan is documented in the OPEX Report and/or Corrective Action Report, and communicated to the DROM. Once the action plan is completed the DROM or Manager, OQMT will close out the unplanned event.

Appropriate records are maintained in relation to operating experience.

2.1.6 Change Management

Prior to any changes being made to a procedural process, work, design or product, the changes will be subjected to the same level of review and approval as was done/accepted for the original situation in accordance with the MNR QMS and Change Control Procedure [11]. Changes are reviewed by persons with knowledge of the original intent and requirements. Documents are to be approved by the DROM and other appropriate personnel before implementation.

An integral part of the Change Control Procedure [11] is the Change Request Form [12]. This form identifies the person(s) initiating, justifying, reviewing, and approving the change(s) and associated requirements, and initiating work action and completion. The persons filling out this form are identified by date, signature, name and job title.

2.1.7 Safety Culture

To achieve the objective of safe operation within a good safety culture, MNR management applies the following safe practices to all program areas. Changes to equipment, procedures or processes require independent review and approval before implementation.

All work is performed in compliance with the program for Work Planning and Control [13], including written and approved procedures as required.

During execution of a work task, any member of a work team will refuse any order that may contravene approved procedures or work controls.

All staff are obligated to raise any issue that they perceive to have an impact on safety and to see that each such issue is reported.

Good work management practices (i.e., planning, scheduling, briefings, implementation, verification, and compliance) are included and appropriately implemented in all program areas. Good work control practices (i.e., advance authorization, compliance with procedures, and recording of progress and results) are also included and appropriately implemented in all program areas.

To ensure coordination and the assignment of responsibilities for team activities important to safety, a pre-job briefing is conducted as required in accordance with [13].

The safety culture at MNR is shaped by the behaviours and the beliefs of every person who works in the organization and includes personal and organizational attitudes towards risk.

Management is committed to fostering the safety culture and providing resources to understand and work to continuously improve the safety culture. This commitment includes providing means to support workers in carrying out tasks safely and effectively.

As an integral part of the safety culture, the organization, and all workers within the organization are committed to adhering to the management system. Processes defined in the management system consider interactions between individuals, technology, and the organization.

Work practices, established using Work Planning and Control [13] and Document Control [14] practices, are developed and implemented to contribute to excellence in worker performance. Training and evaluation according to Training of Staff [15] ensures that workers are capable of working safely and effectively.

Good continuous improvement practices [i.e., assessments including Program Review [6], Internal Audits [7], Operating Experience [8], and Corrective Action [16] processes are utilized to monitor, understand, and improve safety culture.

On an annual basis a training presentation is delivered reinforcing the importance of safety culture and reviewing any relevant operating experience (OPEX) instances found either internally or externally. This training concentrates on defining the safety culture and safety objectives at MNR, describing what error prevention tools are used and how to avoid at-risk behaviours, explaining how MNR cultivates a positive safety culture, identifying what an OPEX is and discussing how root cause analysis is used in the error prevention framework.

2.1.8 Configuration Management

MNR maintains hardware and software configurations in order to keep the facility in a safe operating condition. Any repairs are made as soon as reasonably possible. All repairs and replacements are made with the latest documents representing the configurations of all systems, sub-systems, components, etc. The document control system [16] is used to ensure the latest configurations are always used when making any repairs or replacements. The document control system is administrated using the uniPoint software. Any changes to configuration are made using the change control process [11], [12] outlined in Section 2.1.6 of this document. Once changes are properly implemented the new configuration is documented using the document control process. All configurations, and changes thereto, are made within the framework of safety being the paramount consideration.

2.1.9 Records Management

QMS records are identified, maintained and secured for the period specified in MNR document control provisions, and uniquely identified to allow them to be traced to the items and activities to which they refer, valid, legible and retrievable and protected against damage, deterioration and loss [4].

Records are divided into eighteen (18) types as outlined below. Each type is briefly described along with a reference to the defining documentation and the assignment of responsibility.

- Safety Analysis Report and Revisions
  MNR shall maintain a Safety Analysis Report [17] which documents and justifies the safety case for the operation of the facility. The responsibility for this report rests with the DROM.

- Licensing Documents and Personnel Records
  As called for in the NPROL, a register of all documents related to CNSC requirements is maintained by the DROM. The Personnel Records are maintained by the Manager, Administration and Finance who reports to the AVPR Nuclear. Personnel Training Records are maintained by the Manager, OQMT.

- Emergency Preparedness Planning
  Responsibility for the Emergency Preparedness Plan [18] and its resulting records rests with the DROM. The records called for in response to any Type “D” Emergency are the forms described and included in the Type “D” Emergency Procedures.

- Security and Access Control
  The Security Plan [19] and the associated record keeping described therein are the sole responsibility of

the DROM. The records include access classification lists of personnel granted access to MNR, registration and clearance data forms, photo identification and badge system records, Visitor Information Cards and the Security Checkout Form.

- Change Management
  The records associated with the Change Management are defined and their use described in Change Control [11], [12].

- Effluent Releases
  Effluent records are maintained by the SHP as set out in the MNR Radiation Safety Manual [20]. They are reported annually in the Annual Compliance Report to the CNSC.

- Personnel Exposures
  Personnel Exposure records are maintained by the SHP as set out in the MNR Radiation Safety Manual [20].

- Significant Contamination Events
  Significant Contamination Events are events associated with a potential or actual reportable occurrence, reportable information or events where an Administrative Control Limit or Regulatory Limit may have (or has) been exceeded as defined in the Radiation Safety Manual [20]. Significant contamination reports are submitted to the NFCC and HPAC as well as the CNSC and are archived along with any relevant records as required by the Operating Limits and Conditions (OLCs) [21].

- Facility Drawings
  The MRO is responsible for maintaining the Facility Drawing records up to date.

- Fuel
  Fuel records are maintained as set out in the MNR Fuel Management Program [22]. Inventory records are maintained by the Manager, Reactor Operations and the DROM. Fuel movement records are generated by the Reactor Supervision (typically the DROM or MRO) and checked by another member of Reactor Supervision.

- Routine Operating Data
  Routine operating data is recorded as set out in the document, Periodic Readings and Inspections [23]. In most cases, it is entered on charts or checklists by the Reactor Operators and verified by Reactor Supervision.

- Procedures and Revisions
  Records associated with the procedure review and revision is maintained by the DROM in the Document Management database as set out in Document Control [14].

- CNSC Reports
  Records related to Reportable Incident Reports submitted to the NFCC and the CNSC are archived as required by the OLC's. The Monthly Rod Drop Report and the Annual Compliance Report are submitted to the CNSC by the DROM.

- Experimental Records
  Records associated with Reactor Utilization are generated as set out in MNR's Operating and Irradiation procedures and work instructions [24]. In general, the raw data is supplied by the experimenter and verified by Reactor Supervision. Sample movements within MNR are recorded by the Reactor Operators. Shipping records are the responsibility of the Manager, Reactor Operations. Most records are in the form of data sheets to be filled in and authorized by Reactor Supervision.

- Radiation and Contamination Surveys
  Radiation and contamination survey records are maintained by the SHP as set out in MNR's Radiation Safety Program [20]. Results of surveys are entered on data sheets and posted in the areas surveyed.

- NFCC Documents
  The responsibility for NFCC documents rests primarily with the Chair of the committee as set out the Terms of Reference for the committee. In practice, this responsibility is mostly delegated to the Committee Secretary. Records and reports submitted by others to the NFCC are noted and tabled via the NFCC minutes. Operational records requested by the NFCC are the responsibility of the DROM.

- Surveillance and Maintenance
  Core surveillance records are the responsibility of the Refuelling Supervisor as set out in MNR Fuel Management Program [22]. Applicable Safeguards records are maintained by the MRO. Other surveillance and maintenance records are maintained as set out in MNR's Maintenance and Test Procedures [25]. In general, most surveillance and maintenance records are generated by the Reactor Operators during their maintenance activities and later checked by the Reactor Supervision.

- Deficiencies, Nonconformances and Corrective Actions
  Processes, equipment, items, documents and activities that do not conform to requirements will be documented as set out in Reporting Nonconformances [26].

Records are separated into a classification system which governs the retention periods. Criteria used to determine retention classification include demonstration of safe operation, requirements for maintenance, repair, replacement or modification of an item, determination of the cause of an accident, malfunction or unscheduled occurrence, provision of baseline data for periodic inspection and decommissioning. At the discretion of the DROM or the MRO, or at the written request of the CNSC, documents shall be retained for longer periods than those prescribed. No document shall be disposed of except with prior approval of the DROM or the MRO.

2.1.10 Business Continuity

MNR's operation, business planning, strategic objectives, and desired outcomes are defined, planned, and controlled through its organizational planning and its QMS. The goals, objectives, and policies are effectively communicated to the affected staff and steps are taken to ensure that they are understood.

Objectives are defined for each year by the Director, Reactor Operations and Maintenance (DROM). These objectives are reviewed periodically at the Program Review [8] meeting attended by the management team. Deficiencies are addressed and actions taken as necessary.

MNR has created a business continuity plan [27] which outlines the plan for operations and actions in the event of a major occurrence, which interrupts or challenges normal operational and service levels.

2.2 HUMAN PERFORMANCE MANAGEMENT

2.2.1 General Considerations

MNR maintains processes and procedures which support optimum human performance in the execution of work at the facility. The processes and procedures are in compliance with REGDOCs 2.2.2 Personnel Training [28], 2.2.3 Personnel Certification [29], 2.2.4 Fitness for Duty [30], 2.2.5 Minimum Staff Complement [31], and 2.5.1 General Design Considerations: Human Factors [32]. These processes and procedures are also in compliance with the applicable sections of the *Nuclear Safety Control Act*, [3] Class 1 Nuclear Facilities Regulations [33], and Nuclear Security Regulations [34].

MNR maintains operation with a sufficient number of trained and certified personnel. The training program follows the systematic approach to training (SAT). Personnel are required to have a university or college education that includes credits in science and mathematics. New personnel are trained in activities by experienced workers. Training includes self study, on-the-job (OJT) training with experienced individuals, and classroom training. All certified operators must have at least one year of experience at MNR or an equivalent facility and must pass a certification exam. Continuing training is given as needed and is built into the training program. The training program uses feedback loops in order to facilitate continual improvement. Records of all training are maintained.

2.2.2 Human Performance Program

In order to maintain safe operations at MNR a human performance program is in place. The reactor is always operated with a minimum of 2 operators. It consists of at least one certified Reactor Operator and one Assistant Reactor Operator, who may also be certified. At all times, whether the reactor is in operation or not, there is at least one supervisor on-site or on-call. There are Health Physics personnel available on-site or on-call to assist if necessary. Health Physics maintains the radiation protection program that ensures the safety of all workers and that the doses they receive are within the administrative and regulatory limits. This program also ensures the public is safe from any radiological danger.

All work is completed with adequate supervision and management. The supervisors and managers direct work with the idea that safety is of paramount importance. This includes the safety of themselves, coworkers, university users, and the public at large. There is a strong culture of adherence to procedures and policies, and to error-proof and continually improve work habits and performance. Workers are encouraged to have a questioning attitude and to seek clarification if they are ever unsure about any task. Safety culture is intrinsically linked to the human performance program.

The typical workday at the reactor consists of two eight-hour shifts. This includes appropriate breaks for lunch. There are always at least two people available during operation and each monitors the other for any indications of the onset of issues such as fatigue. Any problems are reported to supervision or management.

2.2.3 Training Program

The training program at MNR is described in the training procedures [15]. The training program is built on SAT philosophy. The training program includes training needs analysis, training program design and development, conducting training, evaluating participants, evaluating the training program, and improving the training program.

All employees are given orientation training, health and safety training, document training, On-the-Job Training (OJT), and continuing training.

Orientation training includes a general description of the reactor and the related facilities, an introduction to regulatory requirements, an introduction to licensing, an introduction to software used to access procedures, an introduction to building access regulations and security awareness, and an introduction to the MNR QMS.

Health and Safety training is implemented by the university and is established based on job requirements. It includes training such as Workplace Hazardous Materials Information System (WHMIS), first aid, asbestos awareness, fire safety, violence and harassment prevention, lock-out-tag-out, amongst many others.

Document training includes all applicable policies, procedures, and work instructions related to each task that a person is to complete. Each position has a list of appliable documents and personnel must read and understand the documents related to their work. Workers are encouraged to seek clarification from supervision if anything is unclear in these documents.

OJT is done for each position. MNR management and Area Managers analyze and determine which tasks require training in addition to document training. Individual training programs are developed for various positions based on the safety significance of the tasks being performed. Depending on the importance of the task, competence may be assessed with a formal evaluation. The record of evaluation can serve as the record for completion of the training. Trainees are given feedback on their performance when an evaluation is completed. Task specific training may be delivered hands-on in the field, in-class with an instructor, or as a table-top walk-through/simulation of the task. Training may be conducted by a qualified internal trainer or a qualified external training provider.

Continuing training is provided for all employees and ensures that personnel maintain compliance with all McMaster University based and external training requirements. It ensures that personnel maintain the knowledge and skill obtained during qualification and/or certification programs; acquire new skills and knowledge required because of changes or additions to reactor equipment, facilities or operating practices; incorporate operating experience into operating practices; and are aware of and understand changes in regulations, legislation or the operating licence. Continuing training includes:

- Procedure refresher training.
- Procedure effectiveness review.
- New procedure training including equipment demonstration where appropriate.
- Review of operating experience.
- Changes to the operating licence of operating limits.
- Skills refresher training.
- Regulatory changes.
- Safety requirements (radiation, conventional, and culture) including response to emergency, accident or abnormal events.

In order to become a Reactor Operator (RO), personnel must complete the CNSC certification process. A person seeking certification as a RO at the MNR shall, at the time of certification, have a college diploma or university degree that includes credits in science and mathematics. A person must have a minimum of one year’s experience at MNR, or an equivalent nuclear facility prior to applying for certification as an RO.

Personnel complete general training, appropriate to the knowledge requirements of the position, covering:

- science fundamentals;
- principles of nuclear safety;

- reactor physics and principles of reactor operations; and
- principles of operation of the equipment and systems of the reactor.

The training includes evaluations that confirm and document that, at the completion of general training; the person has the required knowledge to perform the duties of a RO.

A person must complete radiation protection training, appropriate to the knowledge requirements of the position, covering:

- radiation fundamentals,
- radiation hazards,
- radiation protection theory and practices; and
- radiation protection procedures used during normal, abnormal and emergency operation.

This training is developed and implemented by the Health Physics group. The training includes evaluations that confirm and document that, at the completion of radiation protection training; the person has the required knowledge to perform the duties of a RO.

Personnel complete facility specific training, appropriate to the knowledge requirements of the position, covering:

- operation of the equipment and systems of the reactor,
- fuel characteristics and properties of irradiated fuel,
- factors influencing fuel temperature and cooling; and
- constraints and limits associated with reactor fueling.

The training includes evaluations that confirm and document that, at the completion of facility specific training; the person has the required knowledge to perform the duties of a RO.

A person must complete on-the-job-training, appropriate to the knowledge and skill requirements of the position. The training includes evaluations that confirm and document that, at the completion of On-the-Job Training, the person has the required knowledge to perform the duties of a RO. A person must perform the duties of a RO under the supervision of a certified incumbent of the position for a minimum of 160 hours prior to the certification examination. A person must complete an interview administered by MNR management that confirms and documents the person's knowledge and skills to perform the duties of Reactor Operator.

To become a certified RO the personnel in question complete the CNSC approved exam and receive a passing grade.

2.2.4 Work Organization and Job Design

All licensed activities are designed with Human Factors in mind. A graded approach is used to ensure that activities consider human factors based on the safety implications of the activity.

Consideration is given to the following:

- Human-machine interfaces.
- Automation vs. human input.
- Reliability of people performing certain tasks successfully with appropriate resources.

- How tasks are completed.
- Who completes the tasks.
- When the tasks are completed.
- The review of OPEX events.
- The physical environment in which tasks are completed.
- How procedures are developed and used.
- How shifts are scheduled.
- What resources are needed including people.
- How systems are validated.
- How work is verified.

2.2.5 Fitness for Duty

MNR supervisors and managers ensure that employees are fit for duty at all times. Due to the small size of the organization supervision and management interact with all employees on a day-to-day basis. They are well acquainted and changes in behaviour are easily noticed. In addition to this, supervisory awareness training is given to supervisors, managers and reactor operators that gives them guidance on how to recognize issues that may inhibit personnel's fitness for duty.

McMaster University also has an extensive Employee and Family Assistance Program (EFAP) to assist with any issues employees may be facing at home. If a supervisor notices a change in behaviour, they actively encourage employees to use the supports provided to absolve whatever issues may be affecting the employee.

2.3 OPERATING PERFORMANCE

2.3.1 General Considerations

Policies, programs, processes, and procedures are formulated to ensure operations are carried out in a manner such that radiation exposures to workers, members of the public, and releases to the environment are As Low As Reasonably Achievable (ALARA), within the limits established in facility governance documents, and in compliance with all applicable codes and standards. MNR has processes and procedures in place to ensure that it operates in a safe manner and in compliance with its license conditions.

The annual Performance Review conducted by the management team at MNR establishes Key Performance Indicators (KPIs), for the facility which include quality, operating, radiological safety and industrial safety and environmental goals and objectives. Performance is tracked against KPIs and corrective actions are taken should negative trends develop.

An annual compliance report (ACR) is submitted to the CNSC in accordance with REGDOC 3.1.2 [35]. The ACR compiles pertinent operating and safety information on the facility for the year. The ACR reviews and discusses operating, radiological and environmental performance including any trends, if applicable.

Monthly operating reports detailing operating and radiological performance are documented and reviewed by the McMaster NFCC prior to submission to the Senior Management Team of the University (SMT) and the CNSC. The Senior Health Physicist (SHP) ensures compliance with the Radiation Safety Protection Program. Health Physics (HP) staff under the delegation of the SHP are responsible for activities such as monitoring, surveys, waste collection and disposal, monitoring of radioactive shipments, development and provision of radiation safety training, review and approval of procedures for radiological work and supervision of radiation emergencies.

Monthly report cards on MNR ALARA performance are prepared by the SHP and are submitted for review to the NFCC and the HPAC.

2.3.2 Conduct of Licensed Activity

Only licensed Reactor Operators, Reactor Supervisors, the Manager of Reactor Operations (MRO) and the Director Reactor Operations and Maintenance (DROM) have keys to the Reactor Facility and Control Room. McMaster Security Services Special Constables have keys to the Facility without Control Room access in order to carry out routine security checks while the Facility is vacated. All visitors, contractors, and students must have approval from the DROM or the MRO prior to gaining Facility access. All visitors must be accompanied at all times by a staff member with reactor access while within the Facility.

The MRO is responsible for the overall operation and maintenance of the Reactor and all activities performed within the Facility. All activities are carried out in accordance with Facility policies, procedures and the NPROL to ensure that all practices have a strong emphasis on safety and compliance. The MRO is responsible for the oversight of all changes made to the Facility that may have any impact on safety or reliability of structures, systems or components (SSC) as described in the AP-1010 Change Control [11] procedure. Minor changes (i.e., like-for-like changes) may be approved by the MRO solely. Depending on the level of significance, changes deemed to be safety significant must be approved by further levels of oversight, including the DROM, the MNR Change Control Committee the NFCC, and the CNSC as required.

The policies, methods, and procedures for carrying out the licenced activities of the Facility are described in the NPROL, the Licence Conditions Handbook (LCH) [36], the OLCs [21] and the MNR Policy Manual [4]. The routine surveillance and testing of SSCs are carried to ensure compliance with the OLCs. When an SSC is found to be non-functional or operating beyond the limits specified by the OLCs the issue is brought to the attention of the MRO. Corrective action(s) are taken, and a non-conformance (NC) report is generated withing the internal NC database: uniPoint. If the NC was deemed to be reportable under the REGDOC-3.1.2, the DROM, SMT, NFCC and CNSC are notified.

The SHP is responsible for the implementation of the radiation protection program. This includes oversight of the handling, storage, and transport of nuclear material in the Facility. Instructions and explanations are given in the MNR Radiation Safety Program [20].

The NFCC is responsible for the review and audit of policies, procedures, and operating data, under which the Facility operates. The NFCC reports directly to the VP Research who in turn reports to the President and the Board of Governors. The DROM has the ultimate responsibility for overseeing the safe operation of the Facility.

The MRO is responsible for the overall operation of the reactor, maintaining policies, making operating decisions, initiating maintenance, modifying equipment, modifying maintenance and operating procedures, and permitting staff and all other categories of persons to enter the Facility. Experiments are reviewed and approved by the MRO, the MNR Change Control Committee, the NFCC and the CNSC as required. See section 2.1.3 for details on organization.

2.3.3 Procedures

Current operating and maintenance procedures covering normal, unplanned, and emergency events are described in the following documents:

- OP-3000 series, Operating Procedures
- MT-4000 series, Maintenance Program
- EP-7000 series, Emergency Preparedness

- HP-9000 series, Health Physics Radiation Safety

A number of procedures and policies govern the development, implementation, verification, and validation of procedures.

AP-1215 Document Control [14] provides the guidelines for development, maintenance, review, revision, approval, and control of documents used at MNR. Roles and responsibilities of MNR staff as well as NFCC and CNSC are outlined in this document. This also covers distribution and retention of policies.

AP-1214 MNR Procedural Style Guide [37] provides guidance to be applied in preparing procedure, policy, form and work instruction documents for MNR. The Guide provides consistency in document production incorporating industry best practises focussed on safety of operations.

AP-1011 MNR Commissioning Procedure [38] defines the process used at MNR for effective commissioning of new and substantially modified facility equipment, systems, and processes. Commissioning covers planning, review, approval, implementation, and documentation of the implementation of structures, systems, and components (SSC) associated with licensed activities at MNR.

AP-1010 Change Control [11] defines the process providing effective control of temporary or permanent changes at MNR. The final stage of the change control process defines the implementation of the changes including issuance of new documents and procedures or updates and training on existing procedures.

AP-1000 Policy Manual [4] Section 18 Document Control defines the policy around preparation, review, approval, issue, and revision of documents.

2.3.4 Reporting and Trending

MNR provides all reports and notifications including annual compliance reports to CNSC in accordance with REGDOC-3.1.2 [35].

Reactor operations staff take control room readings on 30-minute intervals while the reactor is operating. These readings include rod positions, values from neutronics channels, flow and temperature data for the primary cooling system, and visual verification that flow through the fuel channels is unobstructed.

Periodic shift readings are taken to monitor and record data around building ventilation, water quality, cooling systems, and operability of all systems and components that support safe and compliant operation. Control room and miscellaneous shift readings are entered into the Data Control System (DCS) readings system and stored in a digital database.

Maintenance is carried out by Reactor Operators and overseen by the Assistant Reactor Supervisor per the maintenance program outlined in the MT series of documents. Completed maintenance and the date completed are recorded on the weekly or annual maintenance form as required. Maintenance is also logged in the digital maintenance database. Reactor operators are trained to identify trends and perform maintenance in areas that require regular attention such as ventilation filter changes.

Records from reactor operation, reactor maintenance, control room readings and miscellaneous shift readings govern and track the safe operation of the Facility. They identify areas or equipment that require attention to maintain compliance with the current licence requirements. See below sub-section 2.3.5, which discusses operating limits and conditions [21].

Reactor Supervisors and the MRO analyze trends in the operating and maintenance data to plan outages for required maintenance or refuelling activities. Reports can be compiled by the database software to populate monthly operating reports and ACRs.

The DROM prepares an ACR in compliance with REGDOC-3.1.2 [35] which tracks facility safety and operating performance in all Safety Control, Areas (SCAs). The report is reviewed by NFCC, HPAC, SMT and submitted to the CNSC.

2.3.5 Operating Limits and Conditions

The operating limits and conditions (OLCs) for MNR are stated in the MNR Operating Limits and Conditions [21]. The OLCs provide clearly defined limits for safe operation. The OLCs which determine the operating envelope of MNR are derived from the Safety Analysis Report [17] and TN-2001-03 Safe Operating Envelope of MNR [39].

Section 4.10 Reporting Requirements of [21] define the requirements related to reportable occurrences and reportable information. Definitions of reportable occurrences and information arise from conditions 5.1 and 5.2 of the NPROL. Following either a reportable occurrence or reportable information, the DROM shall provide verbal notification no later than 24 hours after the discovery of the event and provide a written report within 10 working days after the discovery of the event.

Section 4.11 of [21] Prescribed Actions defines the actions taken by MNR staff following an event of reportable information or reportable occurrence. In and event of reportable occurrence the DROM shall be notified as soon as possible. The DROM shall ensure that corrective action is taken. If a safety limit is violated the reactor shall remain shut down and not restarted without approval of the NFCC and the CNSC. The DROM shall submit a report as per section 4.10 [21]. In an event of reportable information, the DROM shall be notified as soon as possible and shall follow the actions prescribed in section 4.10 [21].

AP-1000 Policy manual [2] section 5.4 states that it is the responsibility of the MRO to explain the terms and conditions of the OLCs to facility personnel. This is accomplished through the various training plans for staff at MNR which ensure Facility personnel are thoroughly familiar with the OLCs as they apply to their role at MNR. Training focuses on understanding the reasons behind an individual limit and the staff member’s role in ensuring compliance. The DROM is responsible for ensuring that all working documents and procedures are consistent with the spirit and intent of the OLCs.

2.4 SAFETY ANALYSIS

The McMaster Nuclear Reactor is one of many Materials Testing Reactor (MTR) type pool reactors which have operated safely in North America, Europe and Asia for over fifty years. The robust nature of MNR and the “fail-safe” philosophy taken during design provides for a safe reactor that meets the requirements of CNSC Class 1 Nuclear Facility Regulations [33]. The open pool design and negative temperature coefficient contributes greatly to the inherently safe characteristics of the MNR. Shutdown absorber rods are in place to drop in core if any of the numerous trip parameters exceed their trip setpoint value. There is also a manual trip that can be actuated from numerous locations in the MNR facility including the control room. Only passive processes are used in the safe shutdown states of the MNR, and on-going no monitoring or control of these passive processes is required.

2.4.1 General Considerations

The MNR safety analysis captured in Chapter 16 of the SAR [17] is compliant with REGDOC-2.4.4 Safety Analysis for Class IB Nuclear Facilities [40]. It demonstrates that safety objectives are met for all credible events that have a potential for serious consequences and/or significant frequency of occurrence.

A Defense In Depth review of the MNR [41] was conducted in 2011 with emphasis on control of severe accident conditions. The purpose of the report was to provide supporting information for re-examining the MNR safety case in light of the Fukushima event, as requested by the CNSC. The report concluded that MNR has strong provisions for protecting workers, the public and the environment against internal and external hazards. No significant gaps in Defense In Depth provisions were found.

Since the Defense In Depth report [41] was issued, modifications have been made to further enhance the existing provisions in the area of Severe Accident Management. The main changes are:

- Backup power is now routed from the four campus diesel generators.
- The Class 3 electrical supply and distribution equipment was replaced.
- An external connection to the Class 3 system was installed to allow a portable generator to be tied - in the event of loss of all four generators.
- The building fire alarm system was upgraded with new panels and detectors to improve reliability and monitoring capabilities.
- An external fire water connection was installed to allow flooding of the containment building in the event of a loss-of-coolant accident (LOCA) that requires the containment building to be evacuated.
- A core spray system was installed to allow cooling water to be sprayed directly onto the core in the event of a LOCA with risk of uncovering the core.
- The Class 1 DC backup power system was upgraded with a new rectifier and increased capacity battery bank.

During the 2023 update of the SAR [17], the analysis was reviewed for potential events pertaining to Climate Change. These events included flooding, ice storms, external fire hazards, lightning, extreme winds and tornados. The SAR concludes that the facility is not susceptible to potential events pertaining to Climate Change as demonstrated in the analyses in [17], [66] and [41].

2.4.2 Postulated Initiating Events

The geographical location of McMaster University and the placement of the MNR on campus largely mitigates the risk from external events including seismic, flooding and high wind events. This SAR [17] conclusion was reaffirmed with the aforementioned Defense in Depth review which included in its scope extreme meteorological conditions (wind, lightning, precipitation, floods), earthquake, external fires, external explosions, impacts by vehicles and aircraft, hazardous materials in adjacent buildings and intrusion.

MNR safety analysis address the following four broad accident categories:

- loss of regulation and loss of reactivity control events;
- fuel power/cooling mismatch events;
- loss-of-coolant accidents;
- failures of safety support systems.

The MNR safety analysis also considers radioactive material handling events, which are not related to reactor operation but have the potential for release of energy or radioactive materials at locations other than the reactor core. This could be caused by an inadvertent criticality accident or by damage to a primary boundary which normally contains radioactive materials (irradiated fuel cladding and Iodine 125 irradiation chambers).

The SAR also includes a broad engineering assessment of internal hazards which do not directly affect the reactor. These hazards include fires, explosions within the building, flooding from internal sources, disruptive equipment failures, falling objects, and release of non-radioactive gases or fluids.

2.4.3 Deterministic Safety Analysis

The MNR safety analysis acceptance criteria are risk-based criteria based on IAEA guidelines, expressed in terms of individual and population doses as a function of accident frequency.

Safety analysis of the postulated event categories quantify both frequency and consequence for each scenario for comparison with risk-based criteria. The accident progression paths are systematically identified by event trees, with branches having different probability of occurrence, depending mainly on the availability and reliability of mitigating features provided by the design and on the time available for manual actions. The branches also have different consequences depending mainly on the state of barriers that prevent the release of radioactivity and again on the time available for manual actions.

Manual operator actions initiating events are important for many accidents in small reactors. The risk profile of the facility would be significantly distorted if an overly conservative bounding approach was used which neglects manual operator actions and any phenomena that are difficult to enumerate. As such the MNR safety analysis considers all relevant events and phenomena using "best-estimates" of frequencies and consequences whenever possible. Invariably, this involves sensitivity analyses and engineering judgements. For some accident phenomena or topics, only conservative parameters are available, or are required to be used by convention and/or precedence. Conservative values are then used for these phenomena and topics in conjunction with best estimates for the remaining phenomena. This approach, which combines realistic and conservative components, is sometimes called the "best-effort" approach.

In order to provide confidence that important accident sequences were not omitted on the basis of perhaps tenuous frequency estimates, this report does not use the "cut-off" frequency of 10^{-6} events per year beyond which consequences need not be assessed. Instead, the accident sequences are developed up to the first fuel failures, regardless of its frequency, when there is less than twelve hours from the unambiguous indication of the accident and the time of fuel failure. Accidents with frequency less than 10^{-6} per year are called Rare Events. The consequences of these rare events are evaluated in the MNR safety analysis.

2.4.4 Hazard Analysis

For all plausible accidents (i.e., frequency greater than 10^{-6} per year), fuel failure is avoided which is sufficient but not necessary means of demonstrating that the risk-based safety criteria are met. The frequency estimates are made mainly by judgement, guided by operating experience. The assessment of consequences uses operating experience, test data, documented hand calculations, and existing simulations to establish that fuel failure is avoided. This ensures that the Safe Operating Envelope, which is defined to preclude boiling in any flow channel of the MNR core, also holds for accident conditions.

The consequence of irradiated fuel mishandling is bounded fuel assembly damage from severe flow blockage which is shown to have dose consequences that are several orders of magnitude below risk-based safety limits for frequent events, which is a very conservative criterion given that no such fuel mishandling events have occurred over the 60-year operating life of the MNR.

The I-125 production at MNR is performed using double containment production rigs which allow for irradiation and decay of the target gas. These production rigs are moved within the pool to and from the reactor in accordance with a predetermined production cycle. Dose consequences due to failure of the production rig and or its containment have been analyzed at various stages of the production cycle I-125 production with dose consequences that are well below the public dose limits.

As discussed in 4.4.2 the SAR [17] also includes a broad engineering assessment of internal hazards which do not directly affect the reactor. The conclusion of this assessment is that internal hazards which do not directly involve the reactor are all sufficiently benign as to not require detailed and formal assessment.

2.4.5 Criticality Safety

New fuel is stored in a single row along the wall of the new fuel storage room. The MNR criticality assessment [42] which is compliant with REGDOC-2.4.3 Nuclear Criticality Safety [43] demonstrates that inadvertent criticality is not an issue for new fuel storage, even with the highly conservative assumption of the new fuel racks being submerged in fresh water due to a highly improbable postulated flooding event.

In the underwater fuel storage facility, the fuel assemblies spacing is greater than in the new fuel assembly storage room. This, combined with the lower reactivity of the spent fuel than fresh fuel means that the previously discussed analysis for flooded new fuel racks conservatively bounds the criticality risk for the spent fuel storage facility.

Fuel movements in the reactor pool are limited to one assembly at a time. The reactivity of a row of fuel assemblies decreases with increased spacing therefore the inadvertent reactivity risk of an individual fuel assembly in the reactor pool will always be enveloped by both the analysis for the new fuel storage facility and the underwater spent fuel storage facility.

2.5 PHYSICAL DESIGN

2.5.1 General Considerations

The design basis for the McMaster Nuclear Reactor is documented in the McMaster Nuclear Reactor Safety Analysis Report (SAR) [17]. The SAR [17] is reviewed at least every 10 years against the following criteria: any modification, new program, or new procedure, inclusion of a hazard not previously analysed and/or inclusion of a hazard greater in magnitude than that previously analysed. The SAR [17] was updated in early 2023 with no significant changes to safety analysis.

The facility was designed using conservative design principles and incorporating, fail-safe components and systems wherever possible. The principal of As Low As Reasonably Achievable (ALARA) is used in the creation of policies and procedures to minimize releases of radiation to personnel, the public and the environment in all conceivable scenarios.

2.5.2 Design Governance

Design governance is assured through appropriate oversight and control of changes at MNR. The NFCC provides oversight of risk and control processes. MNR's AP-1000 Policy Manual [4] is in full compliance with N286 12 [5] and describes the policies governing change control at the Facility as well as the general principles of quality that are practiced. Descriptions of the roles and responsibilities of facility staff and of McMaster University SMT can be found in AP-1130 Organizational Structure [2].

There have been no significant changes to the design of the MNR SSCs. All facility changes and modifications are reflected in the latest version of the SAR [17] which required no change to Chapter 16 Safety Analysis [17] during the latest revision.

2.5.3 Site Characterization

The geological, seismological, and hydrological information is described in the Safety Analysis Report Chapter 3 Site Characteristics [17] and the MNR Environmental Risk Assessment 2023 [44].

The University's main campus is located at the western end of the City of Hamilton, west of the community of Westdale and east of the town of Dundas. The University is situated on lands previously owned and maintained by the Royal Botanical Gardens.

The campus is bounded on the west by Cootes Drive, on the east by Forsythe Avenue, on the south by Main Street, and on the north by Cootes Paradise valley.

MNR is located within 5 km of Highway 403 and approximately 10 km from the Hamilton International Airport. Events initiated by air or vehicle traffic have been screened out in the SAR [17].

2.5.4 Facility Design

The reactor building is a full containment structure divided into three floors. The topmost being the Experimental Floor, located above grade and including the main facility access, the control room and reactor pool. The Mechanical Floor is at grade level and encompasses the mechanical room with the HVAC systems as well as the hot cell facility. The Beam port floor is fully below grade and houses the 6 beam ports, the pump room and hot waste storage area. The stairwells on the east and west sides of the building allow access to each floor and each contain grade level emergency exit airlock doors. There is also mezzanine level containing offices above the experimental floor accessible from the east stairwell.

All areas of the reactor building are considered free of contamination and of a low radiation background unless otherwise posted by Health Physics. Health Physics does monthly surveys for contamination and radiation areas to update the posted areas. All posted areas are marked by a sign as either radiation area, high radiation area, contamination area, or airborne contamination area. These signs are located outside physical barriers to areas: doors or temporary access gates. See HP-9000 section 6 Facility Internal Surveillance and Posting [20] for details.

All storage of radiation sources and contaminated equipment is marked by radioactive trefoil and 'CAUTION RADIOCTIVE MATERIAL' on the sign or label. Sources are stored only in approved shielded areas or approved containers marked appropriately. See section HP-9000 7.4 [20].

All areas, rooms, and enclosures are organized by floor according to **Table 2.5.4-1**.

Table 2.5.4-1: MNR Facility Areas

Reactor Floor	Description
Hall – Experimental Floor	Main airlock access doors; control room; changerooms; I-125 enclosure; reactor pool
Mechanical Floor	Mechanical room; hot cell loading area; hot cell window; gamma room
Beam Port Floor	Beam ports 1-6; pump room; hot waste storage area, Pump Room
Mezzanine	Reactor offices

A detailed description of all SSCs as well as the criteria and methodology used in classification of SSCs is found in TN-2010-04 Status of MNR Structures, Systems, and Components [45]. The general design philosophy of the Facility is to use conservative design principles with robust components in a fail-safe application wherever possible.

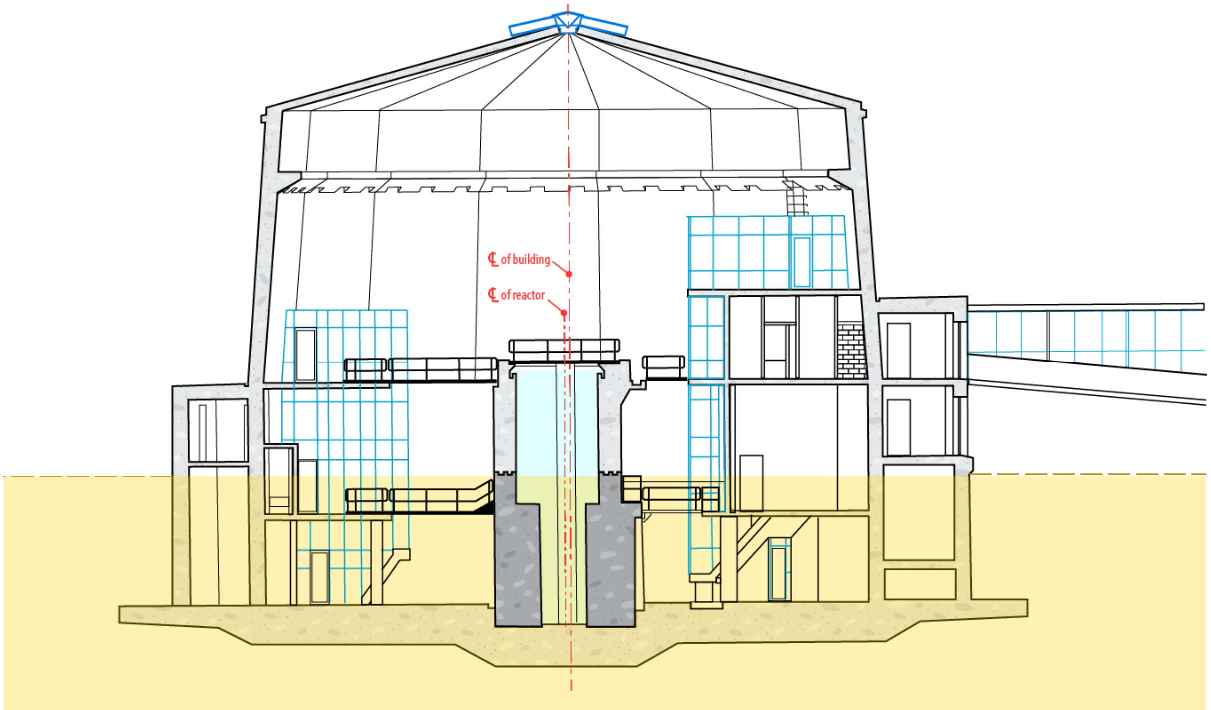


Figure 2.5.4-1: MNR Containment Building E-W

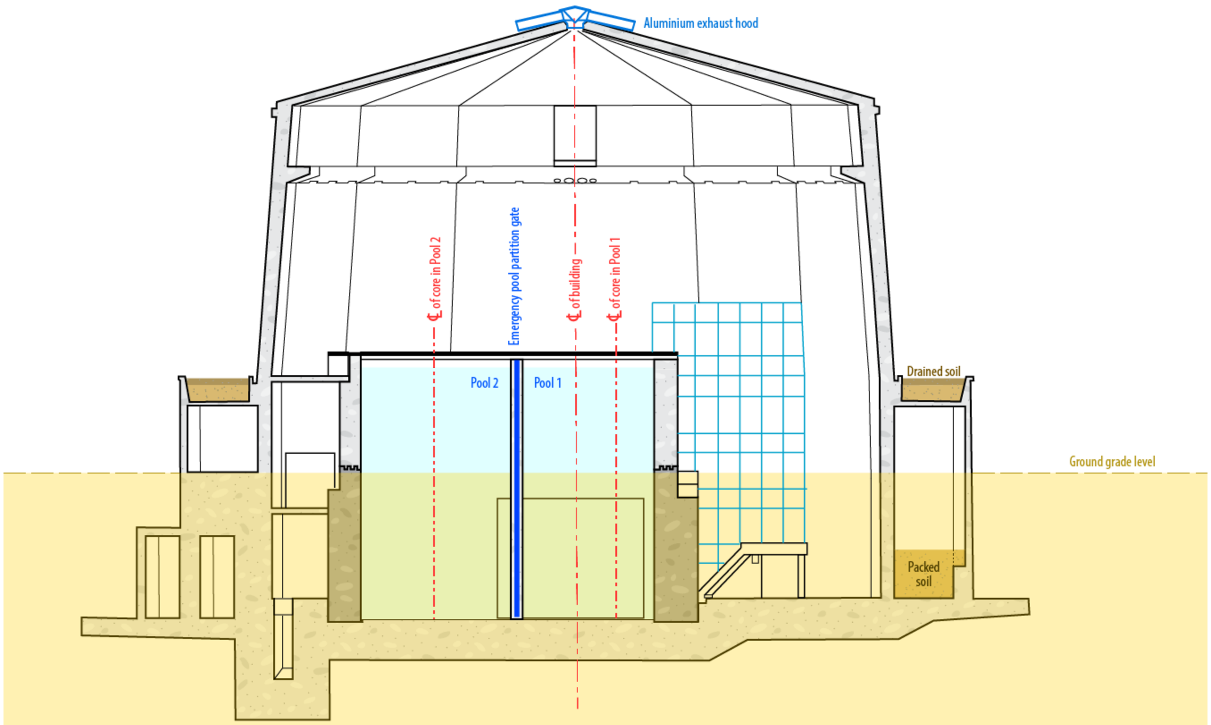


Figure 2.5.4-2: MNR Containment Building E-W

2.5.5 System and Component Design

The MNR containment structure is constructed of a 70 cm thick reinforced concrete walls and 30 cm thick concrete roof. The structure was designed to withstand any credible nuclear accident. The building is maintained at slightly negative pressure to atmosphere by modulating the building air inlet damper with a differential pressure controller. The exhaust air is filtered and monitored for radioactivity before exiting the building. If a reading above the minimum trigger level for radioactivity in the exhaust is detected, the inlet and outlet duct dampers seal the building, the fans shut down automatically and a control room alarm is actuated. Dampers contain fail-safe, air-to-open actuators which fail closed on loss of power or loss of building air. Building leakage is tested annually by pressurizing the building to a set level and measuring the outflow of air. A maximum leakage rate is prescribed by the OLCs [21].

Fresh air is fed into the reactor through the inlet duct and directly into stairwells, offices, change rooms, and the control room of the reactor. These areas are maintained at slight positive pressure to the reactor hall. The iodine processing enclosure utilizes charcoal filters to strip radioactive iodine-25 from the processing area. The enclosure is also maintained at negative pressure to the hall to ensure no radioiodine can escape into the hall.

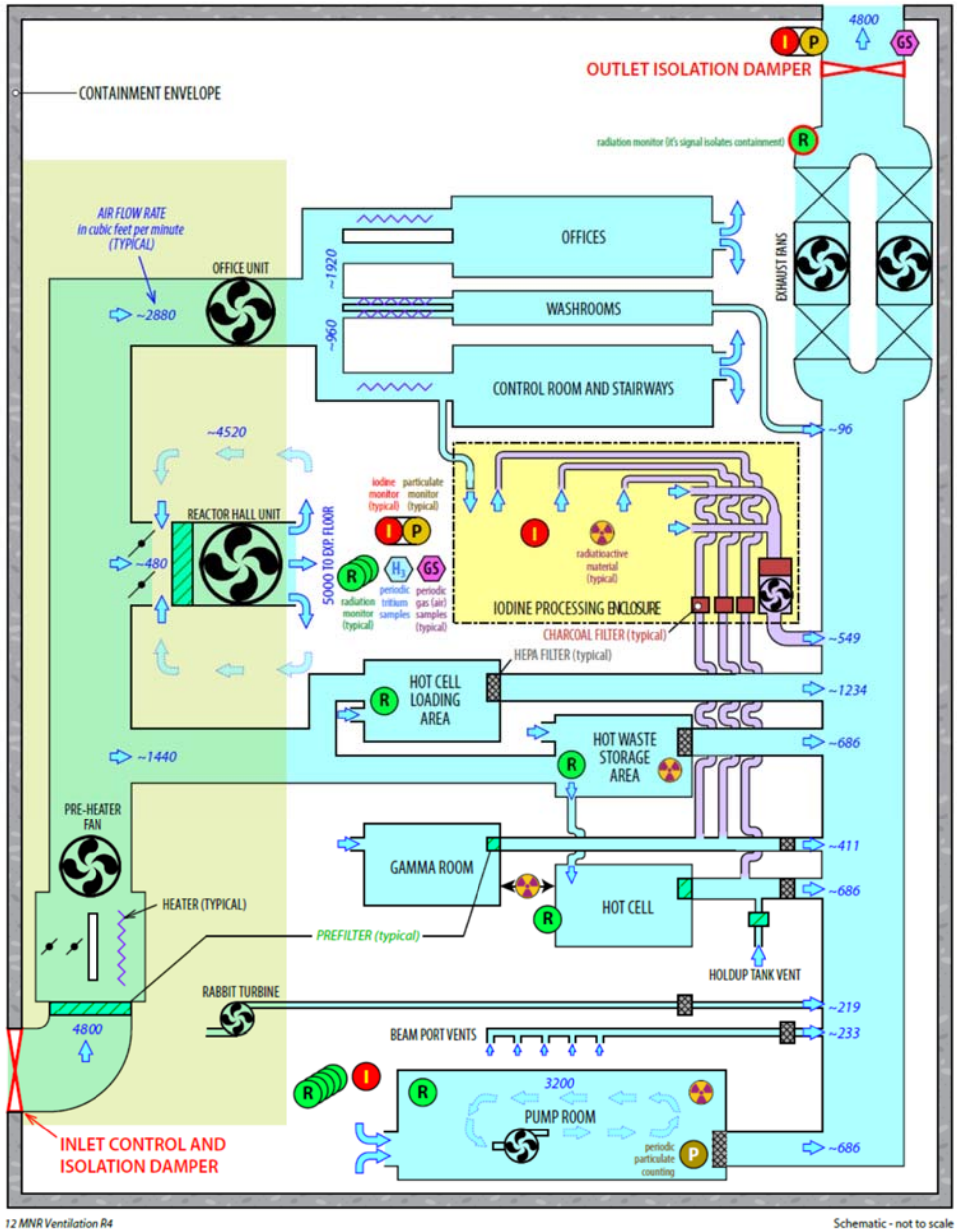


Figure 2.5.5-1: MNR Ventilation System

2.5.6 Waste Treatment and Control

Waste handling, storage and control is described in HP-9000 [20] sections 7 and 9. The majority of solid waste is low level contaminated PPE such as gloves and Tyvek suits. Waste is bagged and removed from the facility by Health Physics.

Contaminated water from minor pool seepage is directed to the cold sumps on the beam port floor. Leakage of potentially contaminated water from other processes such as pump packing glands is also directed to the sumps. Once a significant level of water is collected it is directed to the hot waste storage tank in the HWSA. The water can then be run through a clean-up loop consisting of micron filters and ion exchange resins until the quality of the water is of an acceptable level to return to the reactor pool. While there is the capacity to dump liquid effluent to sewers, this is never done in practice, all active wastewater is recycled to the pool.

2.5.7 Control Facilities

The MNR control system is an analogue control system utilising 4 neutronics channels and relay logic to drive the shim safety rods that control the reactor core. Fail safe design principle is used in the control system so that if any singular channel or relay should fail it will default to releasing the shim rods and placing the reactor in a safe shutdown state. The absorbers are attached to the shim safety rods using electro-magnets which release the absorbers into the core on loss of power to provide a fail-safe shut down of the reactor. Further details on the control system can be found in SAR Chapter 8 [17].

From the control panel reactor operators can start up or shut down the reactor by driving the control rods. Power can be adjusted via the demand and range controls on the console. Primary, secondary, and demineralizer system pumps and the cooling tower fan speed can be remotely controlled. All building alarms including local radiation monitoring and audible and visual reactor system notifications are displayed on the console status panel. Alarms of significance including reactor scrams, reverses, and radiation alarms, are also displayed on the Programmable Message Display (PMD) notification screen and logged on the control room computer. Temperatures, flows, neutronics channels, rod positions, and fission products monitoring outputs are displayed and logged on chart recorders in the control room in order to identify trends in operation.

The control room is fed by a fresh air feed from the outside and maintained at slight positive pressure with regards to the reactor hall. This will reduce the effects of airborne contamination in the control room in the event of a widespread contamination event. The control room contains P100 full face respirators which the ROs are trained to use. There is also a self-contained breathing apparatus (SCBA) in the hall outside the control room which the ROs are certified to use. In emergency events staff are trained to put the reactor in a safe state and vacate the building as soon as practical. From the control room it is possible to scram the reactor and seal the building with 2 buttons on the control panel.

2.5.8 Structure Design

The reactor building is constructed on a 1.5 metre thick, 33 metre diameter reinforced concrete slab, contoured to provide this thickness under the reactor pool and various sumps. The bottom of the pad is at 92.9 metres and is thus about 45 centimetres above the ground water table. The pad section under the reactor pool is 76 centimetres lower; thus, the bottom of the pad here is slightly below the water table. The concrete support pad forms the base of the building and contains the primary water system piping and other embedded components.

The building walls are regular concrete with reinforcing rod. They are 70 centimetres thick at the Experimental Floor level. In addition to structural considerations, this thickness acts as shielding to provide time for warning and evacuation of surrounding areas should a release occur. The roof slabs have a minimum thickness of 30 centimetres, primarily for structural reasons.

The building possesses adequate strength to withstand any pressure increase resulting from an excursion, as well

as certain seismic events. The following is a summary of information from G. Williams and J.D. Beath, "Report on McMaster Reactor Building Preliminary Structural Analysis" [46]:

The Reactor Building was designed and built to the requirements of the 1953 National Building Code of Canada (NBCC). The building was structurally designed for an internal over-pressure of 3.4 kPa (0.5 psi), but not designed for earthquake load.

Using the NISA II finite element method code, the building was analysed to determine its response to earthquake loads as specified in NBCC 1990. The results are:

(1) *the walls and roof are structurally adequate;*
(2) *the building has sufficient reserves of strength to withstand higher levels of loading;*
(3) *loads due to an NBCC 1990 earthquake do not have significant effect. Loads 3 times the NBCC 1990 earthquake load are well within the structural capacity of the building.*
(4) *the building is structurally adequate for a containment [over-pressure] of at least 6.8 kPa (1.0 psi).*
(5) *Loads due to internal pressure have a greater effect than the NBCC 1990 design earthquake load.*

McMaster Security Services provides primary security and monitoring services to the reactor. In emergency situations Security Services provides assistance to Hamilton Fire Department and Hamilton Police Services as required. Security Services can also assist with emergency communication and building evacuation as required.

Hamilton Fire Department responds to all fire alarms in the reactor building. The nearest fire station is 200 metres from MNR. Hamilton Police Services provides traffic and crowd control during an emergency as requested. HPS has an Emergency Response Tactical Unit trained to respond to high-risk situations in the reactor building.

2.6 FITNESS FOR SERVICE

2.6.1 General Considerations

The McMaster Nuclear Reactor continues to effectively provide the University community with safe reliable operation, creating an environment suitable for education, research, and isotope production. MNR addresses the maintenance requirements set forth in IAEA, "Aging Management for Research Reactors", Specific Safety Guide No. SSG-10, 2010. [47].

There have been no facility modifications for the duration of the current operating licence that could compromise or negatively impact the Safety and Control area. All routine maintenance has been completed diligently on a regular schedule. Aging management concerns are addressed individually through ongoing improvements through planned maintenance, the change control process, and corrective actions due to identified non-conformances.

Periodic inspections, testing, and calibrations are carried out by reactor staff and qualified third-party contractors on an established inspection cycle.

2.6.2 Maintenance

Conventional building maintenance including all building services: steam, condensate, water, air, and Class III/IV power are maintained by campus Facility Services.

Routine preventative maintenance is performed by reactor staff on a scheduled basis using appropriate procedures. Weekly and annual maintenance schedules are used to ensure that all required maintenance is completed and recorded as required by MT-4000 [25].

Corrective maintenance is performed by reactor staff and often utilizes qualified third-party contractors. Any performance issues are logged by reactor staff in the daily logs. If necessary, formal non-conformances are recorded and a corrective action plan is created and implemented. Work is typically completed under the guidance of work plans uniquely prepared for the work being completed [13].

During regularly scheduled maintenance, if a condition is found that inhibits the ability to operate the reactor safely, Reactor Operations staff will ensure the reactor is shutdown, and follow the unplanned shutdown procedure to ensure that an appropriate level of review is conducted before the reactor is permitted to restart [49], [48].

2.6.3 Aging Management

MNR is compliant through routine maintenance activities, continuous improvements and tracking of non-conformances [26], [16], [48]. In 2010, a detailed review and status assessment was completed for all MNR SSCs [45]. There have not been any significant changes to that assessment and efforts to monitor and improve the various SSCs are ongoing.

The storage tank for the primary system is normally inaccessible due to the combination of the radiological contamination and being classified as a confined space. In 2017 the tank underwent a condition inspection before and after an adjacent construction project. Videos were taken of both inspections and have been archived should there be a need to review the condition of the structure. The inspection showed that there were no structural concerns before or after the construction activities.

Intermittent repairs to concrete spalling and surface delamination are completed to address deterioration of concrete structures throughout the reactor building. The containment isolation system is tested weekly. A full containment air test is completed annually to ensure the containment structure and all its components are functioning effectively. A complete refurbishment of the exterior of the containment structure was completed in 2021.

Major upgrades as part of aging and obsolescence are managed by the Director of Reactor Operation and Maintenance. Improvements are evaluated for overall impact and prioritized based on importance within the allocated annual budget.

MNR manages critical spare equipment and components that are known to have long lead times, as well as obsolescence issues. In the case of the control system, plans are underway for component improvements.

However, a stock of spare parts is maintained for the short to medium term to ensure reliable performance.

2.6.4 Periodic Inspection and Testing

Reactor control instrumentation is calibrated and tested by reactor staff on a set schedule as dictated by the operating cycle [50]. The calibration and testing of instrumentation used to test the reactor instrumentation is completed on a scheduled or as needed basis, by reactor staff, or outsourced to licensed third-party contractors [51], [52].

The health physics department is responsible for the calibration of all the radiological safety equipment. The radiation protection technicians will complete the calibrations on an established and approved schedule to ensure that sufficient equipment is available to perform routine work throughout the facility [53].

Normal shift routines include visual inspections of the core and its structure. The control rod worth calibrations are completed annually. Operationally they are tested daily, magnets are tested weekly, and shutdown tests are completed monthly and quarterly.

As maintenance allows, internal inspections of the beam port liner tubes are intermittently completed. In 2013 and 2023 two liner tubes were removed and replaced. The removed liners showed no signs of degradation.

Accessible piping and equipment of the reactor cooling systems are subject to routine inspection. There is no evidence of deterioration. Primary water is checked for chemistry daily during operation to ensure minimal corrosive effect to the system.

Fire detection system was replaced in 2014. Monthly tests, and annual maintenance are completed by qualified third-party contractors via campus Facility Services.

2.7 RADIATION PROTECTION

2.7.1 Dose Control Data

The overall objectives of the MNR Radiation Safety Program are:

- Prevent deterministic effects (radiation injuries).
- Minimize the probability of stochastic effects for workers by requiring that doses be maintained as low as reasonably achievable (ALARA).
- Protect the public and environment by ensuring that releases of radioactive material are maintained ALARA.
- Achieve compliance with the Canadian Nuclear Safety Commission Radiation Protection Regulations.

These objectives continued to be met throughout the licensing period.

The Radiation Safety Program at MNR is documented in HP-9000, the MNR Radiation Safety Program [20], which specifies requirements in the following areas: responsibilities, training and qualification, external and internal exposure limits, personnel monitoring and dosimetry, facility internal surveillance and posting, conduct of radiological work, facility boundary surveillance, radioactive waste disposal, instrumentation and calibration, incidents and emergencies and program assessment.

Performance of the radiation safety program has been strong throughout the licensing period with continuous improvements being made in several areas. Detailed annual radiation safety program assessments are completed by MNR and Health Physics Department management are presented to the Health Physics Advisory Committee and Nuclear Facilities Control Committee. The assessments include reporting of performance against goals and establishing goals for the upcoming year.

The main aspects of significance with respect to radiation safety performance during the licensing period include:

- All radiation doses associated with the facility were far less than Regulatory Dose Limits at all times during the licensing period.
- There were no Action Level exceedances related to the Radiation Protection Program during the licensing period.

- As of December 2022, the annual collective dose to the most significantly exposed workers[1] at the facility continue to remain at historical lows, with doses below 50 person-mSv. This continued performance is the result of the implementation of ongoing ALARA improvements, particularly during facility maintenance and refurbishment activities. Performance tracking against ALARA dose targets continued throughout the period, with all of the goals being achieved.
- A new monthly radiation protection performance report was implemented in 2018, which includes current and projected tracking of collective radiation exposure for significantly exposed work groups, internal uptakes, personal contamination events and contamination control metrics.
- Extensive annual radiation safety program reviews continue to be conducted, with strong support and input from all levels of the organization.
- A significant expansion and updating of radiation safety program documentation, including procedures, training programs, supporting records and basis documents, occurred during the period.
- Facility radiation safety training programs were significantly expanded and updated, particularly with the transition of initial training to online formats and the addition of on-the-job training for practical elements like the use of portable radiation instruments.
- During the licensing period, a detailed assessment of the facility radiological source term was completed and no changes to the release of material, exit monitoring or dosimetry were required as a result of the assessment. Furthermore, assessments continue to confirm that there is no current significant source-term of alpha-emitting contamination within the facility, with the exception of the MNR hot cell, which has low level alpha contamination present due to the processing of components from external nuclear facilities (e.g. pressure tubes from CANDU nuclear power plants).

2.7.1.1 Operations Personnel

Operations Personnel comprise of the Director of Nuclear Operations and Facilities (replaced by the Director Reactor Operations and Maintenance during the recent NOF reorganization), the Manager, Reactor Operations, Reactor Supervisors, Reactor Operators, Assistant Reactor Operators and Student Operators.

As in previous years, the only contribution to effective dose was external deep dose (Hp(10)). There is no indication of any significant internal exposures from extensive facility air and surface contamination monitoring or from personnel contamination monitoring.

A comparison of the maximum annual dose of each type for 2022 (the most recent year for which data is available) with the facility Administrative Control Levels (ACLs) and Regulatory Limits is presented in **Table 2.7.1-1**. No doses exceeded the corresponding ACL or Regulatory Limit in 2022.

Table 2.7.1-1: Comparison of Maximum Annual Doses with Limits – MNR Operations

Dose	Maximum Annual Value in 2022 (mSv)	ACL (mSv)	Dose as % of the ACL	Regulatory Limit (mSv)	Dose as a % of the Regulatory Limit
Effective Dose	2.03	15	14%	50	4%
Shallow Dose	2.06	150	1%	500	0.41%
Extremity Dose	2.93	250	1%	500	0.59%

[1] Includes all work groups with any individual having an annual dose in excess of 1 mSv. During this licence period, the groups include Reactor Operations, Iodine Production and NRay Neutron Radiographers.

The historical values of the average, maximum and collective effective dose for this group are presented in **Figure 2.7.1-1**. No trends of concern are indicated by the data. The average, maximum and collective effective doses are all well within the recent operating experience for the facility.

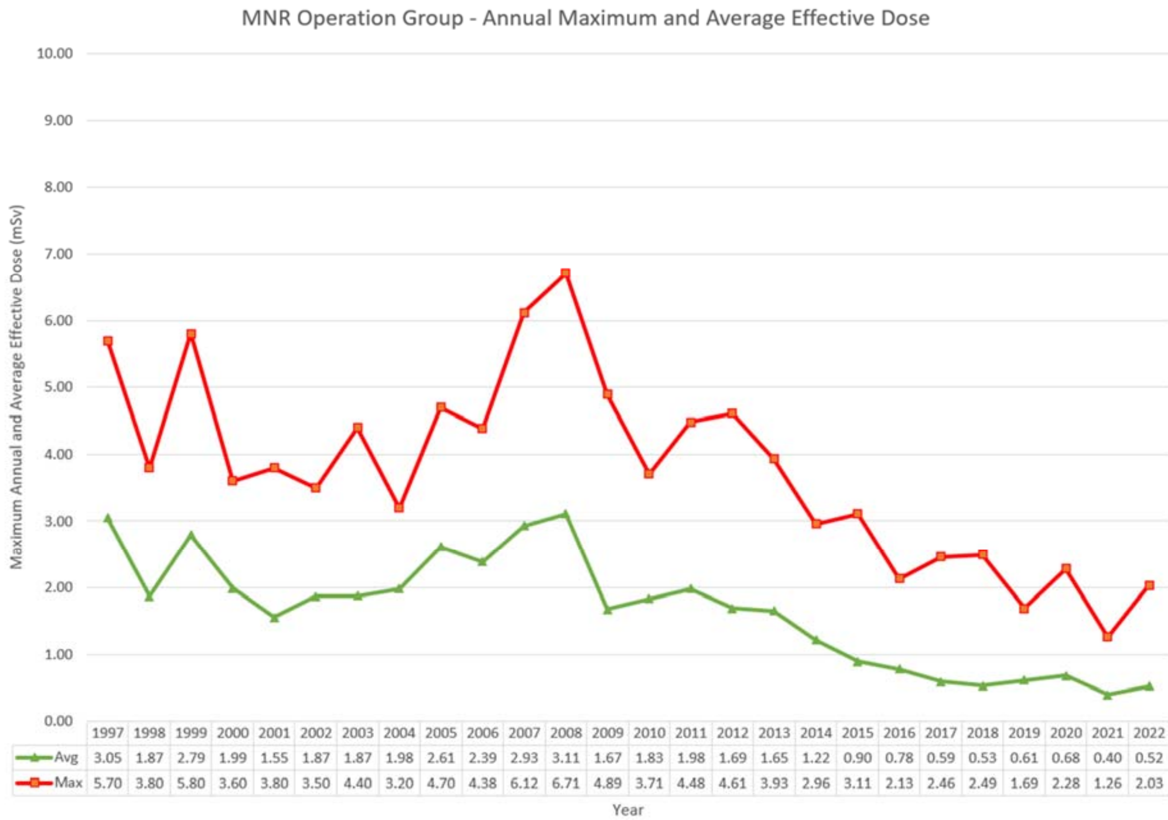


Figure 2.7.1-1 – Annual maximum and average effective dose for MNR Operations

Dose performance goals for the Operations Group are established annually and are based on the collective effective dose per unit output, with output taken as normalized MW-h energy output of the reactor (adjusted by a constant arbitrary normalizing factor). The recent annual values of this quantity are shown in **Figure 2.7.1-2**. A generally positive trend in this performance throughout the current licence period (2014 to 2023) is evident, with normalized collective doses remaining at historical lows.

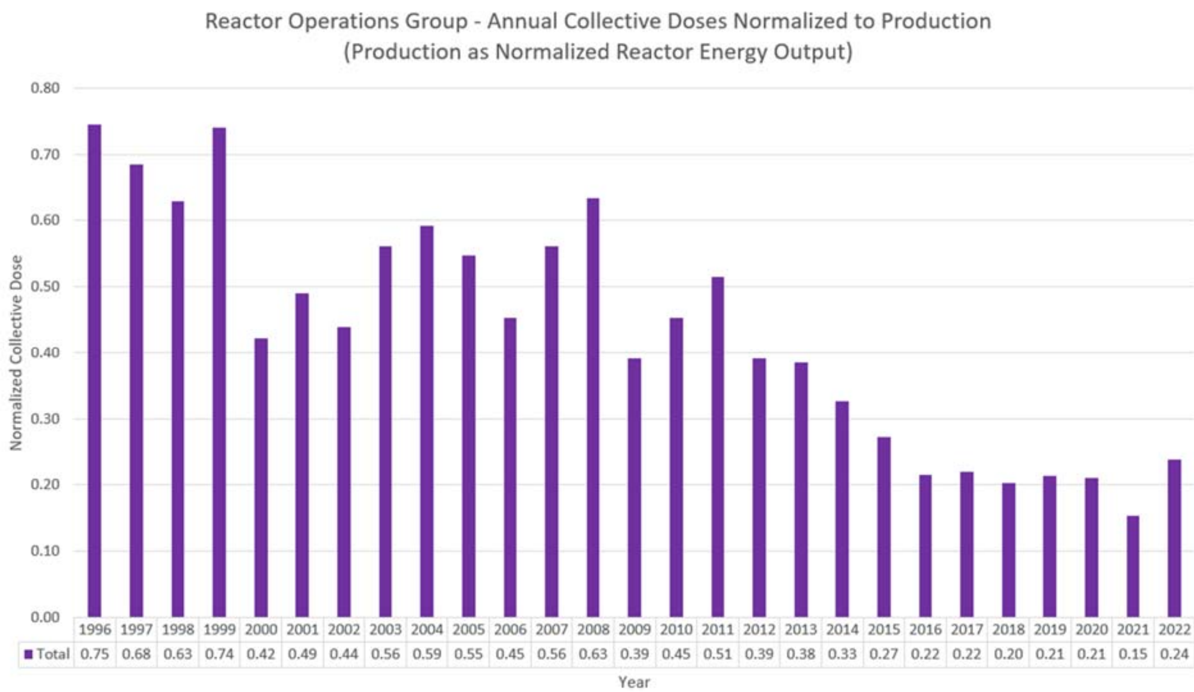


Figure 2.7.1-2 – Normalized collective effective dose for MNR Operations

2.7.1.2 Iodine Production Personnel

Iodine Production Personnel comprise the Production Manager, Production Technologist, the Manager of Laboratory Services, the Research and Development Scientist, the Quality Control Technologist and Production Assistants.

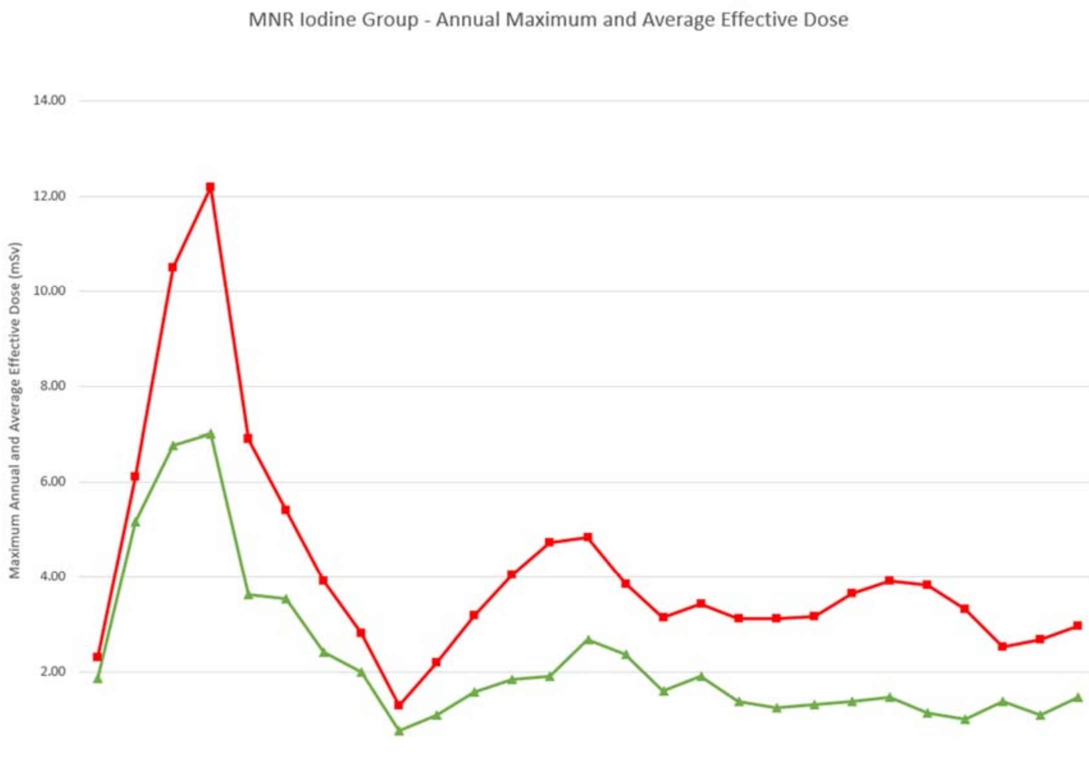
As in previous years, the only contribution to effective dose was external deep dose (Hp(10)). There is no indication of any significant internal exposures from extensive facility air and surface contamination monitoring, personnel contamination monitoring or thyroid screening.

A comparison of the maximum dose of each type for 2022 (the most recent year for which data is available) with the facility Administrative Control Levels (ACLs) and Regulatory Limits is presented in **Table 2.7.1-2**.

Table 2.7.1-2: Comparison of Maximum Annual Doses with Limits – Iodine Production Personnel

Dose	Maximum Annual Value in 2022 (mSv)	ACL (mSv)	Dose as % of the ACL	Regulatory Limit (mSv)	Dose as a % of the Regulatory Limit
Effective Dose	2.96	15	20%	50	6%
Shallow Dose	2.91	150	2%	500	0.58%
Extremity Dose	24.96	250	10%	500	4.99%
Thyroid Burden	230 Bq	1000 Bq	23%	Limited by contribution to effective dose	--

The historical values of the average, maximum and collective effective dose for this group are presented in **Figure 2.7.1-3**. No trends of concern are indicated by the data. The average, maximum and collective effective doses are all well within the recent radioiodine production experience for the facility.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Avg	1.85	5.17	6.77	7.00	3.62	3.53	2.40	2.00	0.76	1.09	1.58	1.84	1.90	2.68	2.37	1.59	1.91	1.37	1.24	1.32	1.37	1.46	1.14	1.00	1.38	1.09	1.46
Max	2.30	6.10	10.50	12.20	6.90	5.40	3.90	2.80	1.30	2.20	3.18	4.04	4.72	4.82	3.85	3.14	3.43	3.12	3.11	3.15	3.64	3.91	3.81	3.31	2.51	2.67	2.96

Year

Figure 2.7.1-3 – Annual maximum and average effective dose for Iodine Production Personnel

Dose performance goals for the Iodine Production Group are established annually and are based on the collective effective dose per unit output, with output taken as activity of I-125 produced (adjusted by a constant arbitrary normalizing factor). The recent annual values of this quantity are shown in **Figure 2.7.1-4**. Normalized collective doses remain at historical lows throughout the current licence period (2014 to 2023).

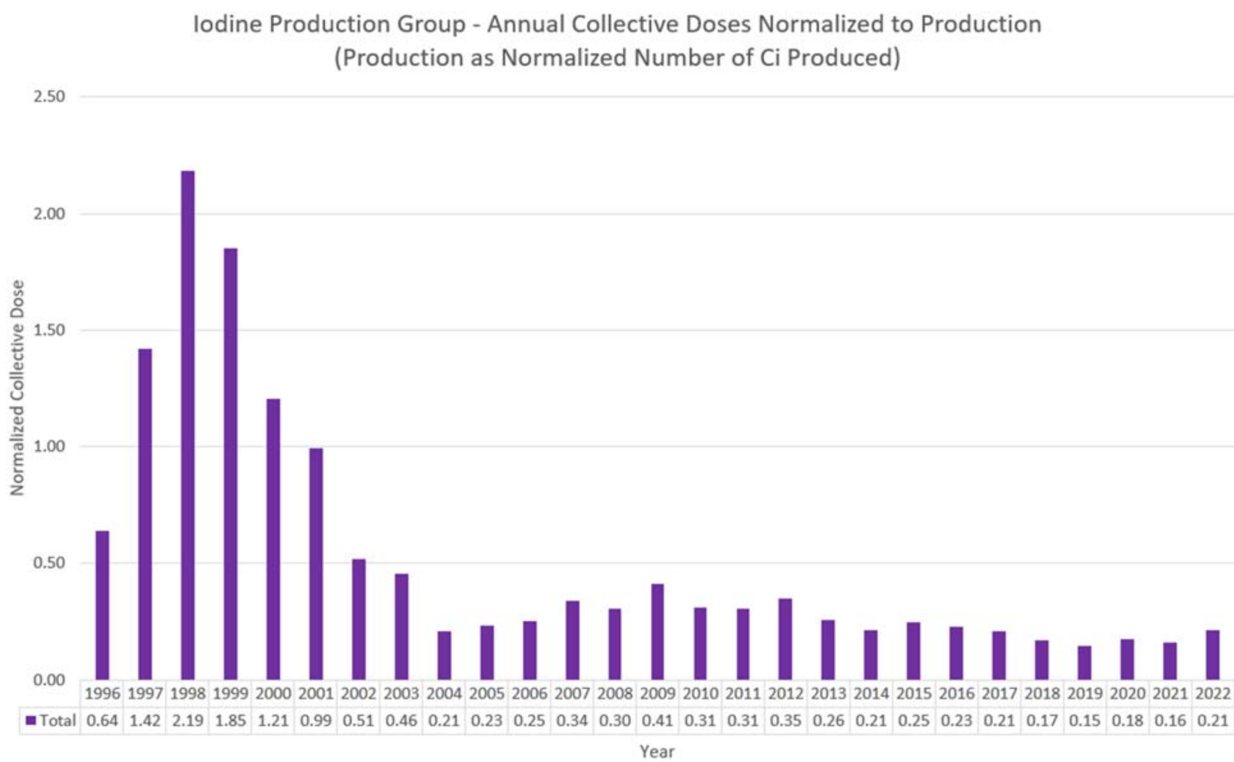


Figure 2.7.1-4 – Normalized collective effective dose for the Iodine Production Group

2.7.1.3 NRay Radiographers

The NRay Radiographer group comprises the Operations Manager, the Development Officer, the Radiography Manager, the Radiography Supervisors, and the Material Handlers. All are employees of NRay Inc., a private company that utilizes beam ports in the reactor under contract. There is no distinction for users based on employer under the MNR radiation safety program.

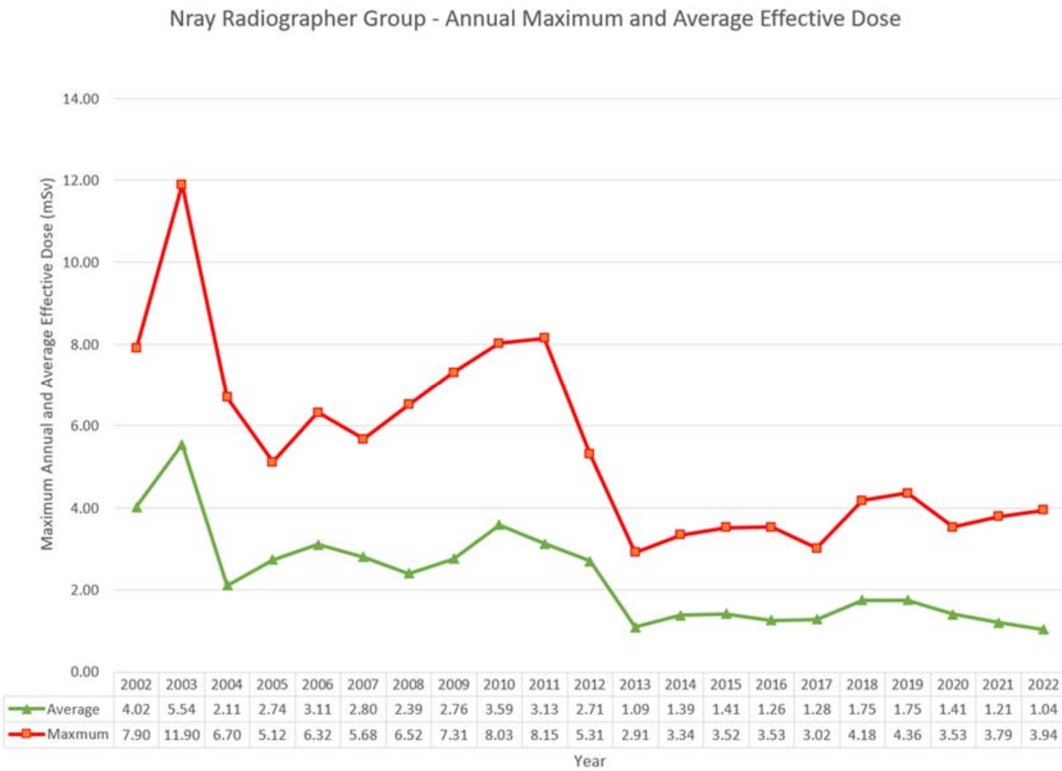
As in previous years, the only contribution to effective dose was external deep dose (Hp(10)). There is no indication of any significant internal exposures from extensive facility air and surface contamination monitoring or from personnel contamination monitoring.

A comparison of the maximum dose of each type for 2022 (the most recent year for which data is available) with the facility Administrative Control Levels (ACLs) and Regulatory Limits is presented in **Table 2.7.1-3**. No doses exceeded the corresponding ACL or Regulatory Limit in 2022.

Table 2.7.1-3: Comparison of Maximum Annual Doses with Limits – NRay Personnel

Dose	Maximum Annual Value in 2022 (mSv)	ACL (mSv)	Dose as % of the ACL	Regulatory Limit (mSv)	Dose as a % of the Regulatory Limit
Effective Dose	3.94	15	26%	50	8%
Shallow Dose	4.84	150	3%	500	0.97%
Extremity Dose	15.21	250	6%	500	3.04%

The historical values of the average, maximum and collective effective dose for this group are presented in **Figure 2.7.1-5**. No trends of concern are indicated by the data. The average, maximum and collective effective doses are all well within the recent operating experience for the facility.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Average	4.02	5.54	2.11	2.74	3.11	2.80	2.39	2.76	3.59	3.13	2.71	1.09	1.39	1.41	1.26	1.28	1.75	1.75	1.41	1.21	1.04
Maxmum	7.90	11.90	6.70	5.12	6.32	5.68	6.52	7.31	8.03	8.15	5.31	2.91	3.34	3.52	3.53	3.02	4.18	4.36	3.53	3.79	3.94

Figure 2.7.1-5 – Annual maximum and average effective dose for NRay Radiography Personnel

Dose performance goals for the NRay Radiography Group are established annually and are based on the collective effective dose per unit output, with output taken as the normalized number of radiographs produced (adjusted by a constant arbitrary normalizing factor). The recent annual values of this quantity are shown in **Figure 2.7.1-6**. Normalized collective doses remain at historical lows throughout the current licence period (2014 to 2023).

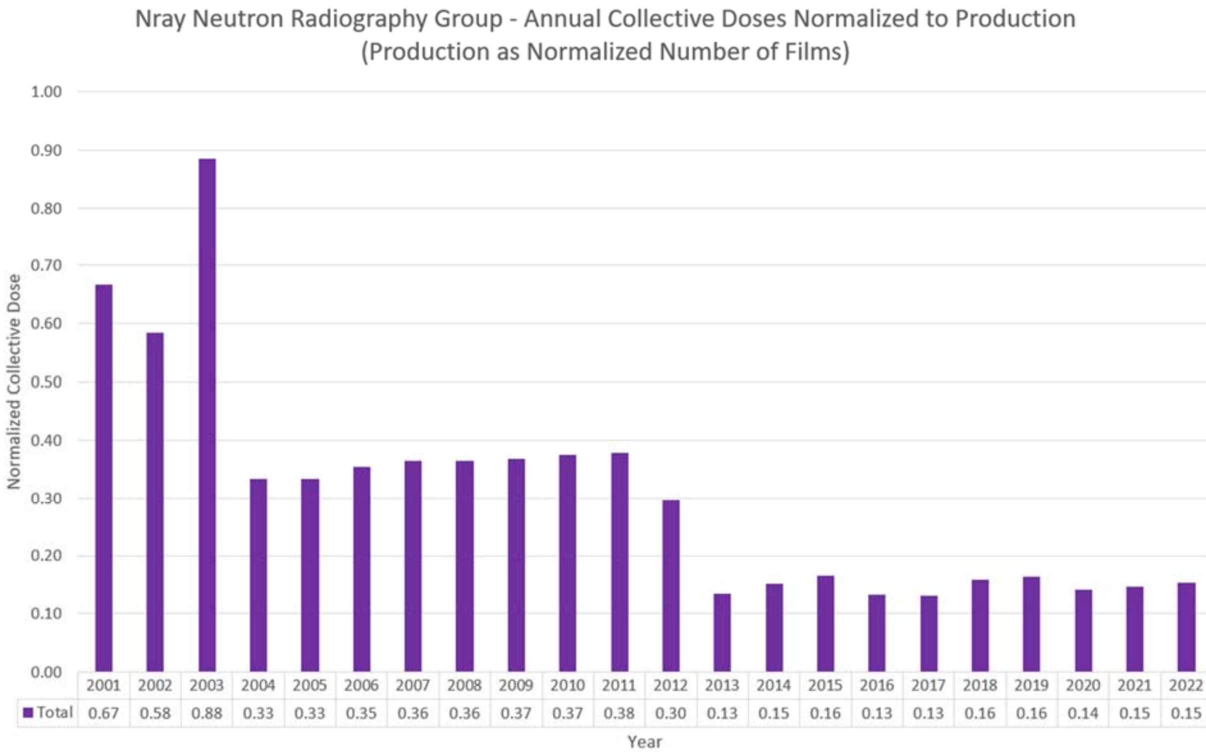


Figure 2.7.1-6 – Normalized collective effective dose for the NRay Radiography Group

2.7.2 Contamination Control Program

The contamination control program at MNR remained highly effective throughout the licencing period. The results of the routine workplace contamination program from 2008 to 2022 (the most recent year for which data is available) are presented in **Figures 2.7.2-1 to 2.7.2-5**. Routine workplace contamination surveys of the office floor were established in 2021.

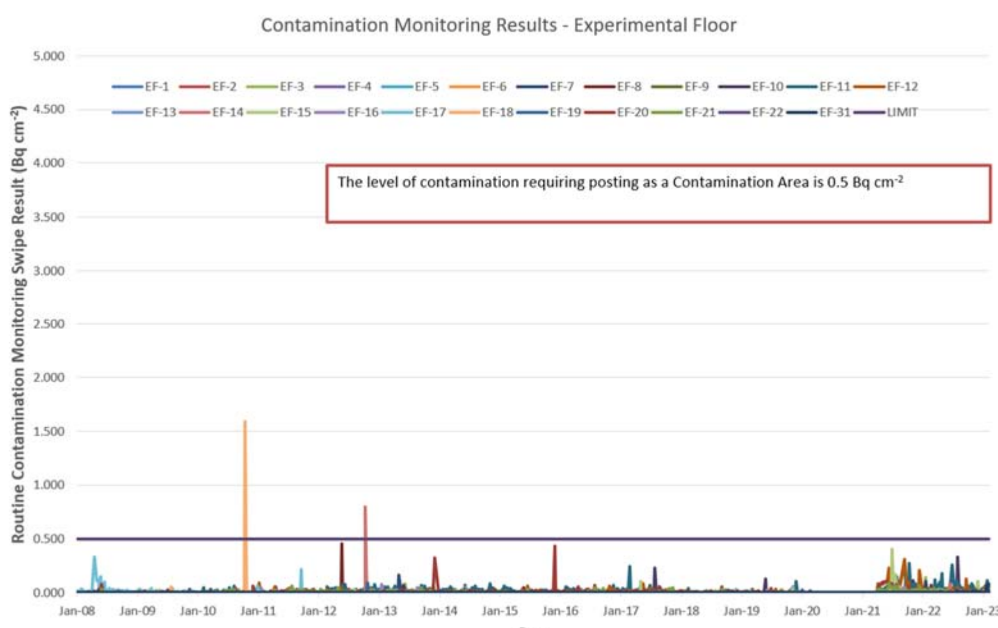


Figure 2.7.2-1 – Contamination monitoring results for the experimental floor

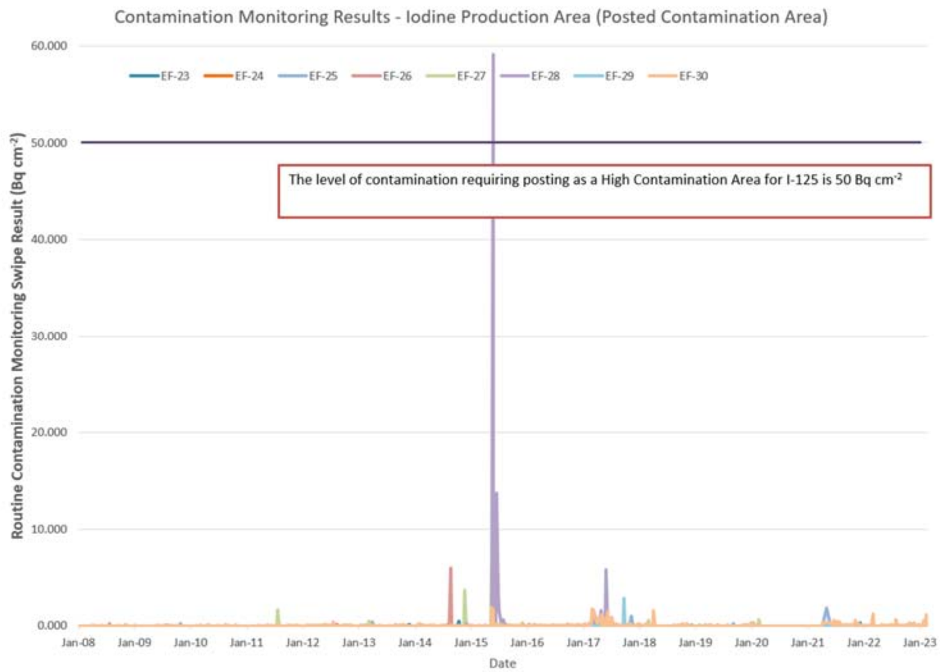


Figure 2.7.2-2 – Contamination monitoring results for the iodine production

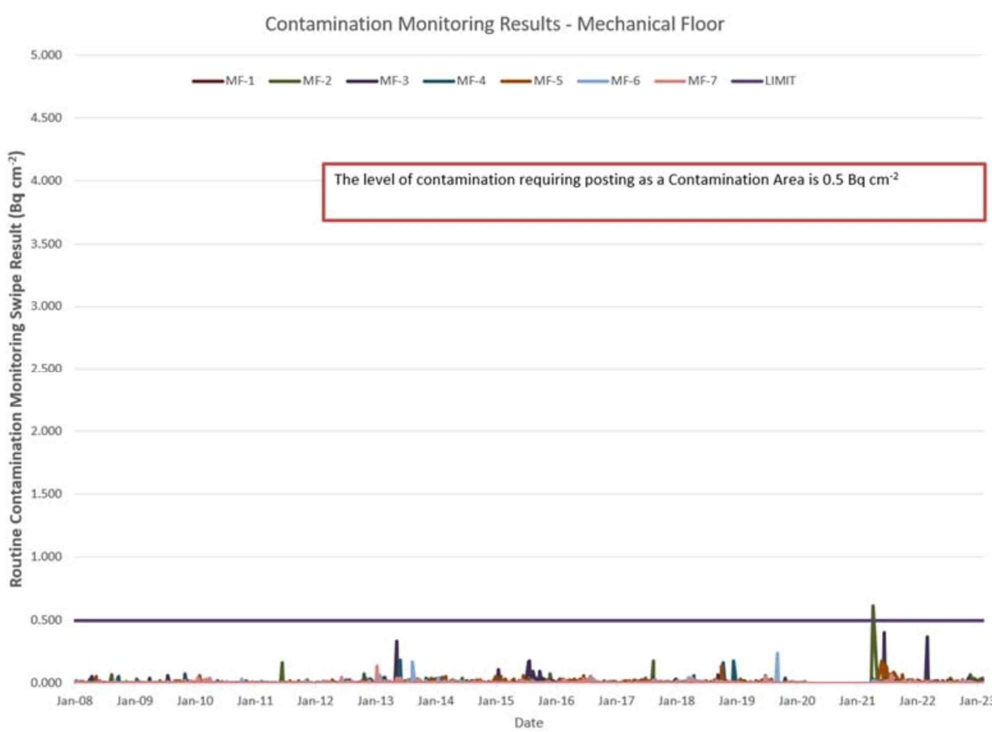


Figure 2.7.2-3 – Contamination monitoring results for the mechanical floor

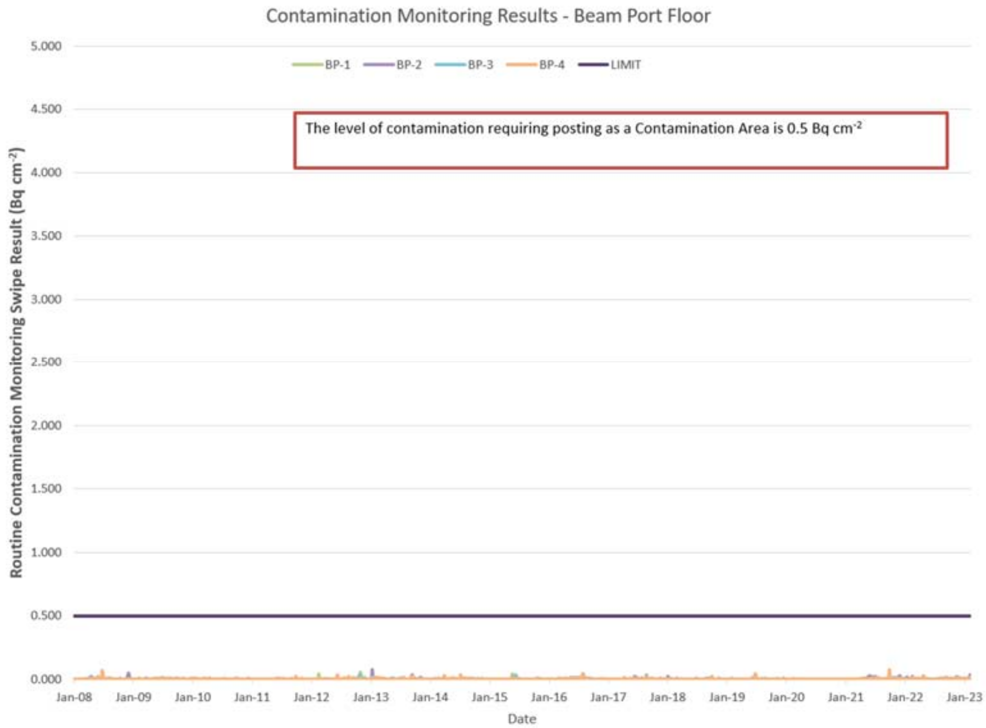


Figure 2.7.2-4 – Contamination monitoring results for the beam port floor

Figure 2.7.2-5 – Contamination monitoring results for the office floor

There were no significant personnel contamination events during the 2014 to 2022 period. Significant personnel contamination events are defined as incidents in which skin dose was assigned. The frequency of occurrence of personnel contamination events is shown in **Figure 2.3.1-13**. There was a slight reduction in the number of personal contamination incidents in 2022. In general, these represent the identification of small quantities of contamination. No trend of concern is evident in personal contamination events. There were no skin doses assigned as a result of these incidents.

There were no significant personnel contamination events (an event in which a worker received a skin dose in excess of the Administrative Control Level) during the licencing period. The frequency of occurrence of all personnel contamination events from 2017 to 2022 is shown in **Figure 2.7.2-6**. In general, these represent the identification of small quantities of contamination, usually on personnel clothing (shoes) at exit or when passing a hand-and-foot monitor in the facility. No trend of concern is evident.

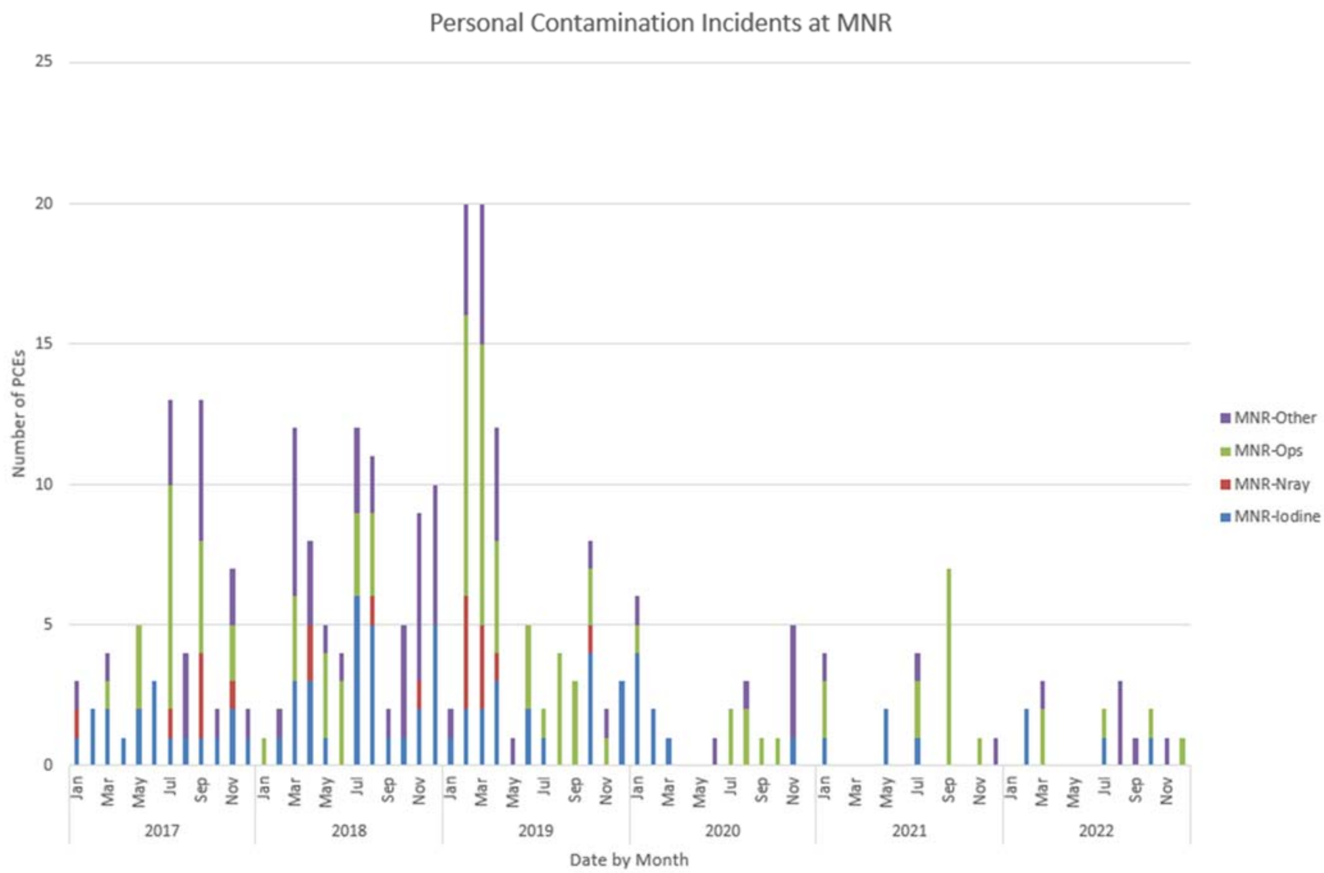


Figure 2.7.2-6 – Frequency of personal contamination events at MNR by exposure group

2.7.3 Facility Radiological Conditions

The facility radiological conditions monitoring program comprises: monitoring of gross beta-gamma contamination in air at several facility locations, monitoring of gross alpha emitting contamination in air at several facility locations, monitoring of I-125 contamination in air at several facility locations, monitoring of Ar-41 concentrations in the reactor hall air, monitoring of ambient radiation fields at several facility location using environmental thermo-luminescent dosimeters (TLDs) and the performance of routine contamination and radiation surveys. In addition, reactor water systems are monitored for short-lived gross-beta emitting contamination, long-lived gross beta emitting contamination and gross alpha emitting contamination at several points.

The results of the gross beta-emitting contamination in air monitoring for 2022 and several previous years are presented in **Figure 2.7.3-1**. Monitoring is performed in the Reactor Hall (sampling point on the Experimental Floor), the Gas Handling Station (GHS), the Hot Waste Storage Area (HWSA), the Iodine Production Enclosure ("Enclosure") and the Pump Room. Concentrations in the facility remained low in 2022. The most restrictive radionuclide typical of a nuclear reactor source term is Sr-90. The Derived Air Concentration (DAC) for Sr-90 is 300 Bq/m^3. Typical values of beta emitting airborne contamination detected in 2022 were in the range of 1E-6 to 2E-2 Bq/m^3. The maximum detected weekly average airborne concentration of gross beta emitting contamination was 0.018 Bq/m^3, or <0.01% of the DAC for Sr-90. There is no indication that gross beta-emitting contaminants in air pose a significant radiological risk to personnel at the facility and there is no trend of concern evident.

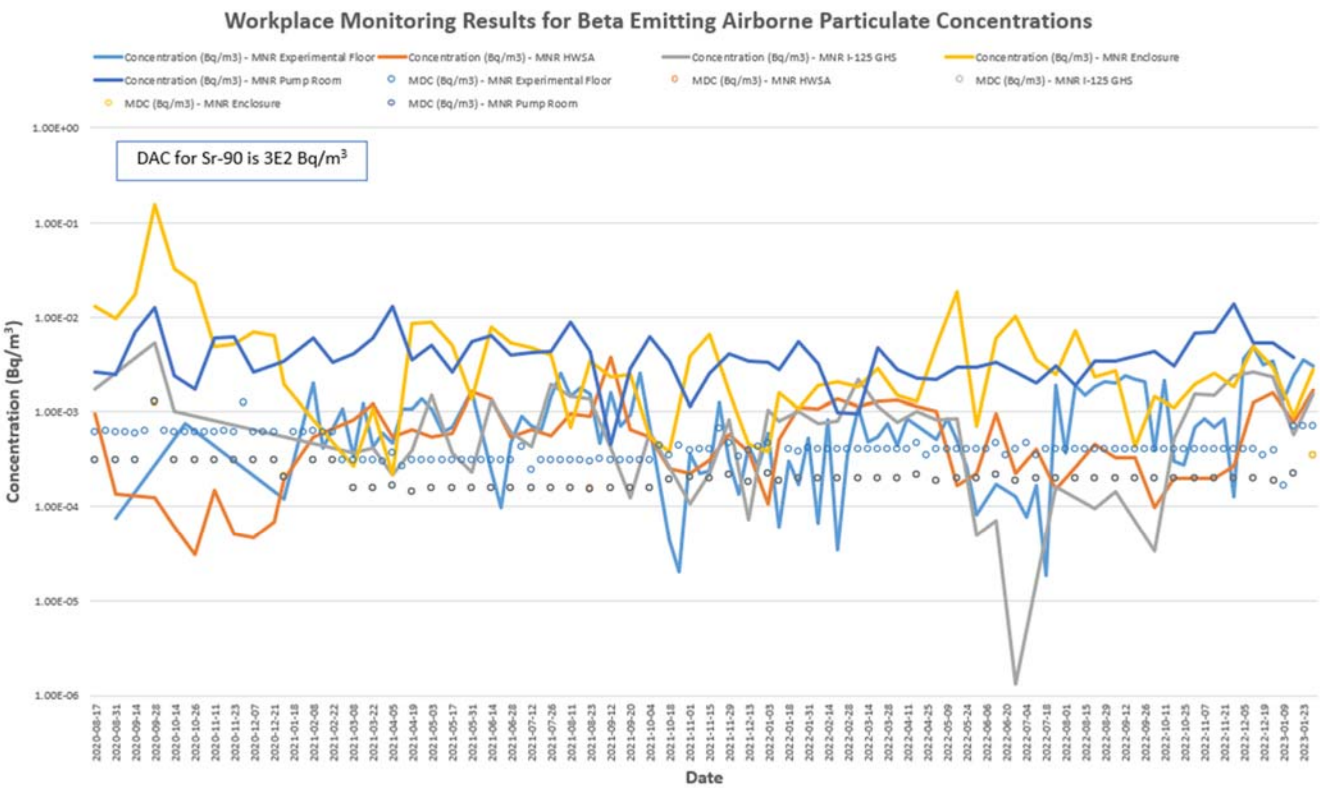


Figure 2.7.3-1 – Workplace monitoring results for beta emitting airborne particulate concentrations

The gross alpha emitting concentration is assessed for the Reactor Hall (sampling point on the Experimental Floor), the Gas Handling Station (GHS), Hot Waste Storage Area (HWSA) and Pump Room. The results for 2022 and several previous years are presented in **Figure 2.7.3-2**. The most restrictive radionuclide typical of a nuclear reactor source term is Am-241. The Derived Air Concentration (DAC) for Am-241 is 300 mBq/m^3. The minimum detectable concentration (MDC) for the methodology employed is approximately 0.1 to 0.4 mBq/m^3. Samples typically have concentrations of long-lived gross alpha emitters at or below the MDC. The maximum weekly average concentration detected during 2022 was 0.13 mBq m 3 or 0.04% of a DAC for Am-241. There is no indication that gross alpha-emitting contaminants in the air pose a significant radiological risk to personnel at the facility and there is no trend of concern evident.

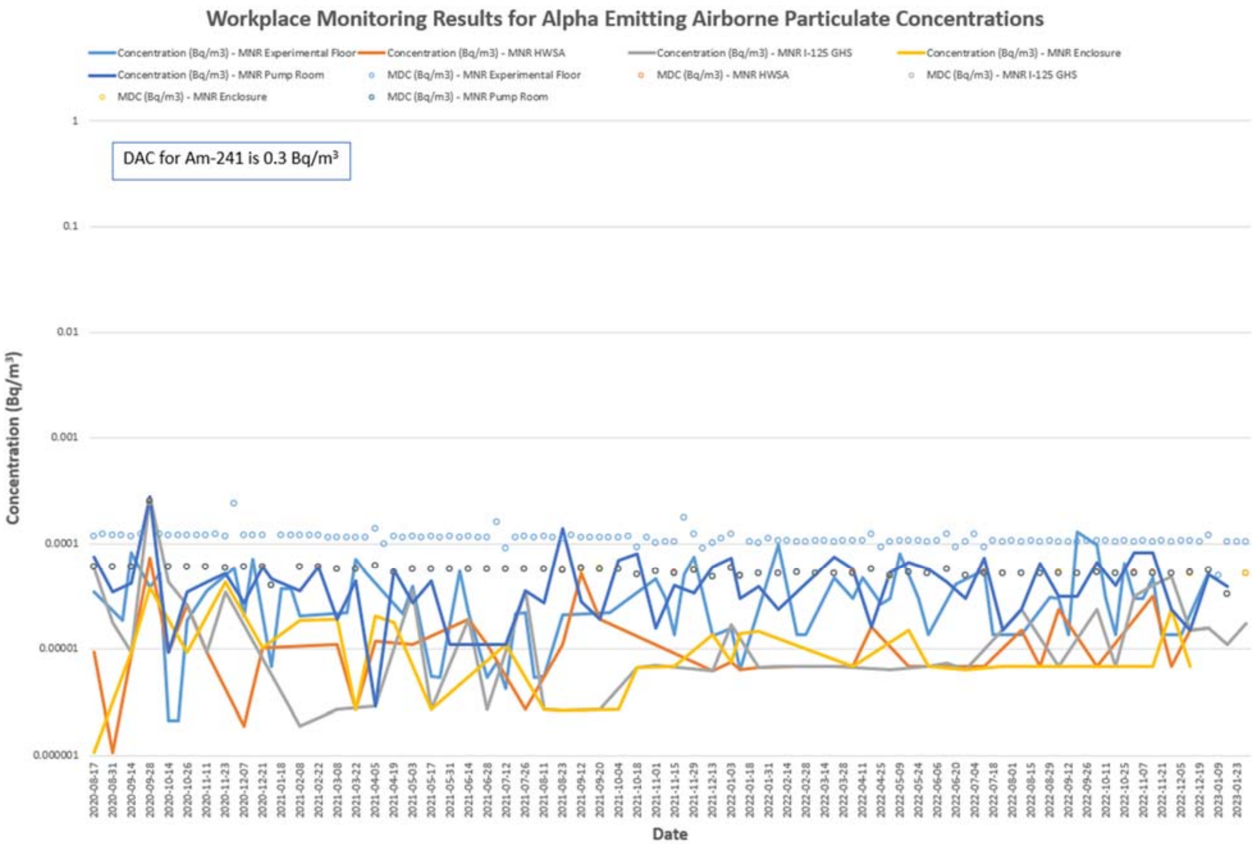


Figure 2.7.3-2 – Workplace monitoring results for alpha emitting airborne particulate concentrations

Concentrations of airborne I-125 are monitored on the Experimental Floor (sampling point near the Control Room, the Enclosure, the Hot Waste Storage Area, and the area on the Experimental Floor where production activities occur (the GHS)). The results of the monitoring for 2021 to 2022 are presented in **Figure 2.7.3-3**. The DAC for I-125 in its most restrictive chemical form (vapour) is 400 Bq/m^3. During 2022, measured weekly average values ranged from less than 0.1 Bq/m^3 to 2 Bq/m^3 in normally accessible areas of the facility (less than 0.5% of one DAC). The Enclosure is a posted Airborne Contamination Area and work in that area is performed with respiratory protection. Weekly average concentrations in the Enclosure ranged from approximately 5 Bq/m^3 to 80 Bq/m^3 (up to 20% of the DAC). The shorter-term averages for this area in particular are subject to considerable variation.

There is no indication that airborne I-125 concentrations in the facility pose an unreasonable radiological risk to personnel in the facility. Confirmation of the appropriateness of the precautions to the level of hazard is provided by the thyroid screening program and the absence of significant inhalation intakes by personnel.

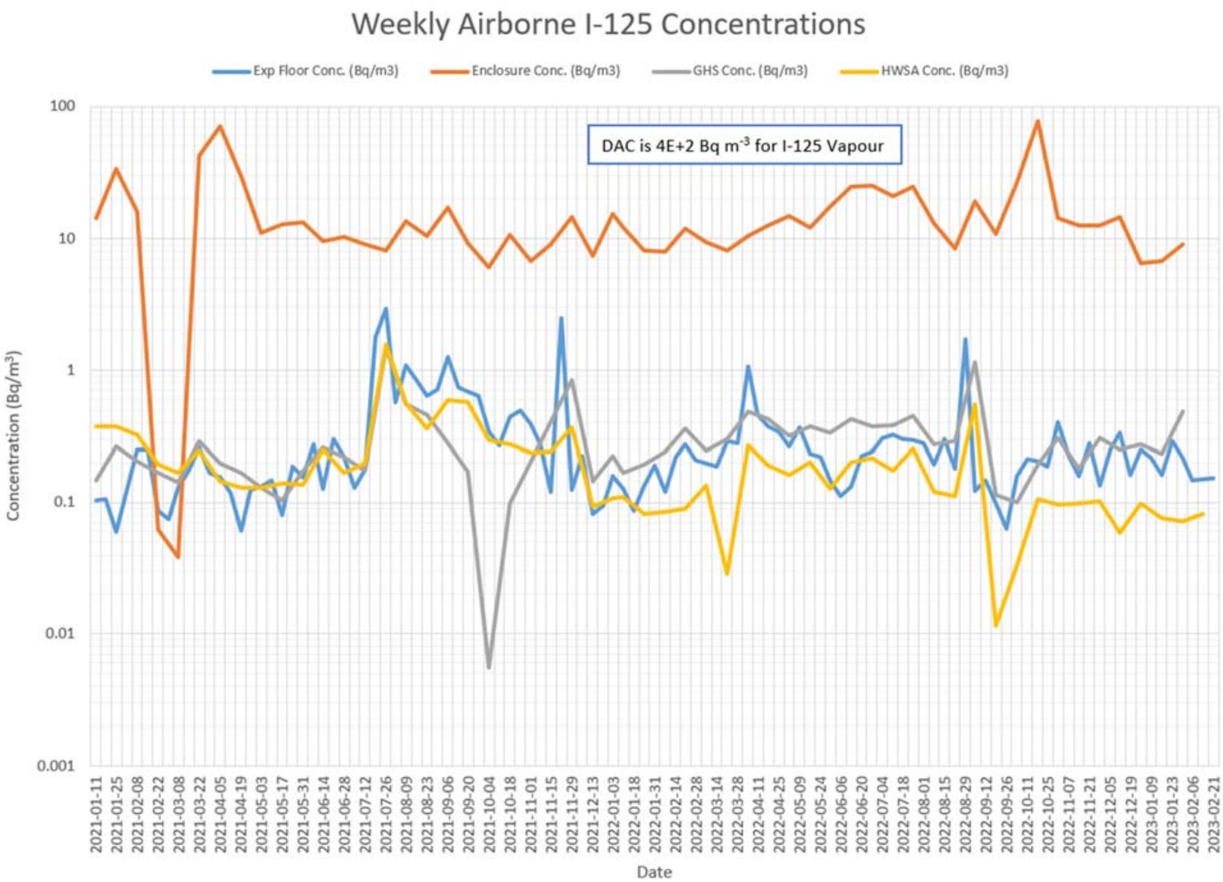


Figure 2.7.3-3 – Workplace monitoring results for I-125 airborne concentrations

Ar-41 sampling is performed each shift on the Experimental Floor. The results are presented in **Figure 2.7.3-4**. Typical concentrations were approximately 13 kBq/m^3 with a maximum value of 17 kBq/m^3. This corresponds to approximately 2% of the DAC for Ar-41. Ar-41 levels in the facility do not constitute an unreasonable hazard to facility personnel and no trend of concern is evident.

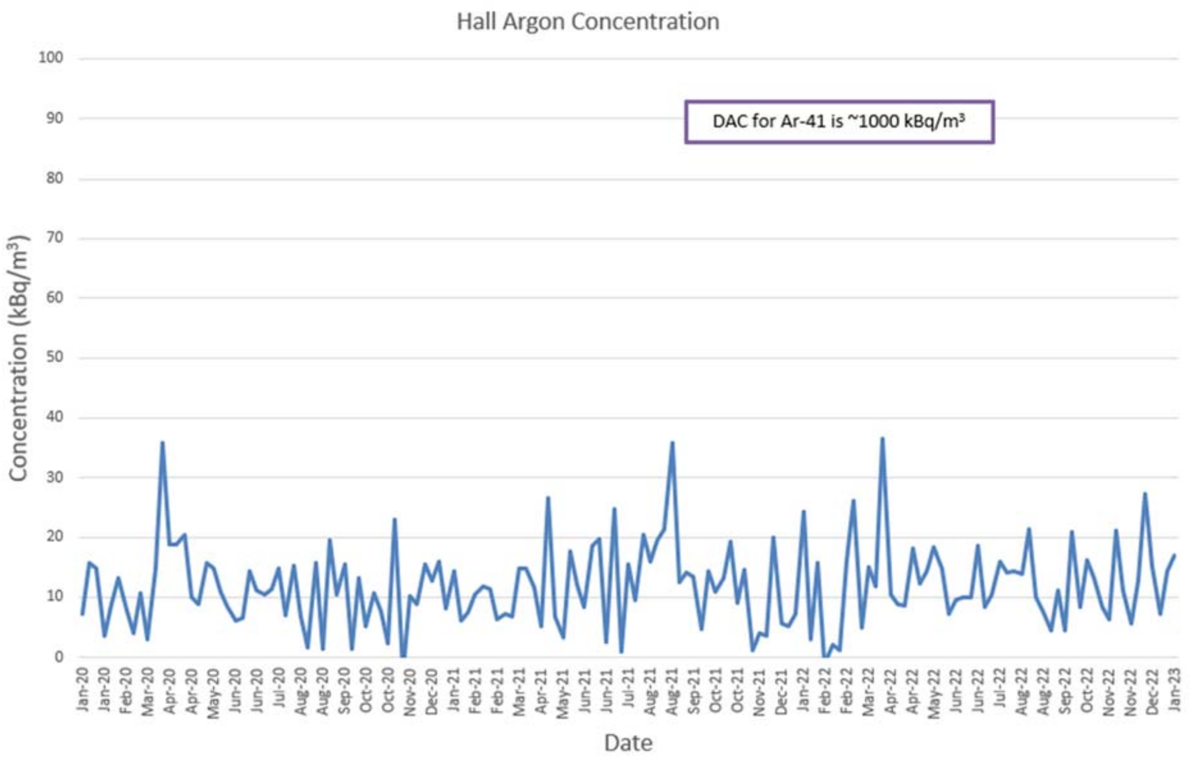


Figure 2.7.3-4 – Workplace monitoring results for Ar-41 airborne concentrations.

Ambient radiation fields are monitored in the facility utilizing environmental TLDs in addition to periodic surveys and area radiation monitors. The results of the environmental TLD monitoring are presented in **Figures 2.7.3-5** to **2.7.3-8**.

Ambient radiation fields at the facility are generally stable or gradually improving year-to-year. There are periods of elevated dose rates in the Hot Waste Storage Area (a posted Radiation Area with low occupancy and traffic) observed in **Figure 2.7.3-6**. This increase in dose rates is a result of the storage of waste in close proximity to the environmental TLD and levels increase and decrease as waste builds up and is removed from the area. There is no indication that ambient radiation fields present an unreasonable hazard to personnel at the facility and no trends of concern are evident.

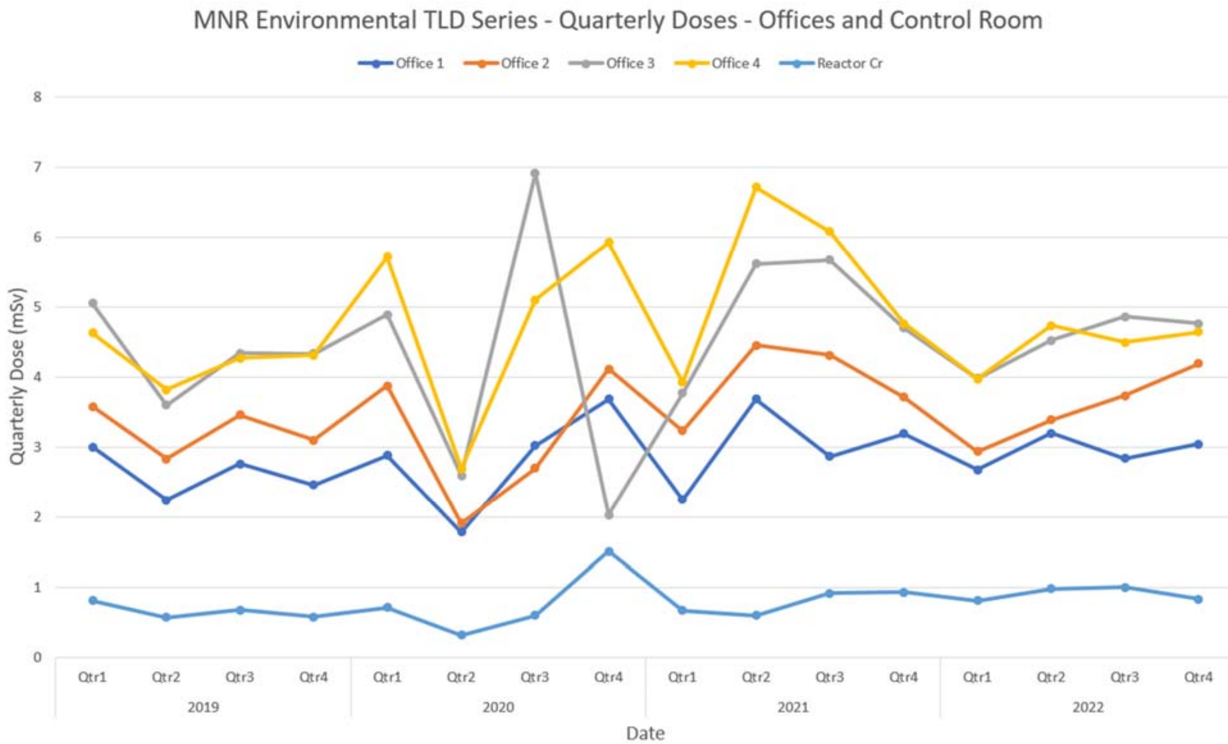


Figure 2.7.3-5 – MNR environmental monitoring results from the offices and control room

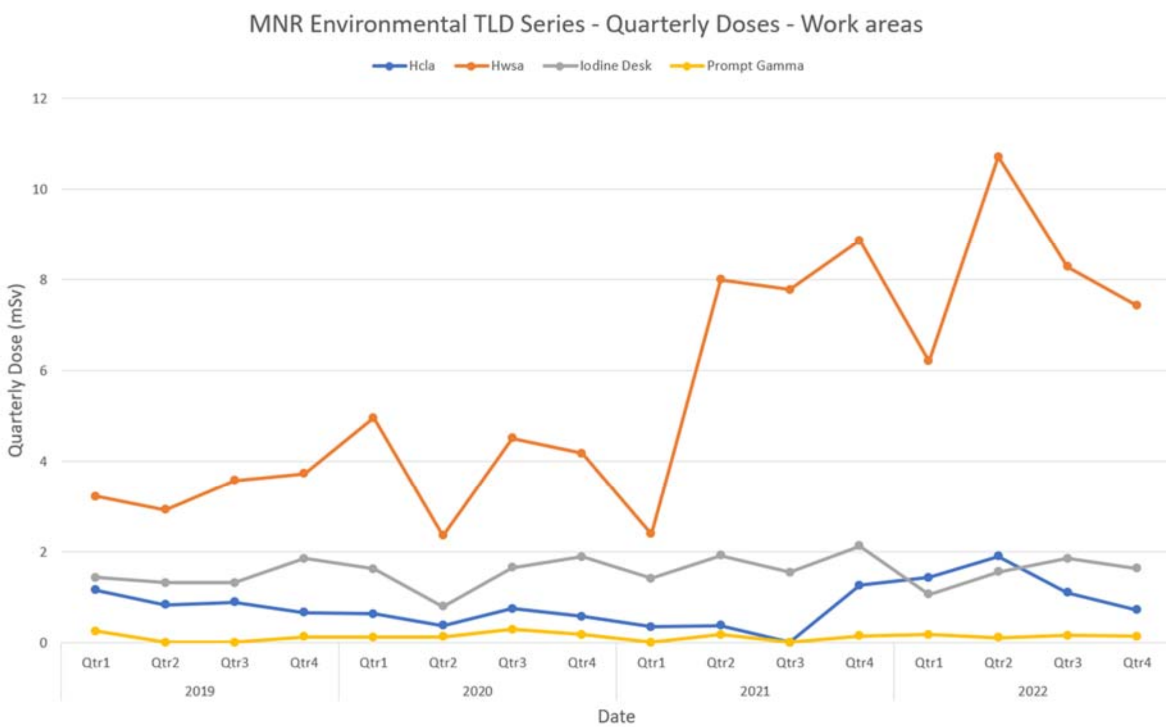


Figure 2.7.3-6 – MNR environmental monitoring results from work areas

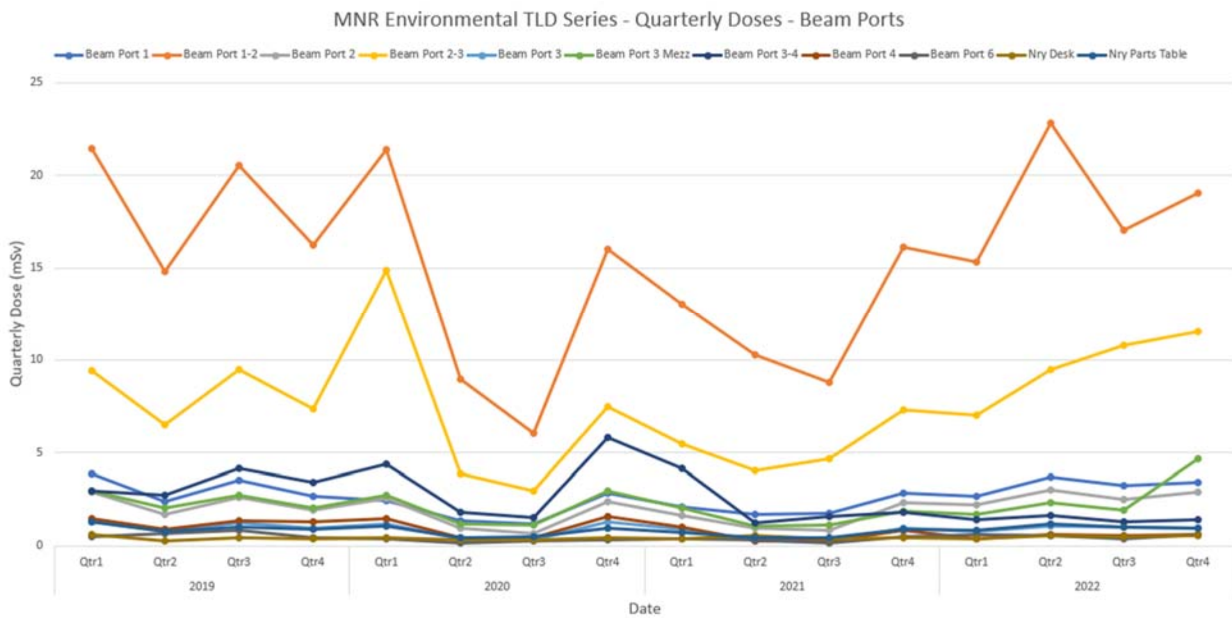


Figure 2.7.3-7 – MNR environmental monitoring results from beam ports

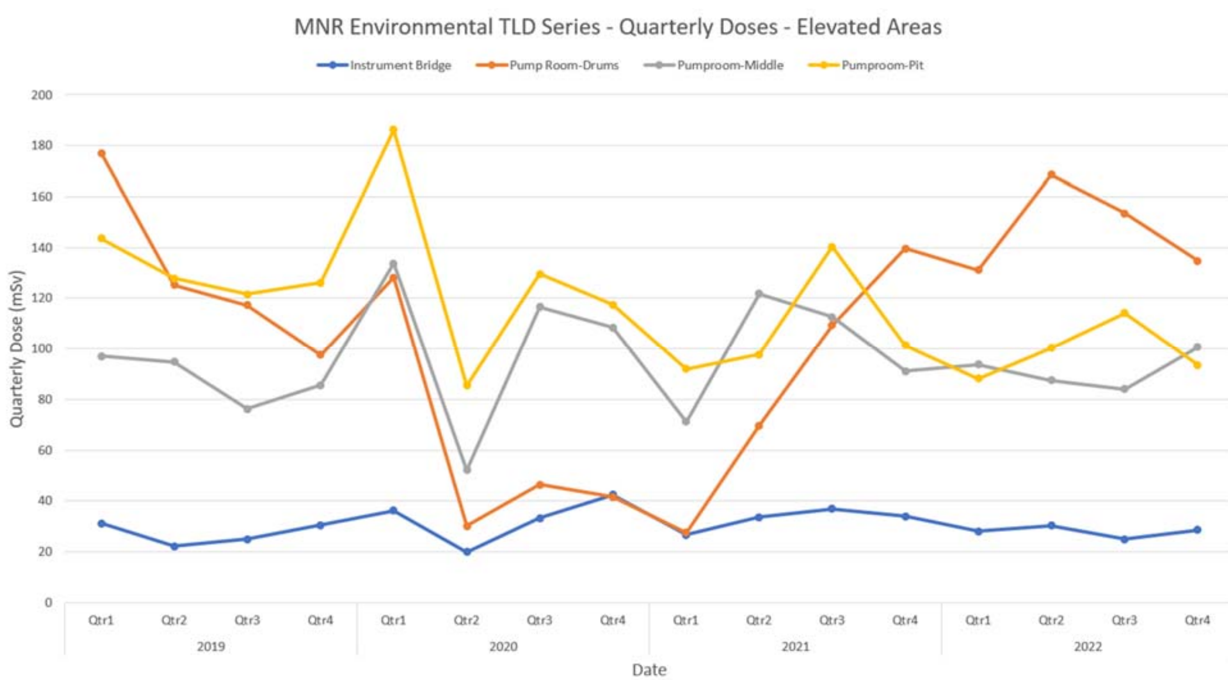


Figure 2.7.3-8 – MNR environmental monitoring results from elevated areas

The reactor water systems are monitored for radioactivity. The gross beta emitting activity is assessed soon after sample collection from the pool (designated as “Total Activity”) and again after the sample has been aged for a week (designated as “Long-Lived Activity”). Results of the measurements are shown in **Figures 2.7.3-9** and **2.7.3-10**. There is no indication that the gross beta-emitting activity in the primary water constitutes an unreasonable risk to facility personnel.

Occasional trigger level exceedances in the total primary water are typically attributed to the fact that the samples were taken slightly later in the day than when they are normally collected. Sustained elevated levels are not observed. Some spikes in the primary water long lived activity have occurred over the reporting period. Attempts to reproduce these results were unsuccessful and they were not typically present in subsequent weeks. There was no impact to facility dose rates, doses to personnel, or any continued evidence of prolonged instances of heightened long-lived activity.

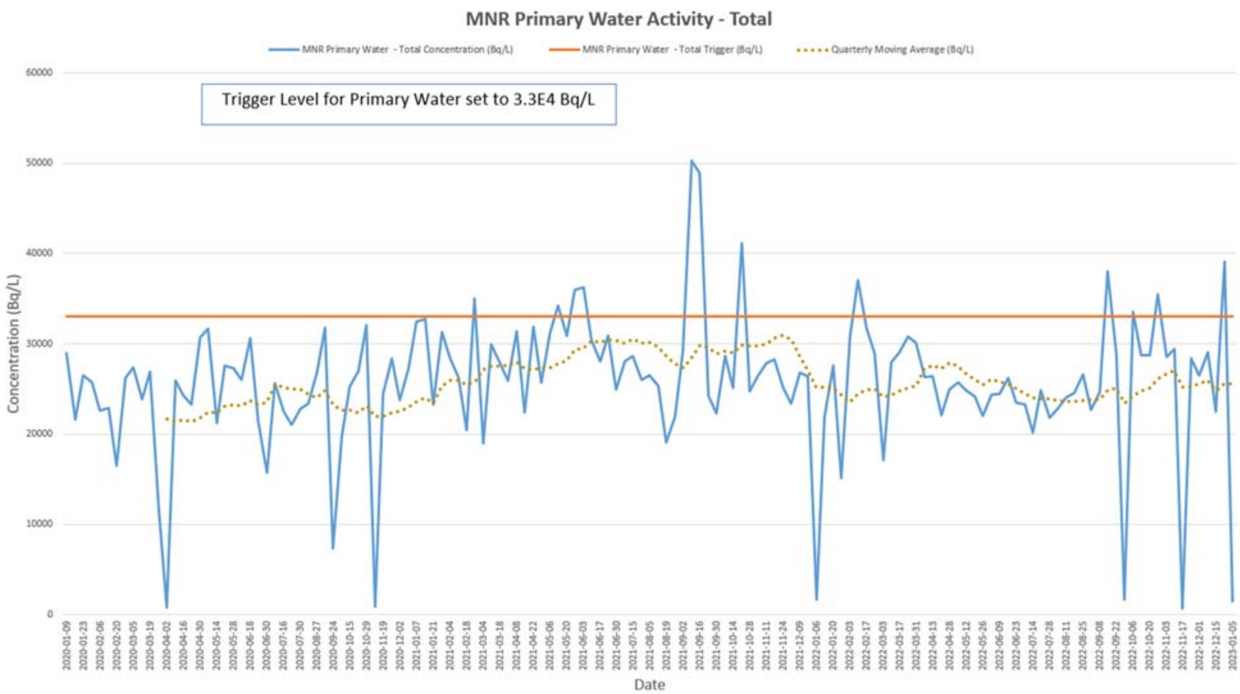


Figure 2.7.3-9 – MNR primary water total activity

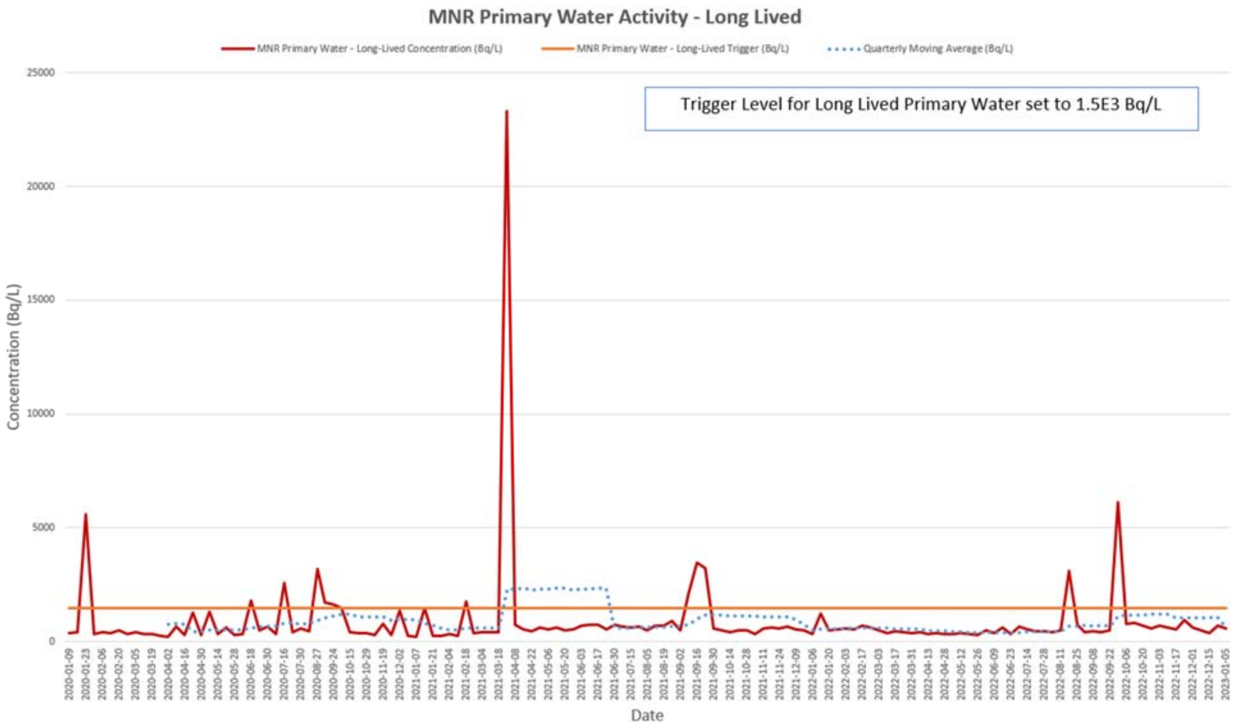


Figure 2.7.3-10 – MNR primary water long-lived activity

The primary water system is also monitored for gross alpha-emitting activity concentrations. Results are presented in **Figure 2.7.3-11**. The concentration is typically below the minimum detectable concentration of approximately 10 Bq per litre. There is no indication that the gross alpha-emitting activity of the primary system water constitutes an unreasonable hazard to facility personnel, and no trend of concern is evident.

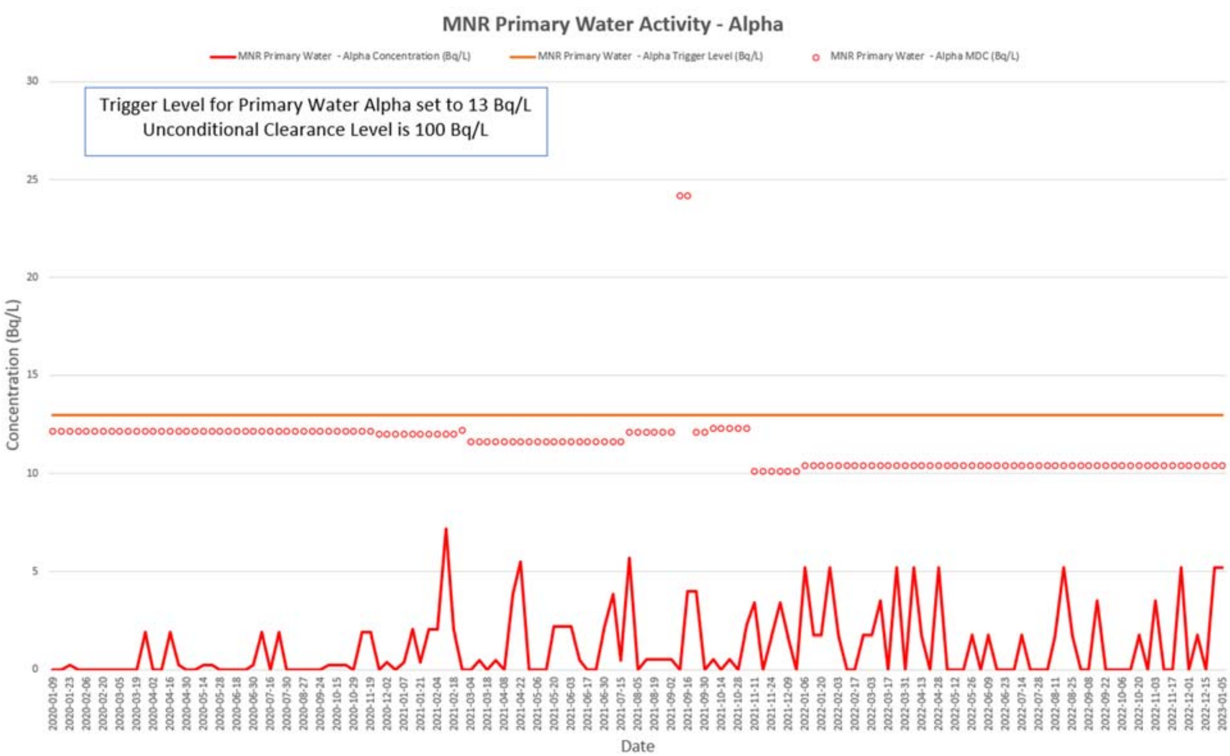


Figure 2.7.3-11 – MNR primary water alpha activity

The total and long-lived components of the gross beta-emitting activity at the outlet of the demineralizer system are assessed in the same manner as the primary system. The results are shown in **Figures 2.7.3-11** to **2.7.3-12**. This monitoring is primarily intended to provide feedback to operations personnel on the effectiveness of the system. The demineralizer system feeds back to the primary system (in pool 2). No trends of concern are evident.

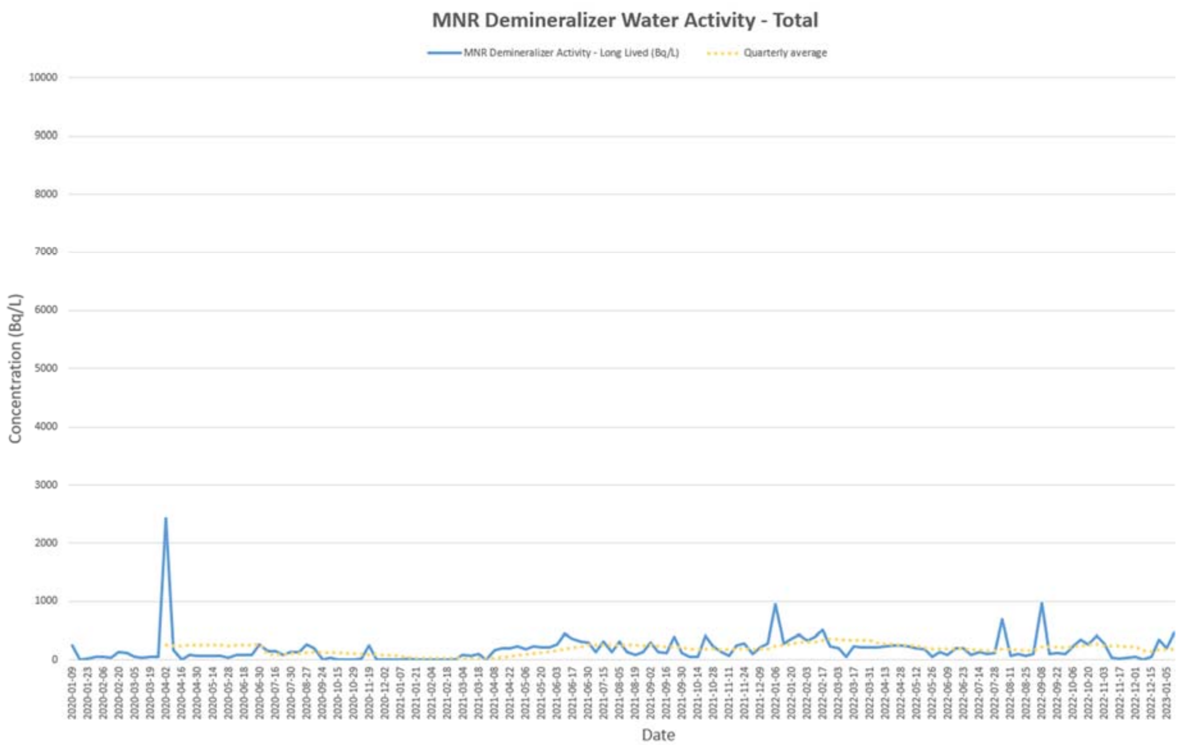


Figure 2.7.3-11 – MNR demineralizer water total activity

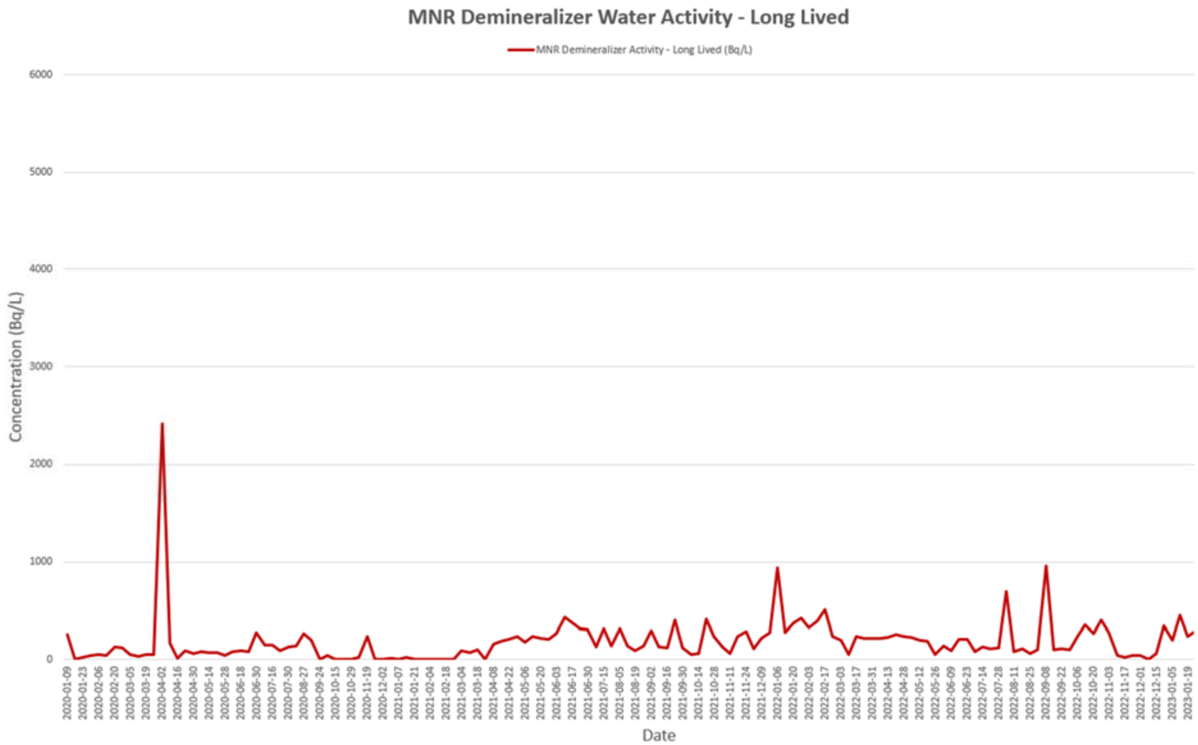


Figure 2.7.3-12 – MNR demineralizer water long-lived activity

2.7.4 Overall Performance of the Radiation Safety Program

The radiation safety program at MNR continued to operate effectively throughout the licence period.

The overall objectives of the radiation safety program at MNR are to:

- Prevent deterministic effects (radiation injuries),
- Maintain doses to workers and members of the public As Low as Reasonably Achievable (social and economic factors being taken into consideration), and
- Achieve compliance with the Radiation Protection Regulations under the *Nuclear Safety and Control Act*.

These objectives were all achieved during the period.

Commitment to ALARA strategies is strengthened specifically in the work planning process. Work plans and procedures are carefully planned and communicated. A collaborative effort between Health Physics and Operations incorporate ALARA approaches into all work at MNR. Operations staff propose a task, including strategies to maintain doses ALARA. Health Physics reviews the work plan and works with Operations to incorporate additional dose reduction strategies with socioeconomic factors considered. Upon completion, the work is reviewed and opportunities for improvements are logged for future work of the same type. Thus, the process is iterative, with continuous improvement with respect to dose reduction and optimization.

2.8 CONVENTIONAL HEALTH AND SAFETY

2.8.1 General Consideration

McMaster Nuclear Reactor (MNR) complies with REGDOC-2.8.1 Conventional Health and Safety [54]. McMaster University's Risk Management Manuals (RMM) contain programs and policies designed to implement and support the Risk Management System (RMS). The program is in full compliance with the *Canada Labour Code Part II*, *Canada Occupational Health and Safety Regulations* [55], *Ontario Health and Safety Act* (OHSA) [56] and *Workplace Safety Insurance Act* (WSIA) [57].

2.8.2 Practices

McMaster University's Health and Safety program is administered by the *University Health and Safety* team (UHS). This central committee supports the University's commitment to compliance with all policies for occupational health & safety, loss prevention and mitigation.

The University provides employees access to standard health & safety online modules (e.g., hazard awareness, WHMIS, etc.), in addition to job specific worker training for MNR employees.

MNR is a part of the McMaster Institute of Applied Radiation Science (McIARS) local *Joint Health and Safety Committee* (JHSC). This committee holds meetings which exceed the minimum requirements set by the OHSA. Workplace inspections are completed monthly by members of the JHSC, with the support of the reactor management team. Any deficiencies or findings noted during facility inspections are reviewed, with corrective actions implemented promptly.

MNR staff completes monthly inspections of eye wash stations, safety showers and first aid kits, with respective documentation kept on file. Monthly inspections of fire extinguishers and hoses are performed by third party companies. Annual inspections of safety equipment, completed by third party companies or facility personnel, include fume hoods, eyewash stations, safety showers and biosafety cabinets.

Non-radioactive hazardous substances are stored and used in accordance with *Workplace Hazardous Materials Information System* (WHMIS). Third party companies are contracted for disposal of biohazardous and chemical wastes, *sharps* waste, and glass.

During the current license period of June 2014 to present, there have been no lost time injuries reported.

2.9 ENVIRONMENTAL PROTECTION

2.9.1 General Considerations and Management System

McMaster University has a comprehensive Workplace and Environmental Health and Safety Policy documented in Risk Management Program RMM 100 [58]. This top-level document establishes the University's commitment to workplace and environmental safety through implementation of best practices, compliance with regulation (including the Environmental Protection Act [58]) and establishes the responsibilities in broad terms for implementing these commitments.

The next tier of policies includes the Program RMM 103 "*Environmental Protection Act* of Ontario and Other Federal, Provincial and Municipal Environmental Statutes" [60]. This program establishes processes and defines responsibilities for environmental protection in all University activities, including the operation of MNR. One aspect of the policy is to designate responsibility for internal approval and oversight of radiological environmental releases to the Health Physics Advisory Committee (HPAC) - the Presidential appointed committee responsible for radiation safety at the university.

The MNR Radiation Safety Program [20], is the HPAC approved radiation safety program that is referenced in the MNR licence. This program establishes MNR specific responsibilities and procedures for environmental protection and monitoring. Key aspects related to this safety and control area include:

- One of the key program objectives is to "Protect the public and environment by ensuring that releases of radioactive material are maintained ALARA".
- Requirements for monitoring and criteria for anything passing out through the facility boundary (the reactor building) are established.
- Derived Release Limits (DRLs) and Administrative Control Levels (Action Levels) related to facility air and liquid effluents are established.
- The requirements for monitoring are documented with links to the supporting work instructions and procedures for carrying out the air effluent, liquid effluent and environmental monitoring activities.

Performance in environmental protection has been strong throughout the licence period. Releases have remained far below the corresponding ACLs and DRLs.

Air effluent DRL calculations have been updated to reflect recent weather data and to ensure consistency with the most recent version of CSA-N288.1 [61]. A revised basis document has been submitted as part of the licence renewal supporting documents.

The commissioning of the Noble gas monitor was an improvement to the environmental monitoring program in 2022.

2.9.2 Effluent and Emissions Monitoring and Control

Air effluents from the Reactor Building are continuously sampled for beta emitting particulates and radioiodines. Samples are collected weekly and assessed for activity by windowless proportional counting for gross beta and by gamma spectrometry for I-125. Results for 2022 (the most recent results available), compared to the applicable Administrative Control Levels (ACLs) and Regulatory Limits are presented in **Tables 2.9.2-1** and **2.9.2-2**. Corresponding trends in performance for the past two years are shown in **Figures 2.9.2-1** to **2.9.2-2**.

Table 2.9.2-1: Comparison of MNR exhaust particulate concentrations with applicable limits

Annual Average Concentration: 4.6×10^{-3} Bq m^{-3}
Maximum Weekly Average Concentration: 8.5×10^{-2} Bq m^{-3}

Annual Release			Maximum Weekly Release Rate		
Activity Released	ACL	Release as % of ACL	Activity Release Rate	ACL	Release as % of ACL
Bq	Bq	%	Bq / week	Bq / week	%
3.3×10^5	5.0×10^8	0.07	1.2×10^5	9.0×10^6	1.29

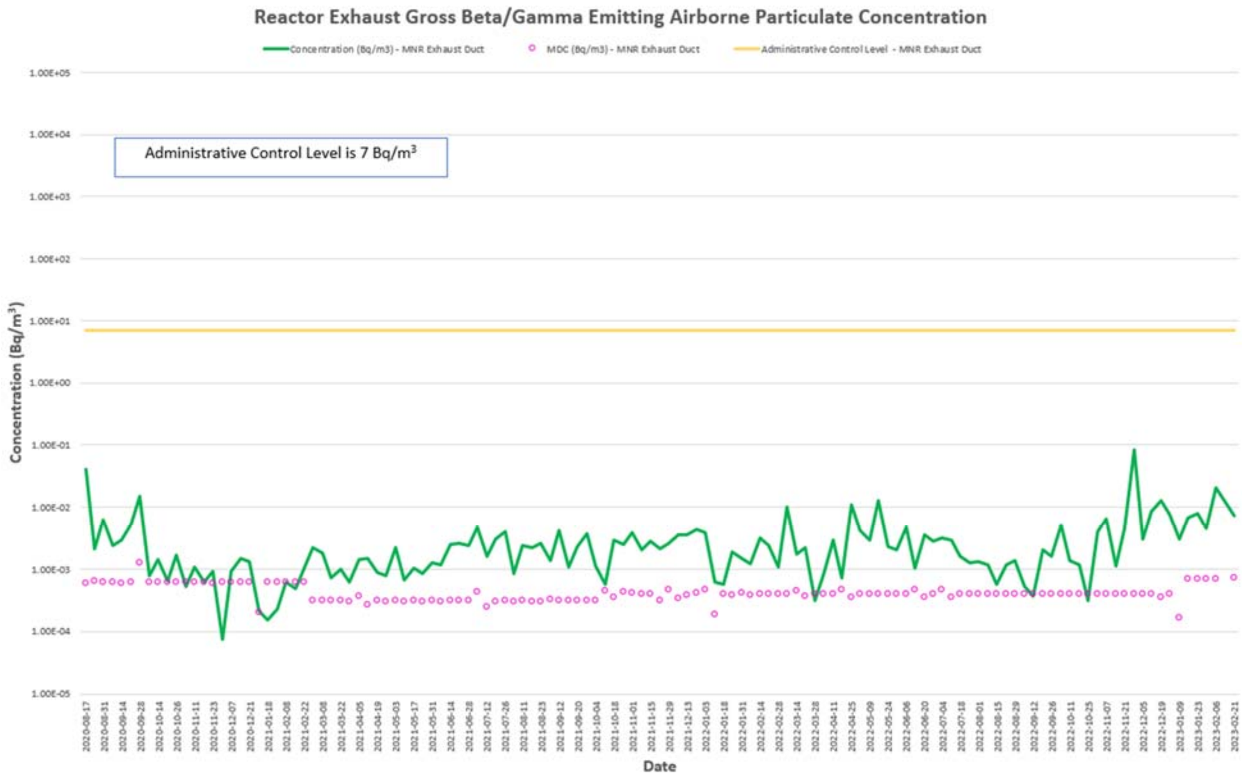


Figure 2.9.2-1: MNR airborne particulate concentration exhaust

Table 2.9.2-2: Comparison of MNR exhaust I-125 concentrations with applicable limits

Annual Average Concentration: 0.5 Bq m^{-3}
Maximum Weekly Average Concentration: 3.5 Bq m^{-3}

Annual Release				Maximum Weekly Release Rate			
Activity Released	ACL	Derived Release Limit	Release as % of DRL	Activity Release Rate	ACL	Derived Release Limit	Release as % of DRL
Bq	Bq	Bq	%	Bq / week	Bq / week	Bq / week	%
3.7×10^{7}	1.0×10^{10}	9.4×10^{12}	0.0004	4.9×10^{6}	2.0×10^{8}	1.8×10^{11}	0.0027

Boundary Dose = 0.009 micro-Sv

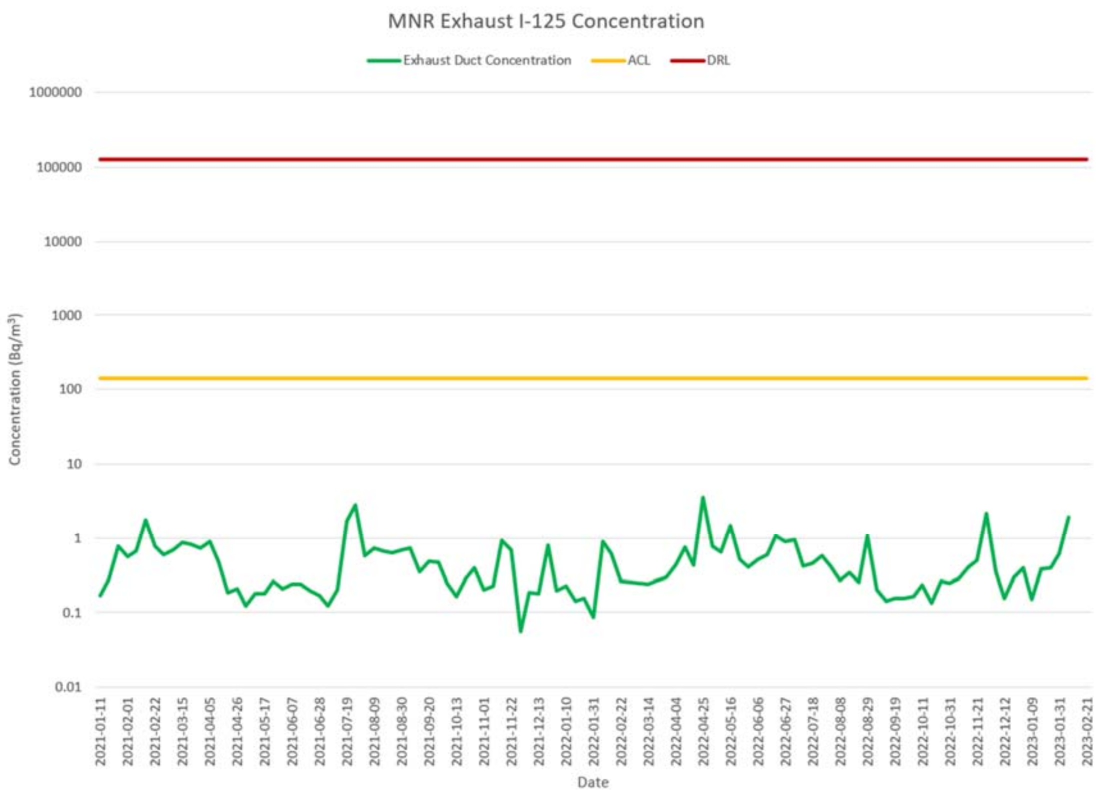


Figure 2.9.2-2: MNR airborne particulate concentration exhaust

During reactor operation, daily measurements of Ar-41 concentrations in the exhaust are made using a gas counting chamber. Ar-41 concentrations are a function of pool water temperature, pool water turbulence, flow rate, reactor power, time since start-up, external temperature, ambient pressure, and ventilation rate. Values obtained on Wednesdays are taken as representative of the week. Results for 2022 compared to the applicable Administrative Control Level (ACLs) and Regulatory Limit are presented in **Table 2.9.2-3**. Recent results are presented in **Figure 2.9.2-3**. There are no trends of concern evident and values are consistent with recent history.

Table 2.9.2-3: Comparison of MNR exhaust Ar-41 concentrations with applicable limits

Annual Average Concentration: 3.3×10^4 Bq m^{-3}
Maximum Weekly Average Concentration: 6.8×10^4 Bq m^{-3}

Annual Release				Maximum Weekly Release Rate			
Activity Released	ACL	Derived Release Limit	Release as % of DRL	Activity Release Rate	ACL	Derived Release Limit	Release as % of DRL
Bq	Bq	Bq	%	Bq / week	Bq / week	Bq / week	%
9.0×10^{11}	1.6×10^{13}	1.3×10^{15}	0.07	3.6×10^{10}	3.1×10^{11}	2.5×10^{13}	0.14

Boundary Dose = 1.9 micro-Sv

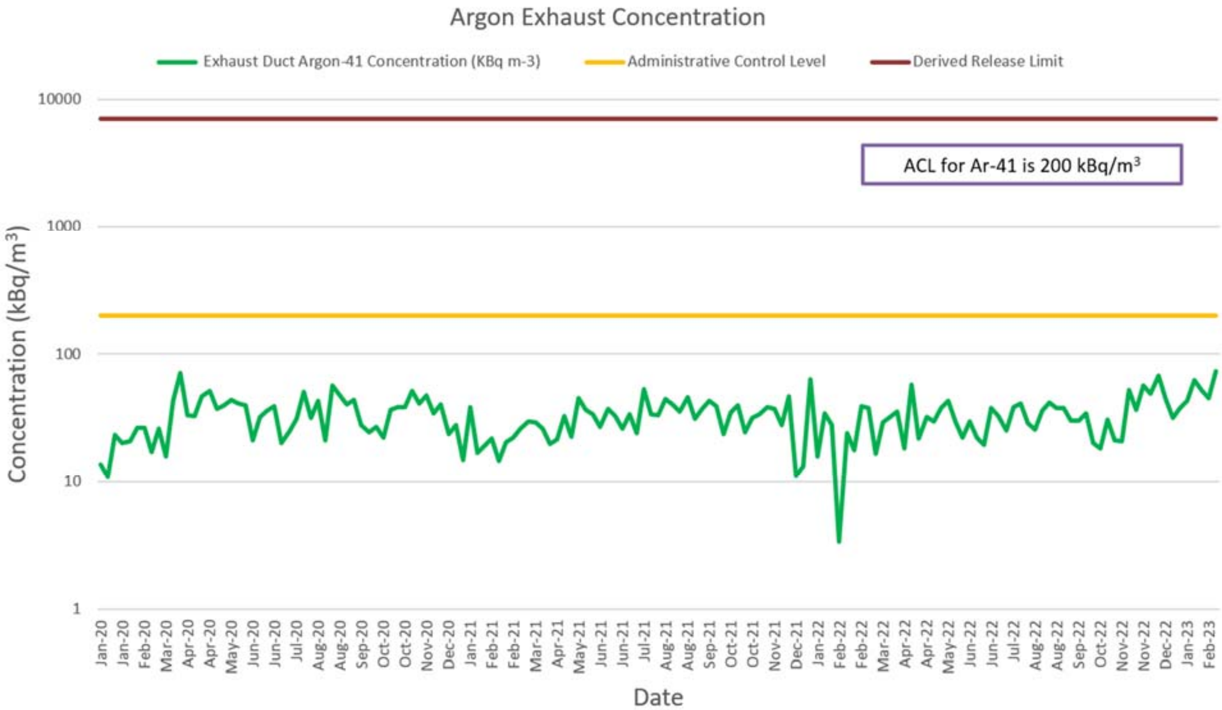


Figure 2.9.2-3: MNR Ar-41 exhaust concentration

2.9.3 Public Exposure

The dose to a hypothetical person at the point of maximum ground level concentration (the "Boundary Dose") is calculated according to the method used to specify the facility Derived Release Limits. The values from 2014 through 2022 for Ar-41 and I-125 are presented in **Table 2.9.3-1**. There were slight changes in the calculation methodology in 2022 which correspond to updated assumptions for facility data, receptor data, local geography and weather data. Some of these changes in assumptions were used to recalculate boundary doses back to 2017. Boundary doses remain extremely low for the period. Historical values are presented in **Figure 2.9.3-1**.

Table 2.9.3-1: Calculated MNR boundary doses

Year	Ar-41 (µSv)	I-125 (µSv)
2014	0.7	0.019
2015	0.7	0.018
2016	0.6	0.027
2017	0.7	0.107
2018	0.8	0.058
2019	0.9	0.018
2020	0.8	0.019
2021	0.7	0.004
2022	1.9	0.009

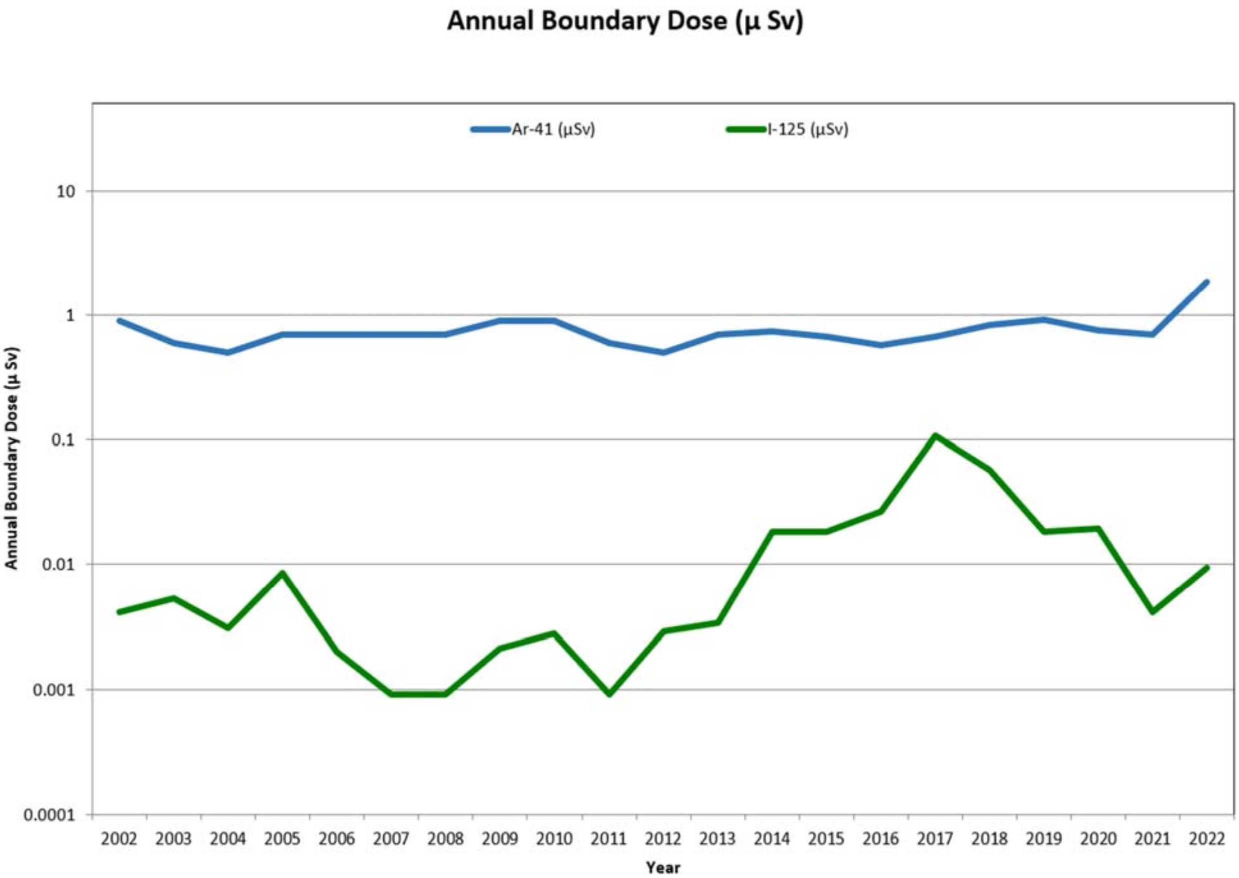


Figure 2.9.3-1: Calculated MNR boundary dose trends

There are two potential pathways for liquid releases from the facility; deliberate pump out from the building sumps to the municipal sewer and breakthrough of primary water to the secondary side of the heat exchanger.

There were no releases of contaminated liquids to the municipal sewer system in the licensing period. Liquid waste continues to be captured and processed or evaporated in the facility. The most recent release to the municipal sewer system occurred in 1988.

The gross beta emitting activity concentration of the secondary water in the heat exchanger is assessed weekly. Recent data from this monitoring are presented in **Figure 2.9.3-2**. There is no indication of any breakthrough to this system in 2022.

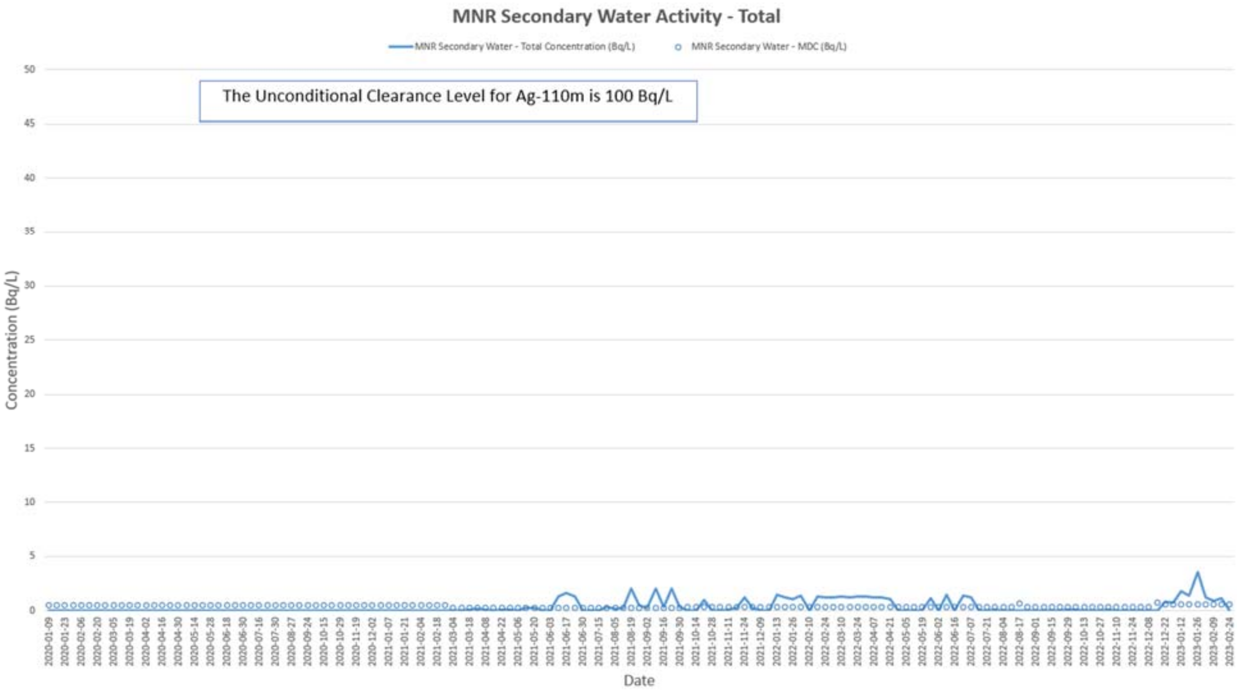


Figure 2.9.2-2: MNR secondary water total activity

No trends of concern are evident in any of the effluent monitoring data and there is no indication that releases from the facility pose an unreasonable hazard to members of the public.

2.9.4 Environmental Monitoring

Several air monitoring stations at locations surrounding the Reactor Building are operated to sample environmental air for particulates and radioiodines. The particulate samples are changed weekly (to prevent excessive dirt loading of the filter) and the charcoal cartridges for radioiodines are collected monthly in order to maintain the minimum detectable concentrations at the lowest reasonable levels. The particulate samples are assessed for gross beta-emitting activity using a low-background sample counter and the cartridges are analyzed for I-125 by gamma spectroscopy. Results of the monitoring for the past several years are shown in **Figure 2.9.4-1** and **Figure 2.9.4-2**.

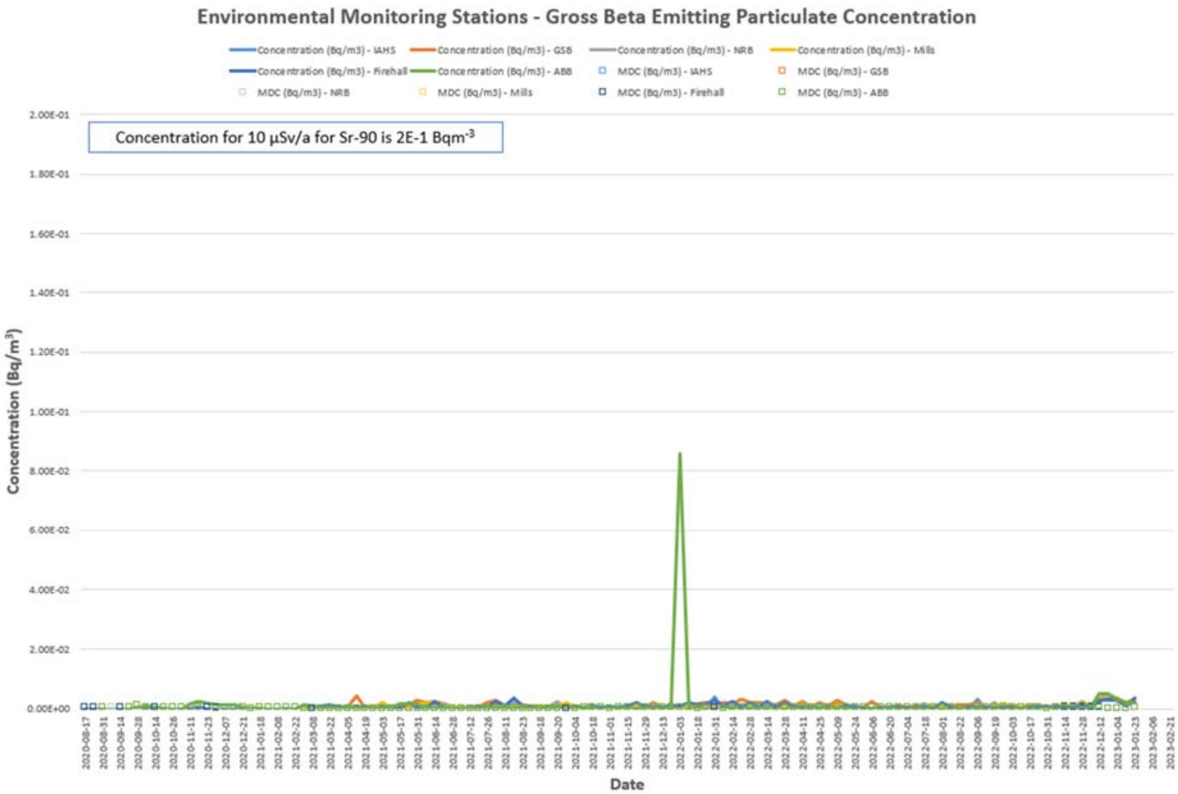


Figure 2.9.4-1: Environmental monitoring station gross beta emitting particulate concentrations

There was one spike identified in the concentration for the ABB location for the gross beta particulate in early 2022. The result was investigated but could not be reproduced and was not observed again. Possible explanations include sample cross-contamination or instrument issues for that one sample.

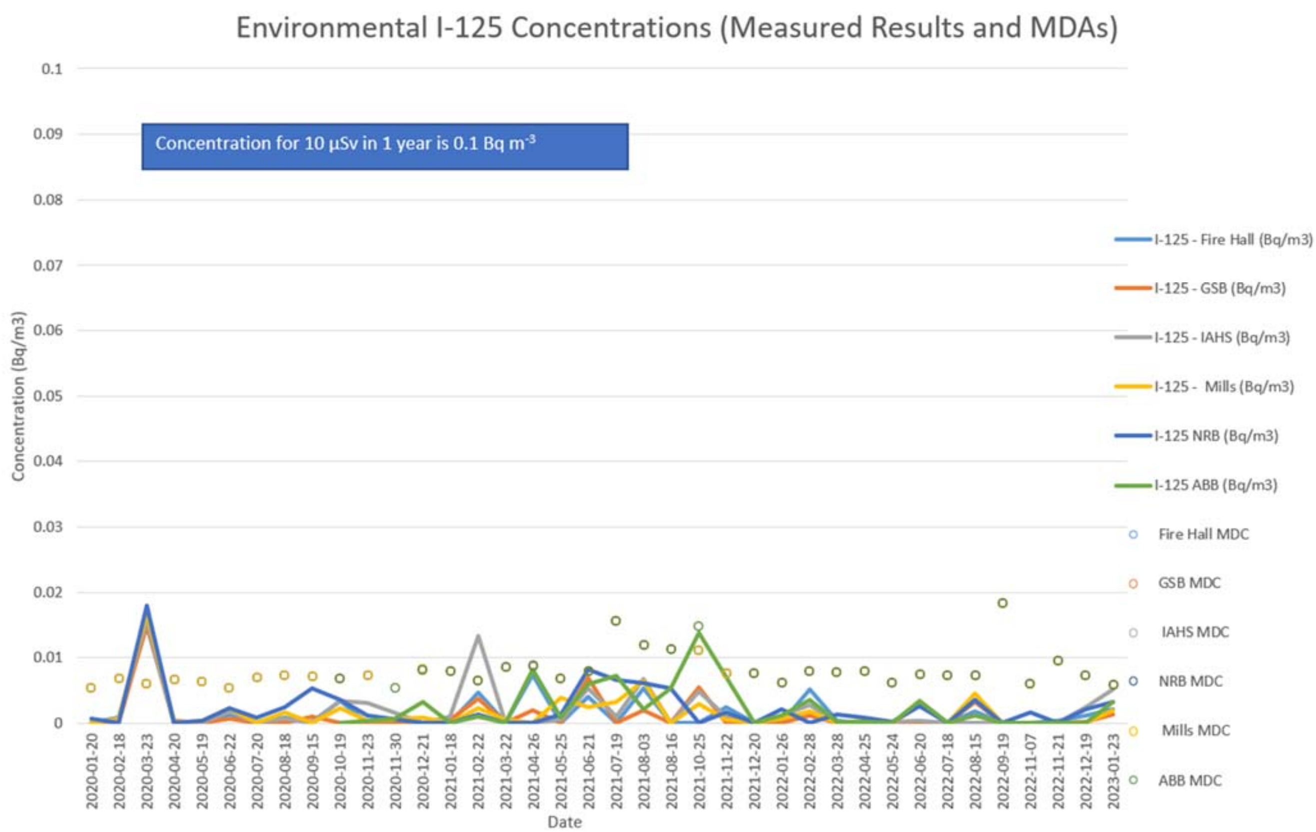


Figure 2.9.4-2: Environmental monitoring station I-125 concentrations

The environmental monitoring program results confirm the conclusion from the effluent monitoring program results that releases from MNR do not pose an unreasonable hazard to members of the public. There are no trends of concern evident and values are consistent with recent history. There were no spills to the environment during the licensing period. MNR contributed no adverse environmental impact.

2.9.5 Environmental Risk Assessment

McMaster University has prepared and submitted an Environmental Risk Assessment (ERA) [44] report to the CNSC in accordance with REGDOC-2.9.1, version 1.2, "Environmental Protection - Environmental Principles, Assessments and Protection Measures", September 2020 [62].

The ERA is an evaluation of hazards that the MNR poses to the environment and of impacts these hazards have on the environment and the public.

REGDOC-2.9.1 outlines "*the* CNSC*'s requirements and guidance to applicants and licensees for developing environmental protection measures, including an* ERA". It is stipulated that, *for Class I facilities and uranium mines and mills, the licensee shall conduct an* ERA *in accordance with CSA N288.6* [62].

The ERA is an iterative activity as illustrated in **Figure 2.9.5-1**. MNR is a small, research reactor which houses only small amounts of hazardous substances. With more than 6 decades of safe operating history, ample data is available on the actual (existing) physical and administrative provisions for protecting humans and the environment from harm. It follows that the conservative Tier 1 process of CSA N288.6 [63] (called the Screening Level Risk Assessment (SLRA) shown in **Figure 2.9.5-1** is adequate and appropriate for MNR.

This assessment has confirmed that the McMaster Nuclear Reactor (MNR) is a Class 1 facility with a very low emissions into the environment. The routine releases are small airborne emissions of:

- Ar-41 (non-reactive noble gas produced mainly by activation of dissolved air in pool water) and minuscule emissions of
- I-125 vapour or aerosols (medical isotope produced in sealed rigs within the reactor pool and handled/packaged on the Experimental Floor of the Reactor Building); and
- Radioactive particles (dust of undefined source).

Radioactive particles suspended in the air are monitored as the matter of principle even though their concentrations are close to, or below, the minimum detectable value and they are insignificant in terms of environmental impact.

There are no liquid effluents from the MNR. Solid radioactive materials are safely and securely stored within the Reactor Building (i.e., within the MNR containment envelope) until they are transferred to facilities certified by the Canadian Nuclear Safety Commission (CNSC) for disposal. Thus, the MNR is a low hazard facility.

Radioactivity is comprehensively monitored within as well as outside of the MNR. The monitoring records are routinely examined by the MNR and Health Physics staff. The data is compiled and reported to the CNSC in the Annual Compliance Reports for independent assessment.

A conservative (bounding) assessment was performed on the emissions, which calculates the worst conceivable impact to the limiting biota receptor (a nesting bird in MNR's case) which is continuously and perpetually exposed to the plume of MNR emissions passing through its habitat.

This results in a continuous and indefinite exposure duration with no averaging of the exposure boundary conditions (wind, rain, snow…). These are unrealistic but bounding assumptions, especially for a bird receptor which is typically stationary in its nest only for a few weeks a year whereas the assessment assumes the bird to remain its nest continuously.

Even under such extreme assessment conditions, it has been shown that the largest emissions to the atmosphere from reactor operation do not affect the limiting biota receptor (i.e., the most vulnerable receptor in terms of radiation effects) with a large margin to spare.

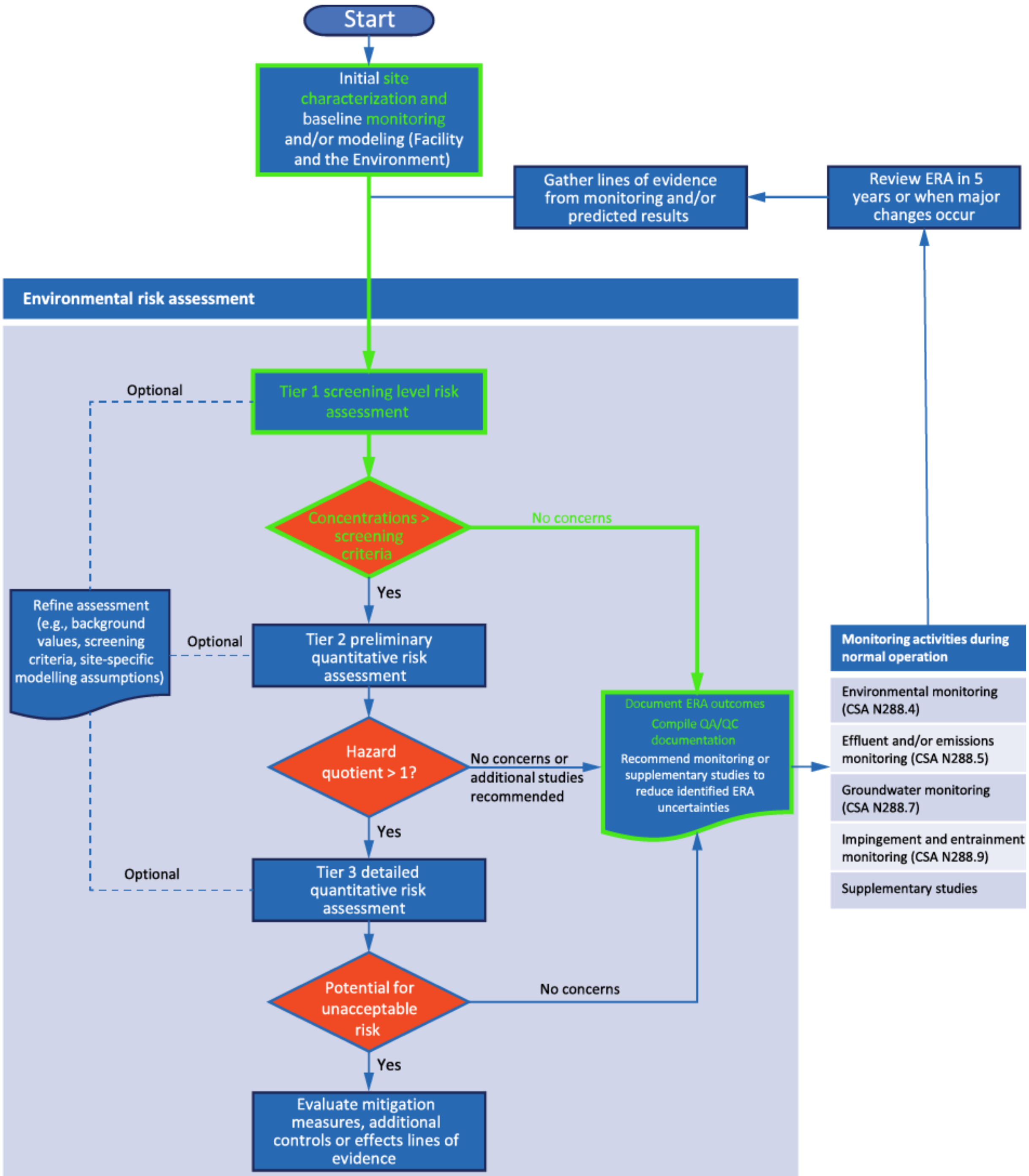


Figure 2.9.5-1: ERA progression through tiers of assessment

Annotated Figure 5.1 from CSA N288.6.

Green lines and text identify the SLRA tasks

2.9.6 Overall Performance of the Environmental Protection Program

The environmental protection program at MNR continued to operate effectively throughout the licence period.

Key aspects related to this safety and control area include:

- One of the key program objectives of the radiation safety program is to "Protect the public and environment by ensuring that releases of radioactive material are maintained ALARA".
- Requirements for monitoring and criteria for anything passing out through the facility boundary (the reactor building) are established.
- Derived Release Limits (DRLs) and Administrative Control Levels (Action Levels) related to facility air and liquid effluents are established.
- The requirements for monitoring are documented with links to the supporting work instructions and procedures for carrying out the air effluent, liquid effluent and environmental monitoring activities.

These objectives were all achieved during the period, with releases to the environment and correlated potential doses to the public maintained ALARA and far below program, licence and regulatory limits.

2.10 NUCLEAR EMERGENCY AND FIRE PROTECTION

2.10.1 Nuclear Emergency and Conventional Emergency Preparedness and Response

The MNR Emergency Preparedness Program is documented in EP-7000, MNR Emergency Preparedness Program [20]. This program was revised and updated in 2022 to incorporate significant revisions to the supporting emergency procedures, lessons learned from recent emergency response drills, incorporate aligned terminology with the Ontario Provincial Nuclear Emergency Response Plan (PNERP) [64] and incorporated best practices applicable to MNR from ANSI/ANS-15.16-2015 Emergency Planning for Research Reactors [65].

Activities throughout the licensing period have focused on the following:

- A review of training requirements for all individuals supporting a nuclear emergency response and the development of specific training for emergency response managers and directors.
- Routine response testing of the automated notification system for activating emergency response.
- Continuation of annual MNR emergency planning conferences with Municipal and University emergency responders, including annual table-top reviews of reactor emergency scenarios and response plans.
- Provision of emergency response training initiated for Hamilton Police Emergency Response Unit and Hamilton Paramedics.
- Continued collaboration and support of local emergency responders including provision of radiological response training for Hamilton Fire Department HazMat personnel and calibration of instruments.
- Organizing and hosting – in conjunction with partners from the local hospitals and City of Hamilton, a delivery of the Heath Canada Medical Emergency Treatment for Exposures to Radiation and assisting in follow up planning to enhance preparedness for contaminated/irradiated victims.
- Acquired additional emergency response instruments, including high range gamma meters.
- Reorganization of emergency response supplies to improve accessibility and implementation of documented routine checks of supplies on a quarterly basis.

A full-scale radiological fire exercise was last conducted at MNR in September 2019, in conjunction with Municipal emergency responders and the City of Hamilton Emergency Planning office. The exercise involved more than 115 individuals and demonstrated successful response and coordination between facility, University and Hamilton first responders (Fire, Police and Paramedics). Peer evaluators were utilized to provide observations and advice on key aspects of the response and an exercise report detailing items for further action was documented to track actions to completion.

Pandemic challenged MNRs ability to coordinate some planned emergency preparedness drills in the licence period. With restrictions no longer in place, there are no specific challenges that have been identified by MNR personnel for this SCA. A transportation emergency response plan exercise, in conjunction with City of Hamilton emergency responders is planned for the fall of 2023. A full Type D emergency is planned for 2024, which will include all internal and external emergency response individuals and organizations.

Close cooperation with City of Hamilton emergency responders continued throughout the licence period. Extensive refresher training on radiological incident response was provided to Hamilton Fire's Hazmat response teams, with most recent training provided to all crews in November of 2022. Day long sessions consisting of classroom training, reactor building orientation and hands-on response exercise with contamination and sealed sources was conducted for each shift. Ongoing support in instrument selection, maintenance and calibration was provided and the ongoing agreement to provide radiological assistance for any City response continued through the licence period.

2.10.2 Fire Emergency Preparedness and Response

The Fire Protection Program (FPP) [66] for MNR ensures activities being carried out at MNR do not result in an unreasonable risk to staff, the public or the environment.

The Program is based on the Fire Hazards Assessment for MNR [67], the MNR Fire Safe Shutdown Analysis [68], the SAR [17] and all relevant local, provincial and federal regulations.

The main objectives of the Program are to:

- Provide reasonable assurance that the safety-related systems perform their required safety function, and
- Meet the Loss Criteria established for the facility as follows:
    - No injury to university personnel or members of the public.
    - No radioactive release to the environment which could result in a dose to a member of the public exceeding 5mSv.

MNR's FPP meets these objectives in terms of three program components: fire prevention, passive fire protection, and active fire protection.

The Program [66] and supporting procedures ([69], [70], [71], [72]) detail the training requirements and the roles and responsibilities for NOF, HP, Security, EOHSS, and Hamilton Fire Department personnel in preventing and responding to a fire at the facility.

The Hamilton Fire Department and the University have established a Memorandum of Understanding (MOU) which provides details on how the two entities support each for emergency preparedness.

Annual building fire evacuation drills are completed for all campus buildings including the reactor building. In person drills were limited during the pandemic, but a virtual Type B fire response drill was completed in June of 2021. The drill involved more than 65 individuals from internal and external agencies, including Hamilton Fire Services and the Canadian Nuclear Safety Commission. The virtual component of the drill was completed by presenting the nuclear fire drill scenario to the participants and working through the response for each work group.

MNR Operations staff received in-person instruction from Hamilton Fire Services on the selection and use of fire extinguishers and under their supervision took turns putting out a fire with the extinguisher. An exercise report detailing items for further action was documented to track actions to completion.

2.10.3 Overall Performance of the Emergency Preparedness Program

The emergency preparedness program at MNR continued to ensure readiness for the response to a nuclear emergency throughout the licensing period. Strong relationships with the City of Hamilton and Province of Ontario continue to support the implementation and continued improvement of the program.

2.11 WASTE MANAGEMENT

2.11.1 General Considerations

Health Physics supervises the disposal of all solid and liquid radiological waste. Normal laboratory dry waste is accumulated in special marked yellow radioactive waste containers and typically transferred to the Hot Waste Storage Area, until disposal can be coordinated by Health Physics as part of regular shipments to an approved waste management vendor.

MNR policy is to treat all wastewater collected through recycling via the Demineralizer Water System. Sewer discharges would only be utilized in the event of an incident or mechanical failure that makes wastewater cleanup impractical.

During the previous licence period, all remaining spent HEU fuel assemblies were returned to a United States Department of Energy facility.

MNR will continue to implement waste minimization through the upcoming licence period. No major changes to the program are anticipated.

2.11.2 Waste Characterization

All radioactive waste is characterized noting the source of the radioactive material, with Ag-110m and I-125 being the primary radionuclides representative of the majority of waste generated at MNR. With most radiological waste having a prominent gamma energy emission, MNR has purchased a Large Article Monitor in 2020.

Technical basis documents have been developed by Health Physics to support the characterization of radiological waste from each waste stream, based on source term.

2.11.3 Waste Minimization

Significant effort continued to be invested in maintaining housekeeping improvements achieved in recent years. The stored inventory of radioactive waste in the facility decreased in 2022. The volume of low-level dry active waste stored in the Hot Waste Storage Area (HWSA) and the pump room was reduced after a campaign to clear built up waste from the last two years.

A significant amount of primary piping and assorted metal equipment from demineralizer system work was removed from the pump room in 2022, following maintenance activities that generated this waste.

2.11.4 Waste Management Practices

Shipments of solid waste to an approved waste management vendor take place three times per year. Typically, these shipments consist of a small portion of higher activity material such as spent resins from the reactor demineralizer system and activated components from irradiations and experimental facilities. Additionally, low level dry active bagged waste and contaminated metal for recycling also take place three times annually. These shipments are typically very low activity items such as slightly contaminated gloves and protective clothing.

No radioactive waste is released to the municipal landfill.

2.11.5 Decommissioning Plans

In accordance with REGDOC-2.11.2 [73], Decommissioning, McMaster University maintains a Preliminary Decommissioning Plan (PDP) [74] consistent with facility of MNR's risk and complexity. The original PDP, TN 2002-08 [74], was issued in 2002 and has been routinely updated since that time. The last update of TN 2002-08 [74] took place at the end of 2021.

The PDP is formulated around a prompt green-field strategy, includes hazards assessments, schedules and cost estimates and provides a five-year escalated cost estimate to undertake decommissioning prior to the next Plan [74] update. A Financial Guarantee, which was updated and approved at a Hearing of the Commission in 2017 (Record of Decision – McMaster University – 2017 [75]) and is maintained per licence requirements by the University.

The comprehensive Plan covers all aspects required by a preliminary decommission plan with the safety of workers and the protection of the public and the environment as the overriding principles throughout the execution of the Plan.

2.12 SECURITY

The McMaster University is in full compliance with Nuclear Security Regulations SOR/2000-209 [76], REGDOC-2.12.3: *Security of Nuclear Substances: Sealed Sources and Category I, II and III Nuclear Material*, Version 2 [77] and REGDOC-2.12.2, *Site Access Security Clearance* [78].

MNR maintains a Security Plan [19] in accordance with the Nuclear Security Regulations to protect against sabotage and unauthorized removal of fissile and radioactive material and to prevent unauthorized access to the Reactor Building.

Special attention is given to physical features and administrative procedures to prevent unauthorized actions, whether intentional or unintentional, by facility personnel or others, which could jeopardize safety.

Access to the facility is controlled by electronic and mechanical means operated by security-approved personnel. All persons entering the facility do so only with authorized permission in accordance with Building Access Regulations [79] and Security Badge Issue and Use [80].

In 2015, McMaster University participated in the International Physical Protection Advisory Services (IPPAS) mission to Canada The objectives of the IPPAS mission were to review the following: the current status of the national nuclear security regime of nuclear and other radioactive material and associated facilities and activities; review the implementation of the nuclear security measures at Bruce Power Nuclear Generating Station, Western Used Fuel Dry Storage Facility operated by Ontario Power Generation, Nordion Kanata nuclear substance processing facility (hereafter referred to as Nordion) and the McMaster University Nuclear Reactor (MNR); compare the procedures and practices of Canada with the *Convention on the Physical Protection of Nuclear Material (CPPNM)* and its 2005 *Amendment; Code of Conduct on the Safety and Security of Radioactive Sources* [81]; *IAEA Nuclear Security Series (NSS) No. 20, Objective and Essential Elements of a State's Nuclear*

Security Regime [82]*; IAEA NSS No.13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5)* [83]*; IAEA NSS No. 14, Nuclear Security Recommendations on Radioactive Material and Associated Facilities* [84]. and with other relevant IAEA NSS documents; provide recommendations and suggestions for continued improvement of nuclear security; and identify good practices.

The summary report identified no "recommendations" and one "suggestion" for MNR which has been implemented.

2.12.1 General Considerations

MNR contains only Category III material since its conversion to Low Enriched Uranium (LEU) fuel in the early 2000s. Due to physical and inventory constraints MNR only maintains a relatively small number of fresh fuel assemblies in inventory.

The physical construction of the reactor building, consisting of approximately one-metre-thick reinforced concrete walls and heavy plate containment doors provides a robust basis for application of physical security measures.

Unescorted access to the facility is strictly controlled. Security checks consisting of police record checks, background checks and reference checks are completed prior to access being granted access by either the DROM or the MRO.

Personnel, who have enhanced access to the facility, also require government of Canada security clearance commensurate to their security role at MNR.

Details of the security provisions at MNR are contained in AP-1420 [19] which is a prescribed protected security document.

2.12.2 Response Arrangements

The security service at MNR comprises the McMaster University Security Services staff. Their structure and administration, responsibilities, duties, training and drills are discussed in "Position and Procedures McMaster University Security Services". Section 6 of this document provides a brief summary of activities relating to MNR.

Security Services Officers are sworn in as Special Constables, with powers of arrest on the campus at McMaster University in the City of Hamilton. Security Services operates 24 hours per day, 365 days of the year on a rotating shift basis with a minimum complement each shift of four patrol officers and a dispatcher.

McMaster University is under the jurisdiction of the Hamilton Police Service (HPS). HPS is the response force for the facility. Response force arrangements between MNR and HPS have been incorporated in a Memorandum of Understanding (MOU) between HPS and McMaster University.

2.12.3 Security Practices

The Site Security Plan AP-1420 [19] details the administrative and technical measures that have been implemented at MNR to secure prescribed assets at the facility.

AP-1420 describes the technical details used to provide physical security and detection systems and the administrative procedures associated with security clearance, access control, and response to alarms or security situations.

The Plan describes the specific security procedures associated with access to the facility, special nuclear material and prescribed information. It documents the personnel permitted access to the materials and their requirements for their security clearance.

A select number of personnel at the University associated with the reactor have obtained Top Secret Clearance to enable them to receive updates from enforcement agencies on threats in the local area.

2.12.4 Security Training and Qualification

Security Services Officers are sworn in as Special Constables, with powers of arrest on the McMaster University campus. Selection for employment is based on standard university practices with the addition of an interview with the Director Parking and Security to ascertain maturity and character. The ability to meet the security background checks required for Reactor Access is a condition of employment. The candidate must also be cleared by the RCMP, provincial and local authorities. Training is via an in-service program, augmented by training from the Hamilton Police Service.

MNR staff are recruited through normal university personnel procedures with Reactor Supervision and Management interviewing suitable candidates to ascertain stability, maturity, and responsibility. The ability to meet the security background checks required for Reactor Access is a condition of employment.

Each member of the operations staff must attend an introductory security briefing given by Reactor Management or Supervision and must be knowledgeable regarding security procedures. Security training, including supervisory awareness training is conducted annually.

In order to enhance capability, security training is augmented with drills and exercises which are routinely planned and executed by MNR and Security Management.

2.12.5 Cyber Security

All of MNR's reactor control and safety systems are analog based and are therefore not subject to cyber security attacks.

Prescribed material is stored in hardcopy in appropriately secured locations.

Operational and commercial information is stored on dedicated and protected servers with two state-of-the-art and diverse fire wall systems deployed to both prevent access and to detect brute force or other attacks on the systems. Data managed on these systems is routinely backed up and monitored for unauthorized access attempts.

Suspicious activity is reported to MNR Management, who then will take appropriate actions including reporting to the CNSC as appropriate.

Personnel managing or servicing the systems have requisite security clearances needed to perform their duties.

The University's Technology Services' (UTS) team supports the MNR Information Technology (IT) team by providing policy direction and technological support, advice and review of MNR's cyber security posture to provide third party input and direction for improvement.

Defensive strategy and security architecture

Launched in 2021, McMaster's Information Security Roadmap is designed to enhance information security governance, policy and standards, information security for researchers, identity and access management, endpoint security, network security, incident response, SIEM, vulnerability management and education and awareness. The McMaster Information Security Roadmap is backed by the Associate Vice-President and Chief Technology Officer of McMaster, the Vice-President Finance and Operations and the Provost. McMaster Information Security Strategy and Architecture provides for a defense in-depth approach with layers of technology and process safeguards. The technology environment provides protection at the firewall level and across the network with a number of safeguards. Information Security also has a number of tools that regularly and in an automated manner scan for vulnerabilities, detect and respond to potential threats and alert a security operations team to resolve. McMaster also has a 24/7 Managed Threat Hunting Service.

Policies and procedures

McMaster's Information Security Roadmap will be updating existing, and introducing new, policies and procedures that support the confidentiality, integrity and availability of our information technology.

Asset identification and classification

McMaster currently provides network scanning as a service, and localized scan tools to various Information Technology teams and managers, including those at the McMaster Nuclear Reactor. The scanners assist with asset identification on the network and provide depth to other telemetry. Enhanced network support (e.g., segmentation, air gaps) and enhanced endpoint protection (e.g. XDR,) are made available upon request. Faculties and key areas across the Institutions manage their assets for their local areas as well and apply safeguards at a local level depending on the use of the assets.

Roles and responsibilities of the involved parties

Administrative safeguards are orchestrated by human resources, and are coordinated with other areas within the University, including campus security (physical) and information technology. Within information technology, cyber security as a practice is supported by multiple enterprise teams who ensure the confidentiality, integrity and availability of digital systems and services that support the McMaster Nuclear Reactor. The Senior Manager Cyber Security Systems and Information Security Officer along with the Manager of Information Security Operations support various security and architecture functions as part of the Information Security Services team. This team is further supported by the Director, Campus Infrastructure Systems whose Senior Managers (Technical, Architecture & Infrastructure, Network and Telecom Services) support various aspects of the CIA triad through collaboration with Information Security Services. Reporting to the Deputy CTO and Director, IT Strategy & Services, are Senior Manager IT Client Services, and Senior Manager Collaboration, Productivity and Cloud Enablement, who support aspects of information security, including cloud resource management, ticketing systems and core ITIL functions. Lastly, the Director of Enterprise Applications & Data Systems has two Senior Managers (Enterprise Applications, and Integration Services and Data Systems) who support aspects of the CIA triad through collaboration with Information Security Services and campus entities, including the McMaster Nuclear Reactor. Collaboration and coordination between teams is by both a strategic direction and overarching accountability to the Associate Vice President and Chief Technology Officer, who oversees IT Governance, strategy, strategic implementation, central administration, communication and culture.

Security controls

McMaster employs a mix of technical, administrative and physical controls at various depths throughout the institution to provide a balanced approach for academic freedom and overall defensive posture. McMaster's Information Security Roadmap clarifies and builds on a spectrum of controls that are available to meet various confidentiality, integrity and availability needs including those of MNR.

Awareness and training

McMaster offers Information Security training through a variety of channels, including our Learning Management System, professional workshops, individualized learning plans and live events. McMaster's Information Security

Roadmap seeks to build upon and enhance our teaching and learning strategy for information security culture and practice.

Configuration management
Endpoint configuration management options are available in various forms, from fully managed SCCM/InTune support, virtual machines and individualized consultation. This practice is evolving through the McMaster Information Security Roadmap through network and endpoint activities, as well as policy and guideline maturation. For system administrators and power users, configuration support at all levels of the stack includes access to subject matter experts and colleagues.

Coordination with other programs
McMaster is a founding member of the Canadian Shared Security Operations Centre (CanSSOC) and is a founding member of the Research Information Security Special Interest Group. This group if focused on sharing security control practices and approaches with other Universities across Canada to aid in the strengthening of the collective risk posture of these Universities. McMaster is also active in the Canadian University Council of Chief Information Officers, where cross-institutional security support and guidance is coordinated across the nation's Universities.

A number of support areas provide coordinated support to the nuclear facility at McMaster including Information Security, Campus Security, Privacy Office, Enterprise Risk, Legal, Information Technology etc.

Incident response, reporting and recovery plan
McMaster employs an Incident Response Plan, Business Continuity Plan and Crisis Management plan. These are a blend of recovery plans based on system criticality and risk. Incident response is managed centrally by the Security Op and Crisis Management is led by the office of the VP Finance and Operations.

Program review and maintenance
McMaster's Information Security Roadmap is a response to a review of our cyber security posture and will include review and maintenance strategies for various aspects of information security, including endpoint and networks, identity and access management, policy and guidelines, incident response, and education and awareness.

Lifecycle approach to cyber assets
Cyber asset lifecycle management support and planning is available through consultations with a mix of professional opinions, including leaders from enterprise infrastructure systems, enterprise applications and data systems, and enterprise security. Support is available through consultations and is furthered by an existing IT Governance structure that enables aspects of lifecycle management coordination.

2.13 SAFEGUARDS AND NON-PROLIFERATION

2.13.1 General Considerations

The McMaster Nuclear Reactor complies with the responsibilities for safeguards and non- proliferation of nuclear material according to Canada's agreement to comply with the international nuclear non-proliferation treaty, INFCIRC/164 [85].

The MNR safeguards materials are prescribed information, subject to the requirements of the Nuclear Safety and Control Regulations.

MNR complies with the obligations from the Canada/IAEA safeguards agreements and all other measures arising from the Treaty. The University complies with REGDOC 2.13.1 "Safeguards and Nuclear Materials

Accountancy" [86] through the activities and commitments put forward in Section 5 of the MNR Policy manual [4] including:

- MNR shall install safeguards equipment or facilitate the installation of safeguards equipment at the request of the CNSC. Appropriate instructions and controls shall be developed as required for any installed equipment or seals.
- MNR shall provide the International Atomic Energy Agency (IAEA), an IAEA inspector or a person acting on behalf of the IAEA with such reasonable services and assistance as are required to enable the IAEA to carry out its duties and functions pursuant to a safeguards agreement.
- MNR shall grant prompt access at all reasonable times to all locations at the *facility* to an inspector of the IAEA or to a person acting on behalf of the IAEA, where such access is required for the purposes of carrying on an activity pursuant to a safeguards agreement.
- MNR shall disclose to the CNSC, to the IAEA or to an IAEA inspector, any records that are required to be kept or any reports that are required to be made under a safeguards agreement. Records shall be generated, submitted, and retained as required to facilitate Canada's compliance with any applicable safeguards agreement.
- MNR shall make such reports and provide such information to the CNSC as are required to facilitate Canada's compliance with any applicable safeguards agreement.
- MNR shall make and submit reports to the CNSC in accordance with REGDOC-2.13.1 [86], Safeguards and Nuclear Material Accountancy, on the inventory and transfer of fissionable and fertile substances.

Safeguards activities are reported to the CNSC in the MNR's Annual Compliance Report and to the public (where appropriate) through its Public Information and Disclosure Policy Disclosure Policy [90].

2.13.2 Nuclear Accountancy and Control

The Facility's responsibilities for nuclear accountancy and control are in the form of communicating to the CNSC:

- changes in an account of nuclear materials' holdings,
- the results of an annual Physical Inventory Taking,
- providing full access to the IAEA inspectors to perform Physical Inventory Verification.

Inventory tracking at MNR is a straight forward matter and consists of counting the relatively small number of fresh fuel assemblies on-hand, calculating burn-up measurements for assemblies which are in or have been in the reactor core and reporting fuel shipments.

This information is provided in reports to the CNSC on an annual basis, who in turn provides the information to the IAEA.

2.13.3 Access and Assistance to the IAEA

As required by REGDOC-2.13.1 [86], the *Nuclear Safety and Control Act* (NSCA) [3] and MNR Policy [4], the University provides the IAEA, IAEA inspectors or persons acting on behalf of the IAEA with services and assistance as are required to enable the IAEA to carry out its duties and functions pursuant to a safeguards agreement.

Additionally, the University grants prompt access at all reasonable times to all locations at MNR to an inspector of the IAEA or to a person acting on behalf of the IAEA, where such access is required for the purposes of carrying on an activity pursuant to a safeguards agreement.

Under the Additional Protocol, the IAEA has the right to request complementary access (CA) at MNR to perform activities such as:

- visual observation
- collection of environmental samples
- utilization of radiation detection and measurement devices
- item counting of nuclear material
- application of seals and/or other tamper indicating devices (not currently applicable at MNR)
- discussions with persons who are or have been involved in work that is reportable under the safeguards agreements
- examination of records relevant to the goals of the CA

McMaster University supports and has supported many such inspections.

2.13.4 Operational and Design Information

The Director Reactor Operations and Maintenance, together with the Manager Reactor Operation are responsible for maintaining accurate design information for the facility structures.

The DROM and the MRO are also responsible for preparing and submitting the annual operational program to the CNSC that includes all of the following information:

- the preferred PIT date for the upcoming calendar year
- any anticipated shutdown periods during the upcoming calendar year
- information on expected transfers of nuclear material in the next calendar year
- updates on current or upcoming projects of relevance to safeguards, such as the construction or decommissioning of a building, the commencement of projects involving nuclear material, changes to the types of nuclear material being possessed, etc.

Annual reports are prepared and submitted according to the timeframes provided in REGDOC-2.13.

2.14 PACKAGING AND TRANSPORT

McMaster University is fully compliant with CNSC Regulation, *Packaging and Transport of Nuclear* Substances *Regulations, 2015 (PTNSR)* [87] and the international regulations as documented in the IAEA, *Regulations for the Safe Transport of Radioactive Material, SSR6, 2018 Edition* [88].

2.14.1 Package Design and Maintenance

MNR designs and tests Type A single-use packages used for the transportation of medical isotopes following the requirements found in IAEA, *Regulations for the Safe Transport of Radioactive Material, SSR6, 2018 Edition* [88]. Designs and tests are documented in Technical Notes (TN) and kept in the MNR document management system.

Visual inspection of the Type A package is completed during shipment preparation and as part of the packaging procedure.

2.14.2 Packaging and Transport

All packages are prepared and labelled in accordance with the regulations under the direct supervision of a Transportation of Dangerous Goods (TDG) trained and certified Staff member using approved procedures.

Training is comprised of radiation safety training (all Staff involved are NEWs), training on TDG regulations and training on the package specific procedure. TDG training was custom designed by third party system matter experts based on MNR activities and includes detailed instruction on the type of containers that are suitable for transporting dangerous goods for Class 7 material. The course also explains the required labelling on the packages and how to measure the transportation index for the package.

Training is followed by a field checkout to ensure the trainee is sufficiently qualified to safely and compliantly prepare packages containing radioactive material for shipment.

TDG Certificates are issued to the Staff members by the DROM once all training has been successfully completed.

2.14.3 Registration for Use

Occasionally, MNR has handled Type “B” flasks at the facility which are owned, maintained and managed by other entities. Certification of the package is a contractual requirement when renting the container and is verified by MNR Staff through the CNSC’s website prior to use. Container certification is also verified by CNSC staff members during the application process for import, export or transport licenses.

3.0 OTHER REGULATORY AREA

3.1 Public Information and Disclosure Program

MNR maintains a Public Information Program and Disclosure Protocol (PIP&DP) [89] in compliance with REGDOC 3.2.1 Public Information and Disclosure [90]. The PIP&DP is posted on the MNR website (https://nuclear.mcmaster.ca/facilities-equipment/facility-list/mcmaster-nuclear-reactor/).

The primary objective of the MNR PIP&DP is to effectively communicate the information related to the health, safety, and security of people and the environment, and issues pertinent to the lifecycle of the facility that are related to the operation of the MNR research reactor at McMaster University. It is intended to address MNR's target audience's information and interests. It also serves to explain and reinforce Canada's international obligations with respect to the peaceful use of nuclear energy in the capacity that it is used at the MNR facility.

The secondary objective is to promote education with respect to the MNR research reactor within McMaster University and the surrounding community. The disclosure of information is intended to inform the public about and alleviate any concerns with regard to the processes being undertaken at the MNR research reactor. It is important to engage the public in a discussion on the safe operation of the MNR research reactor.

The intent of the PIP&DP is to provide information of interest to the target audience(s). The disclosures made under the PIP&DP relate to the licensed activities performed at the MNR research reactor. The main target audiences identified are:

- MNR staff and authorized users in the reactor and the Nuclear Research Building
- Customers who utilize reactor services or products manufactured at MNR
- Students, faculty, and staff located at McMaster University
- Hamilton Fire Department personnel
- Hamilton Police Department personnel
- Members of the Nuclear Facilities Control Committee and the Health Physics Advisory Committee
- Neighbours in the areas surrounding campus
- The general public

On a regular basis, interested members of the public tour MNR facilities. On occasion, the media have been invited to MNR. Individualised tours for members of the public and university staff are carried out upon request. Part of the purpose of these tours is to create transparency for the MNR research reactor amongst the various target audiences.

Dissemination of information regarding the MNR research reactor includes information regarding both routine operations and information regarding planned and unplanned events. The purpose of the PIP&DP is to disclose information in a transparent and consistent manner in order to promote nuclear education and radiation safety. The event reporting is guided by and in accordance with CNSC REGDOC-3.1.2. "Reporting Requirements for Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills" [1].

MNR publishes information promptly for the benefit of the public. Information is released as soon as MNR staff can complete initial investigation steps to be sure that the information released is as accurate as possible. This means that information is published As Soon as Is Reasonably Possible (ASAR).

The purpose of the PIP&DP [89] is to inform the public about the effects of the operation of the MNR research reactor may have on the health and safety of the public and the environment by:

- Communicating significant operation developments such as changes to facility design or operation and research findings.
- Communicating ASAR, unplanned events exceeding regulatory limits, causing offsite effects, or which could result in public or media interest or concern.
- Maintaining two-way communication for the public to interact with MNR.
- Consulting with the public to confirm types of information of public interest.

MNR utilizes multiple tools for communication with the target audience in order to execute this protocol. The majority of information is published on the MNR website. Where additional communication is necessary, information may be published using (but not limited to):

- Social media technology operated by the university Public Relations department and Nuclear Operations and Facilities
- Neighbourhood Update e-newsletter operated by the university Public Relations department
- Local area newspapers - typically the Hamilton Spectator and the McMaster Silhouette
- Local area radio stations - typically CHML AM 900
- Local area television stations - typically CHCH channel 11
- LCD information screens located throughout campus and in student residence buildings
- Email mailing lists

Guidance for public disclosure is based on MNR experience as well as input gained from target audiences through various communications including email, phone calls, tours open house feedback, etc.

MNR shall ensure that the CNSC is advised of non-routine disclosures made to the target audiences at the time or prior to such disclosure. Communications of a routine nature are not necessary to be reported to the CNSC. Documentation and records concerning disclosure are kept and available for compliance verification by the CNSC.

Evaluation of the PIP&DP program [90] is done on a continuing basis. Input from target audiences, regulators, and any potential nonconformances are considered. Updates are made as necessary, and the PIP&DP undergoes improvements as they are identified.

3.2 INDIGENOUS ENGAGEMENT

McMaster University and McMaster Nuclear Reactor (MNR) recognizes and acknowledges that it resides on the traditional territories of the Mississauga of the Credit First Nation (MCFN) and the Haudenosaunee Confederacy (HC). The traditional territory of the MCFN upon which McMaster resides is also covered by the Between the Lakes Treaty No. 3. MNR recognizes the significance of these lands to the Indigenous people and MNR expresses its gratitude to have the privilege to study, learn, live, and work here.

McMaster University is committed to building relationships and enhancing its engagement with local First Nations, Inuit and Métis communities, supporting and encouraging Indigenous students, staff and faculty members, promoting Indigenous education and the study of Indigenous knowledge and culture, and ensuring the participation of First Nations, Inuit and Métis representatives in the University’s decision-making process. As part of the McMaster’s commitment, the University addresses all the applicable requirements stated in REGDOC-3.2.2 [91].

Over the past five years staff at MNR have worked with the Nuclear Waste Management Organisation (NWMO) to provide reactor tours and information to potential host communities for Canada's deep geological repository. Many of the selected sites were found in indigenous communities. These valuable and well received tours provided community members with a view of an operating nuclear reactor and the ability to pose questions to non-industry nuclear and radiation safety experts. The tour program at MNR provides firsthand experience to the visitor, helping to demystify radiation sciences and nuclear technologies.

McMaster University issued their *Indigenous Strategic Directions* [93] in September 2021 in response to the *Truth and Reconciliation Commission's Calls to Action* and the *United Nations Declaration on the Rights of Indigenous* People. This was developed by the University's Indigenous Education Council (IEC) and the McMaster Indigenous Research Institute (MIRI) with a campus wide collective effort with Indigenous groups. It contains four main strategic goals of research, education, student experience, and leadership and governance which will act as a guide for McMaster University.

In February 2023, MNR sent letters to Mississauga of the Credit First Nation, Haudenosaunee Confederacy, Métis Nation of Ontario and Six Nations of the Grand River requesting engagement. MNR wishes to build relationships with these communities beyond the licence renewal process. The first meeting was held on April 11, 2023, and feedback from this meeting is being incorporated into the facility's goals and actions within MNR's Indigenous Engagement Program.

McMaster University had the privilege of hosting the March 2023 meeting of the Indigenous Advisory Council (IAC) on Canada's Small Modular Reactor (SMR) Action Plan. This provided the opportunities for IAC to learn about McMaster University and MNR's areas of research and education in the nuclear space, and for McMaster University and MNR to learn about the IAC's engagement in the nuclear industry.

McMaster University's undergraduate programs in Indigenous Studies is one of the longest standing programs of its kind in Canada. To advance the Indigenous Studies program to departmental status was one of the Indigenous Strategic Directions under education. On July 1, 2022, the University approved the creation of the Indigenous Studies Department. The department officially launched March 2023.

On April 14, 2023, over two dozen staff with Nuclear Operations and Health Physics attended a workshop titled *Working Effectively With Indigenous Peoples* offered by Indigenous Corporate Training Inc. The training is designed to provide trainees with a deeper understanding of indigenous awareness and indigenous relations.

Indigenous Awareness

- Understanding how history impacts Indigenous Peoples
- Understanding how current Indigenous issues impact Indigenous communities
- Understanding Indigenous self-government
- Understanding the constitutional, political and legal context of Indigenous issues
- Understanding how Indigenous and western world views impact decision-making

Indigenous Relations

- Understanding how to cultivate Indigenous relationships
- Understanding business reasons for working with Indigenous Peoples
- How to begin to consult with Indigenous Peoples
- Fear of saying or doing the wrong thing
- How to manage risk when cultivating Indigenous relationships

MNR supports the strategic initiatives of the University and is in the process of finalizing a MNR Indigenous Engagement Program [93] that aligns with the *Indigenous Strategic Directions* [92]. This program will outline goals and actions specific to MNR, with action leads and proposed target dates. Some actions in this Program are from discussions had at the IAC meeting held at McMaster University. Performance will be tracked and monitored annually. The program has been drafted and is being circulated for review and approval. Final approval is expected in Q2 2023 and will be submitted to CNSC upon completion.

3.3 COST RECOVERY

In accordance with the Canadian Nuclear Safety Commission Cost Recovery Fees Regulations, MNR is exempt from any fees associated with the planned regulatory efforts.

3.4 FINANCIAL GUARANTEE

McMaster University a financial guarantee for the decommissioning of MNR as required by Condition 1.4 of NPROL-01.00/2024. The details of the guarantee are captured in the following two documents which have been reviewed and accepted by the Commission at a Hearing [75] which took place in 2017.

1. ***"CNSC Financial Security and Access Agreement"*** signed January 19, 2017. [94]
2. ***"Deed of Trust"*** for the McMaster University Decommissioning Trust Fund signed June 30, 2005. [95]

Both of these documents have been approved by the Board of Governors of McMaster University. The CNSC Financial Security and Access Agreement has been signed by designated officers of the CNSC and McMaster University.

McMaster University continues to maintain its Nuclear Reactor Restricted Reserve Fund and provides an annual independent assessment of the fair market value of the fund to the CNSC as required by the Guarantee.

4.0 SUMMARY

McMaster Nuclear Reactor (MNR) is Canada's only high-powered nuclear research reactor, and the nation's only major neutron source. As such, MNR enables a broad range of neutron-based research programs in health, materials, energy and environmental sciences while providing unique educational experiences for students and the general public.

During the current licensing period, MNR became Canada's largest neutron source and, as such, needs to grow its operations to accommodate this new role. The University and both the Federal and Provincial governments have all committed significant funding to increase the facilities capacity by returning the reactor to a 5 MW 24 hour a day operating schedule (currently the reactor operates only sixteen hours a day at 3 MW). These changes will triple to the capacity of the reactor and furnish Canadian researchers with neutron intensities required to respond to the emerging questions facing them.

The purpose of this application to the Canadian Nuclear Safety Commission (CNSC) is to request the renewal of the non-power reactor operating licence for the MNR located on the University's main campus in Hamilton, Ontario. The current ten-year operating licence, NPROL-01/24 will expire on 30 June 2024 and hence the request for renewal. This request is for a twenty-year operating license; valid from 01 July 2024 to 30 June 2044.

Over the current licence period, McMaster University has operated the McMaster Nuclear Reactor safely, securely, effectively and in compliance with all required regulations.

Marked and consistent improvement has been made in all Safety and Control Areas over the period.

McMaster University continues to demonstrate it is qualified to carry out the activities listed in its NPROL, that it continues to make ample provisions for the protection of the environment, the health and safety of workers and the general public, and has measures in place to continue to implement the international obligations to which Canada has agreed in regard to safeguarding nuclear materials.

McMaster University respectfully requests that NPROL-01 be renewed for a further twenty years.

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GLOSSARY

ACR	Annual Compliance Report
ALARA	As Low As Reasonably Achievable (principle)
ALI	Annual Limit on Intake
ASAR	As Soon As Reasonable
AVP	Assistant Vice President
CA	Complementary Access
CANDU	Canada Deuterium Uranium
CANS	Centre for Advanced Nuclear Systems
CanSSOC	Canadian Shared Security Operations Centre
CFM	Cubic Feet per Minute
CIA	Confidentiality, Integrity, and Availability
CNSC	Canadian Nuclear Safety Commission
CPPMN	Convention on the Physical Protection of Nuclear Material
CSA	Canadian Standards Association
CTO	Chief Technology Officer
DCS	Distributed Control System
DEL	Derived Emission Limit (synonym of DRL)
DRL	Derived Release Limit (synonym of DEL)
DROM	Director, Reactor Operations and Maintenance
EA	Environmental Assessment
ECC	Emergency Control Centre
EFAP	Employee and Family Assistance Program
ERA	Environmental Risk Assessment
GNSCR	General Nuclear Safety and Control Regulations
HC	Haudenosaunee Confederacy
HEPA	High-Efficiency Particulate Absorbing (filter)
HEU	High-Enrichment Uranium
HLLF	High Level Laboratory Facility
HP	Health Physics
HPAC	Health Physics Advisory Committee
HPS	Hamilton Police Service
HVAC	Heating, Ventilation, and Air Conditioning
HWSA	Heads of Workplace Safety Authorities
IAC	Indigenous Advisory Council
IAEA	International Atomic Energy Agency
IEC	Indigenous Education Council
IPPAS	International Physical Protection Advisory Services
IT	Information Technology
ITIL	Information Technology Information Library
JHSC	Joint Health and Safety Committee
KPI	Key Performance Indicator
LCH	Licence Condition Handbook
LEU	Low Enriched Uranium
LOCA	Loss Of Coolant Accidents

MCFN	Mississauga of the Credit First Nation
McIARS	McMaster Institute of Applied Radiation Sciences
MHRA	Multiple High Radiation Alarm
MIRI	McMaster Indigenous Research Institute
MNR	McMaster Nuclear Reactor
MRO	Manager of Reactor Operations
MTR	Materials Test Reactor
MUCF	McMaster University Cyclotron Facility
MW	megawatt
NBCC	National Building Code of Canada
NC	Non-Conformance
NEW	Nuclear Energy Worker
NFCC	Nuclear Facilities Control Committee
NPROL	Non-Power Reactor Operating Licence
NRB	Nuclear Research Building
NSCA	Nuclear Safety and Control Act
NSS	Nuclear Security Series
OHSA	Occupational Health & Safety Act
OJT	On-the-job Training
OLC	Operating Limits and Conditions
OPEX	Operating Experience
OQMT	Operations Quality Management and Training
PDP	Preliminary Decommissioning Plan
PDP	Preliminary Decommissioning Plan
PIP&DP	Public Information Program and Disclosure Policy
PIT	Physical Inventory Taking
PMD	Programmable Message Display
PPE	Personal Protective Equipment
PTNSR	Packaging and transport of Nuclear Substances Regulations
QMS	Quality Management System
RB	Reactor Building
RIFLS	Reactor Irradiation Facilities for Large Samples
RO	Reactor Operator
SAR	Safety Analysis Report
SAT	Systematic Approach to Training
SCA's	Safety Control Areas
SCBA	Self-Contained Breathing Apparatus
SCCM/In Tune	System Center Configuration Manager/In Tune
SHP	Senior Health Physicist
SIEM	Security Information and Event Management
SMR	Small Modular Reactor
SMT	Senior Management Team
SSC	Structures, Systems and Components?
TDG	Transportation of Dangerous Goods
UHS	University Health and Safety
UTS	University's Technology Services

VP	Vice President
WHMIS	Workplace Hazardous Materials Information System
WSIA	Workplace Safety and Insurance Act
XDR	Extended Detection and Response

APPENDIX A: CLAUSES IN THE NSCA AND THE REGULATIONS MADE UNDER THE NSCA, MAPPED TO THE RELEVANT SECTIONS OF MNR's OPERATION LICENCE APPLICATION

Legislation	Clause(s)	Section(s) in this document
NSCA	24(4)	Every SCA (sections 2.1 through 2.14) 3.0 Other regulatory areas
	26(a), (e)	Every SCA (sections 2.1 through 2.14) 3.0 Other regulatory areas
General Nuclear Safety and Control Regulations (GNSCR)	3(1)(a)	1.1.2 Applicant name and business address
	3(1)(b)	1.2 Facility and activities to be licensed
	3(1)(c)	1.1.1 Current licence 2.4 Safety analysis 2.9 Environmental protection 2.11 Waste management
	3(1)(d)	1.2 Facility and activities to be licensed 2.4 Safety analysis 2.5 Physical design 2.12 Security
	3(1)(e)	2.7 Radiation protection 2.9 Environmental protection 2.11 Waste management 2.12 Security 2.14 Packaging and transport
	3(1)(f)	2.7 Radiation protection
	3(1)(g)	2.5 Physical design 2.12 Security 2.13 Safeguards and non-proliferation
	3(1)(h)	2.5 Physical design 2.12 Security 2.13 Safeguards and non-proliferation

Legislation	Clause(s)	Section(s) in this document
	3(1)(i)	2.4 Safety analysis 2.5 Physical design 2.6 Fitness for service 2.7 Radiation protection 2.9 Environmental protection 2.10 Emergency management and fire protection 2.12 Security
	3(1)(j)	2.11 Waste management
	3(1)(k)	1.1.2 Applicant name and business address 1.1.4 Persons with authority to interact with the CNSC on the application 1.1.7 Identification of persons responsible for the management and control of the licensed activity 2.1 Management system
	3(1)(l)	2.11.5 Decommissioning plans 3.4 Financial guarantee
	3(1)(m)	3.0 Other regulatory areas
	3(2)	2.13 Safeguards and non-proliferation 2.14 Packaging and transport
	10(b)	2.13 Safeguards and non-proliferation 2.14 Packaging and transport
	12(1)(a)	2.1, Management system 2.2 Human performance management 2.7 Radiation protection 2.10 Emergency management and fire protection
	12(1)(b)	2.1, Management system 2.2 Human performance management 2.7 Radiation protection 2.10 Emergency management and fire protection
	12(1)(c)	2.3 Operating performance 2.4 Safety analysis 2.5 Physical design 2.6 Fitness for service 2.7 Radiation protection 2.8 Conventional health and safety 2.9 Environmental protection 2.10 Emergency management and fire protection 2.11 Waste management 2.12 Security

Legislation	Clause(s)	Section(s) in this document
	12(1)(d)	2.7 Radiation protection 2.10 Emergency management and fire protection
	12(1)(e)	2.1, Management system 2.2 Human performance management 2.3 Operating performance 2.5 Fitness for Service 2.7 Radiation protection 2.10 Emergency management and fire protection
	12(1)(f)	2.1, Management system 2.2 Human performance management 2.3 Operating performance 2.4 Safety analysis 2.5 Physical design 2.6 Fitness for service 2.7 Radiation protection 2.9 Environmental protection 2.10 Emergency management and fire protection 2.11 Waste management 2.12 Security
	12(1)(g)	2.3 Operating performance 2.10 Emergency management and fire protection 2.12 Security
	12(1)(h)	2.3 Operating performance 2.10 Emergency management and fire protection 2.12 Security
	12(1)(i)	2.13 Safeguards and non-proliferation
	12(1)(j)	2.2 Human performance management 2.12 Security
	15	1.1.4 Persons with Authority to Interact with the CNSC on the Application 1.1.7 Identification of persons responsible for the management and control of the licensed activity 2.1 Management system
	15(a)	1.1.4 Persons with Authority to Interact with the CNSC on the Application 1.1.7 Identification of persons responsible for the management and control of the licensed activity 2.1 Management system
	15(b)	2.1 Management system 2.2 Human performance management
	17(a)	2.2 Human performance management 2.3 Operating performance 2.7 Radiation protection
	17(b)	2.2 Human performance management 2.3 Operating performance 2.7 Radiation protection 2.8 Conventional health and safety 2.9 Environmental protection 2.10 Waste Management

	17(c)	2.1 Management system 2.2 Human performance management 2.3 Operating performance 2.7 Radiation protection 2.8 Conventional health and safety 2.9 Environmental protection 2.12 Security
	17(d)	2.2 Human performance management 2.3 Operating performance 2.7 Radiation protection 2.10 Waste Management
	17(e)	2.1 Management system 2.2 Human performance management 2.3 Operating performance 2.7 Radiation protection 2.8 Conventional health and safety 2.9 Environmental protection 2.10 Waste Management 2.12 Security 2.14 Packaging and transport
	20(a)	2.14 Packaging and transport
	20(d)	2.13 Safeguards and non-proliferation
	21	2.12 Security
	21(1)(a)	2.13 Safeguards and non-proliferation
	21(1)(b)	2.13 Safeguards and non-proliferation
	22	2.12 Security
	23	2.12 Security
	23(2)	2.13 Safeguards and non-proliferation
	27	2.1 Management system
	28	2.1 Management system
	28(1)	2.1 Management system
	29	2.3 Operational performance 2.7 Radiation protection 2.12 Security
	30	2.3 Operating performance 2.12 Security 2.13 Safeguards and non-proliferation
	31	2.3 Operating performance 2.3.4 Reporting and Trending

Legislation	Clause(s)	Section(s) in this document
	32	2.3 Operating performance
Canadian Nuclear Safety Commission Cost Recovery Fees Regulations	all	3.3 Cost recovery 3.4 Financial guarantee
Class I Nuclear Facilities Regulations	3(a)	1.2.3 Description of Site 2.5 Physical design 2.10 Emergency management and fire protection 2.12 Security
	3(b)	2.4 Safety analysis 2.5 Physical design 2.12 Security
	3(c)	1.1.6 Evidence the Applicant is the Owner of the Site
	3(d)	2.1 Management system 2.4 Safety analysis 2.5 Physical design
	3(e)	1.2.5 Nuclear and hazardous material 2.4 Safety Analysis 2.8 Conventional health and safety 2.9 Environmental protection 2.11 Waste management
	3(f)	2.1 Management system 2.2 Human performance management 2.6 Fitness for service 2.8 Conventional health and safety 2.10 Emergency management and fire protection 2.11 Waste management
	3(g)	2.9 Environmental protection
	3(h)	2.8 Conventional health and safety 2.9 Environmental protection
	3(i)	2.5 Physical design 2.12 Security
	3(j)	3.1 Public Information and Disclosure Program
	3(k)	2.11 Waste management

Legislation	Clause(s)	Section(s) in this document
	6(a)	2.3 Operating Performance 2.4 Safety analysis 2.5 Physical design 2.6 Fitness for service
	6(b)	2.3 Operating Performance 2.4 Safety analysis 2.5 Physical design 2.6 Fitness for service
	6(c)	2.4 Safety analysis
	6(d)	2.1 Management system 2.3 Operating performance 2.6 Fitness for service
	6(e)	2.1 Management system 2.3 Operating performance 2.7 Radiation protection 2.8 Conventional health and safety 2.11 Waste management 2.14 Packaging and transport
	6(f)	2.13 Safeguards and non-proliferation
	6(g)	2.1 Management system 2.3 Operating performance 2.5 Physical design
	6(h)	2.1 Management system 2.2 Human performance 2.3 Operating performance 2.4 Safety analysis 2.5 Physical design 2.7 Radiation protection 2.8 Conventional health and safety 2.9 Environmental protection 2.10 Emergency management and fire protection 2.11 Waste management 2.12 Security 2.14 Packaging and transport
	6(i)	2.4 Safety analysis 2.5 Physical design 2.7 Radiation protection 2.9 Environmental protection 2.11 Waste management

Legislation	Clause(s)	Section(s) in this document
	6(j)	2.4 Safety analysis 2.5 Physical design 2.9 Environmental protection 2.11 Waste management
	6(k)	2.1 Management system 2.2 Human performance management 2.3 Operating performance 2.4 Safety analysis 2.5 Physical design 2.7 Radiation protection 2.9 Environmental protection 2.10 Emergency management and fire protection 2.12 Security
	6(l)	2.1 Management system 2.2 Human performance management 2.12 Security
	6(m)	2.1 Management system 2.2 Human performance management 2.6 Fitness for service 2.7 Radiation protection
	6(n)	2.1 Management system 2.2 Human performance management 2.5 Physical design 2.6 Fitness for service 2.7 Radiation protection
	14(1)	2.1 Management system 2.9 Environmental protection 2.11 Waste management
	14(2)	2.1 Management system 2.2 Human performance management 2.3 Operating performance 2.5 Physical design 2.6 Fitness for service 2.7 Radiation protection 2.9 Environmental protection 2.11 Waste management
	14(4)	2.1 Management system

Legislation	Clause(s)	Section(s) in this document
	14(5)	2.1 Management system 2.2 Human performance management
Nuclear Non-proliferation Import and Export Control Regulations	all	2.13 Safeguards and non-proliferation
Nuclear Security Regulations	all	2.5 Physical design 2.12 Security
	3(b)	1.2.3 Description of Site 2.5 Physical Design
	16	1.2.3 Description of Site 2.5 Physical Design 2.12 Security
	37(1), (2) and (3)	2.1 Management system 2.2 Human performance management
	38	2.1 Management system 2.2 Human performance management 2.12 Security
Nuclear Substances and Radiation Devices Regulations	5	2.7 Radiation protection
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	36(1)(a)	2.1 Management system 2.7 Radiation protection 2.12 Security
	36(1)(b)	2.1 Management system 2.7 Radiation protection
	36(1)(c)	2.1 Management system 2.7 Radiation protection
	36(1)(d)	2.1 Management system 2.7 Radiation protection
	36(1)(e)	2.1 Management system 2.7 Radiation protection
Packaging and Transport of Nuclear Substances Regulations, 2015	all	2.14 Packaging and transport

Legislation	Clause(s)	Section(s) in this document
Radiation Protection Regulations	1(3)	2.7 Radiation protection
	4	2.4 Safety analysis 2.6 Fitness for service 2.7 Radiation protection 2.9 Environmental protection 2.10 Emergency management and fire protection 2.11 Waste management
	5-12	2.7 Radiation protection
	13	2.3 Operating performance 2.4 Safety analysis 2.6 Fitness for service 2.7 Radiation protection 2.11 Waste management
	14	2.3 Operating performance 2.4 Safety analysis 2.6 Fitness for service 2.7 Radiation protection 2.11 Waste management
	15	2.3 Operating performance 2.4 Safety analysis 2.6 Fitness for service 2.7 Radiation protection 2.10 Emergency management and fire protection 2.11 Waste management
	16	2.3 Operating Performance 2.7 Radiation protection
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