Cameco

Technical Reports

Public Summary

Port Hope Conversion Facility

Safety Report

Cameco Corporation's (Cameco) Port Hope Conversion Facility (PHCF or site) is located in Port Hope, Ontario on the northern shore of Lake Ontario. The PHCF is comprised of the following properties: the area of the plant operations (Main Site); storage facilities on the Centre Pier; and storage facilities located on Dorset Street East in the Municipality of Port Hope.

The protection of the environment and health and safety of persons is a fundamental principle of the *Nuclear Safety and Control Act,* its regulations and the regulatory approval process. The PHCF operates under a fuel facility operating licence from the Canadian Nuclear Safety Commission (CNSC) to process uranium that is used in the fuel for nuclear power generating stations. A requirement of that licence is that Cameco must regularly review and update a safety analysis report, which identifies potential hazards at the operation and outlines how the facility will prevent and mitigate their potential impact on people and the environment.

The detailed descriptions of process equipment and controls and other information contained within the Safety Report for the PHCF (Safety Report) is prescribed information, controlled nuclear information pursuant to the *Nuclear Non-proliferation Import and Export Control Regulations* or information that is exempted from disclosure under the Access to Information Act, and therefore cannot be made publicly available. This summary provides an overview of the methodology and results of the PHAs described in the Safety Report, which was reviewed and accepted by CNSC Staff in 2016.

Methodology

Hazard risk assessments and safety analyses are now the cornerstone of process safety management throughout the world. The Process Hazard Assessment (PHA) method is widely adopted by industry and regulators to assess the risk and potential impact from facility operations, thereby making it a key component of the process to develop the Safety Report. A PHA:

- is a set of organized and systematic assessments of the potential hazards associated with an industrial process;
- provides information intended to assist managers and employees in making decisions for enhancing safety and reducing the consequences of unwanted or unplanned releases of hazardous chemicals; and,
- is directed toward analyzing potential causes and consequences of fires, explosions, releases of toxic or flammable chemicals and major spills of hazardous chemicals, focusing on equipment, instrumentation, utilities, human actions, and external factors that might impact the process.

PHAs are collaborative efforts between a PHA facilitator and a team selected for their knowledge of the design, operation, maintenance or regulatory requirements of the system or process being reviewed. The facilitator asks a series of questions, and the team then works collectively to identify the potential hazards associated with the system, their causes and consequences, the risk (in terms of severity of impact and frequency of the event), the controls in place, and make recommendations for improvement where a gap is identified.

In 2014 and 2015, the PHCF completed a comprehensive review of the potential incident scenarios and protective barriers (i.e. safety systems) available to prevent or mitigate an uncontrolled release from the PHCF or other undesirable result. This PHA revalidation process included:

- reviewing, and updating where required, the hazards, potential consequences and adequacy of the control measures with a cross-functional team, including operations, technical support and maintenance personnel;
- incorporating design changes made to the facility since the last update;
- incorporating information from project PHAs where appropriate;

- reviewing incidents that occurred between November 2010 and April 2015 and including the relevant information in the Safety Report and/or Environmental Aspects Registry; and,
- conducting systematic air modelling assessment for potential airborne releases from PHCF operations to support emergency response planning and prioritizing efforts to further reduce the impact of a potential release

Following the revalidation of the PHAs, the Safety Report was updated. The Safety Report summarizes the detailed analyses found in the PHAs and documents the hazards, potential accident scenarios and controls in place to prevent and/or mitigate the consequences of these scenarios.

Defence-in-Depth

Cameco's safety systems are built on the defence-in-depth concept. Defence-in-depth is a multiple barrier approach, which was applied throughout the design and construction of production buildings and continues to be applied during the operation of the PHCF. It is intended to eliminate or minimize the potential of radiological, chemical or other physical hazard to facility personnel, the environment and the general public. This is accomplished through implementation of safety features and systems which can prevent hazards and/or ensure appropriate protection in the event that the prevention measure fails. The systems also allow the failure to be detected and compensated for or corrected, and consider organizational and human performance. Many of these features and systems are independent and redundant.

The defence-in-depth model depicts how the emergency planning process begins long before activation of the site and community emergency plans. Safety systems comprise many barriers from design through to containment systems that are implemented before emergency response as illustrated in Figure 1.

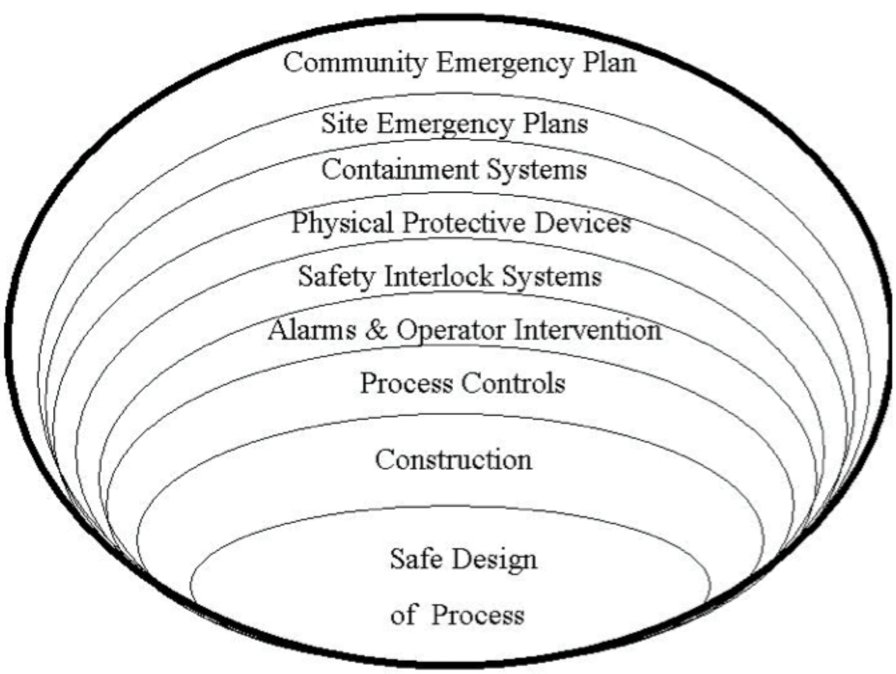

Figure 1 Defence-In-Depth Approach to Safe Operation of a Facility

Overview of the Safety Analysis for Cameco's PHCF Operations

Safety Analysis – Operations

Uranium Hexafluoride (UF_6) Production

In the UF_6 process, UO_3 is pulverized and fed into a fluid bed reactor. Hydrogen gas enters the fluid bed reactors, reducing the uranium trioxide (UO_3) feed powder to uranium dioxide (UO_2). The UO_2 powder is then fed into the hydrofluorination reactors where water, hydrogen fluoride (HF) and dilute aqueous hydrofluoric acid convert the UO_2 to uranium tetrafluoride (UF_4). The UF_4 slurry is then dried and calcined, which heats the UF_4 thereby removing the final traces of water.

The calcined UF_4 is then reacted in a flame reactor with fluorine gas to produce UF_6. Cameco produces fluorine by using electrolytic cells, which contain molten potassium bifluoride and HF. Electric current passes through the cell and dissociates the HF into hydrogen and fluorine. These gases are diverted to separate draw off points in the system and fluorine is used to convert UF_4 to UF_6.

The UF_6 gas produced in the reactors is passed through filters to remove any solid particles before entering the cold traps. The cold traps cool and sublimate the gaseous UF_6 into a white crystalline solid.

When the cold traps are full, they are heated to liquefy the crystallized UF_6. The liquid UF_6 is drained into approved specially designed, heavy walled steel shipping cylinders. The cylinders are allowed to cool to ambient room temperature causing the UF_6 liquid to freeze to a solid. Cylinders containing solid UF_6 are then transported to enrichment plants in other countries.

Within the UF_6 plant effluent treatment circuit, spent potassium hydroxide (KOH) is dried to produce a crystalline flake. The dried flake is known as fluoride product, which is shipped to a licensed facility for uranium recovery.

UF_6 Plant Safety Systems

The following safety systems are used in the design and operation of the UF_6 plant to ensure that workers, the public and the environment are protected.

Engineered Barriers:

- Back up (spare) equipment
- Emergency shutdown systems
- CO_2 injection system in UF_6 cylinder filling stations
- Leak detection systems
    - HF detectors
    - Fluoride analyzers
    - Hydrogen detectors and interlocks
    - Nitrogen purging
    - Smoke detectors
    - Freon detection
    - Uranium in air monitors
    - CCTV cameras in select areas
- Instrumentation systems
    - Level, pressure, temperature, flow and other indicators and alarms throughout the process – significant parameters are also appropriately interlocked to maintain a safe state
    - Redundant instrumentation
    - Fail safe valves
- Emissions control
    - Dust and fume collection lines
    - Bag houses
    - Fume scrubbers and demisters
    - HVAC systems in place with HEPA filtering system
    - Emergency ventilation (interlock and/or manual activation)
- Design controls
    - Liquid containment and management
    - HF-resistant materials
    - Pipe specifications
    - Overpressure prevention/safety relief devices

    - Explosion-proof wiring
    - Conveyors under vacuum
    - Pressure boundary program for vessels and piping
- Emergency power for safety significant equipment and systems
- Fire protection systems

Administrative Barriers:

- Quality Assurance program
    - Change management
    - Interlock management
- Operator training and qualification
- Operating procedures
    - Defined operating parameters
- Process monitoring
    - Operator care rounds
    - Facility fire inspections
- Additional operating controls
    - Purging procedures
    - Passivation procedures
    - Housekeeping procedures
    - Dust and fume collection line cleaning procedures
    - Product approval process
    - Materials used in UF_6 plant are HF/UF_6 compatible
    - Adequate potassium hydroxide onsite to neutralize HF
    - Cylinders have solidified prior to movement outside of the plant
    - No lift zones over HF storage
- Preventative maintenance program for safety significant systems
- Non-Destructive Examination (NDE) program
- Monitoring programs
    - Cooling water discharge is monitored continuously
    - Environmental monitoring program
    - Radiation protection program
- Onsite emergency response capability 24/7
    - Testing and drills
- Coordination with Community Emergency Plans

UO_2 Production

In the UO_2 process, UO_3 powder is dissolved in nitric acid to produce uranyl nitrate. The uranyl nitrate solution is diluted with water and then reacted with aqueous ammonia to precipitate ammonium diurante (ADU).

The ADU slurry undergoes solid liquid separation in centrifuges. The liquid phase is recovered and sent to the ammonium nitrate circuit for treatment prior to sale as a by-product. The wet ADU solids form a cake in the centrifuge, which is dried continuously by direct contact with hot air in a dryer.

The dried ADU solids are reduced with hydrogen to form UO_2 in the heated rotary kilns. The final product of the process is a ceramic grade UO_2 powder. The powder is blended and shipped to domestic and international fuel manufacturers.

The UO_2 process generates an ammonium nitrate (NH_4NO_3) solution as a by-product, which is released to an agricultural supply company for use in production of an agricultural fertilizer. The ammonium nitrate by-product is analyzed to ensure that the uranium and radium contents are less than the exemption quantities specified in the Nuclear Substance and Radiation Devices Regulations, 2015 (NSRDR).

The depleted UO_2 is also produced in the UO_2 plant. The production of depleted uranyl nitrate occurs in a system designed to control the nitrogen oxide (NOx) that is generated during this step. Uranyl nitrate solution is pumped directly to the existing uranyl nitrate storage tank located within the UO_2 processing circuit where it is further processed to ceramic grade depleted UO_2.

UO_2 Plant Safety Systems

The following safety systems are used in the design and operation of the UO_2 plant to ensure that workers, the public and the environment are protected.

Engineering Barriers:

- Back up equipment
- Emergency shutdown system
- Leak detection systems
    - Ammonia analyzers
    - Hydrogen detectors and interlocks
    - Natural gas detectors
    - Uranium in air monitors
    - Nitrogen purging
- Instrumentation systems
    - Level, pressure, temperature, flow and other indicators and alarms throughout the process – significant parameters are also appropriately interlocked to maintain a safe state
    - Redundant instrumentation
    - Fail safe valves
- Emissions control
    - Dust and fume collection lines
    - Bag houses
    - Fume scrubbers and demisters
    - HVAC system in place with HEPA filtering system
    - Emergency ventilation (interlock and/or manual activation)
    - Selective catalytic reduction system for NOx control
- Design controls
    - Liquid containment and management
    - Pipe specifications
    - Overpressure prevention/safety relief devices
    - Explosion-proof wiring
    - Conveyors under vacuum
    - Pressure boundary program for vessels and piping
- Emergency power for safety significant equipment and systems
- Fire protection systems

Administrative Barriers:

- Quality assurance program
    - Change management
    - Interlock management
- Operator training and qualification
- Operating procedures
    - Defined operating parameters
- Process monitoring
    - Operator care rounds
    - Facility fire inspections
- Additional operating controls
    - Purging procedures
    - Housekeeping procedures
    - Dust and fume collection lines cleaning procedures
    - Product approval process
    - Pressure tests on cooling water heat exchanger
- Preventative maintenance program for safety significant systems
- NDE program
- Monitoring programs
    - Cooling water discharge is monitored continuously
    - Environmental monitoring program
    - Radiation protection program
- Onsite emergency response capability 24/7
    - Testing and drills
- Coordination with community emergency plans

Safety Analysis – Support Services

Materials Handling

Materials handling operations deal with the loading, unloading, transportation, and/or storage of various substances used by or produced at the PHCF. Many of the potential hazards associated with materials handling operations involve leaks, spills or releases of materials that could occur in outside areas, with most scenarios expected to occur on Cameco property.

The main operations of the materials handling group are housed in the materials handling warehouses. Additional warehousing facilities for uranium products and wastes and some other raw materials are located on Dorset Street and on the Centre Pier.

Materials Handling – Safety Systems

The following safety systems are used for materials handling activities to ensure that workers, the public and the environment are protected.

Engineering Barriers:

- Fire protection program
- Tote bins are sealed by a closed valve with locking pin and a separate seal cover to prevent UO_3 loss
- Valves on UF_6 cylinders have covers
- UO_2 drums stored indoors
- Pressure boundary program for vessels and piping

Administrative Barriers:

- Quality assurance program
  - Change management
- Operator training and qualification
- Material handling procedures
- Additional administrative controls
  - Chemical unloading is an attended operation
  - Designated truck routes
  - Tankers are escorted on site
  - Area catch basins are covered with spill protection mats to prevent flow of materials directly to the storm sewer system during outdoor unloading
- Preventative maintenance
- NDE program
- Onsite emergency response capability 24/7
  - Spill kits available near onsite storm drains and installed on large equipment
  - Testing and drills
  - Canadian Transport Emergency Centre (CANUTEC)
- Coordination with community emergency plans

Clean-Up Program (CUP)

CUP was established to remove obsolete buildings, equipment and materials for the purpose of reducing environmental obligations, addressing health and safety hazards in underutilized buildings, creating useable space and improving the appearance of the PHCF.

CUP activities can be generally broken down into routine and non-routine operations. Routine operations consist of such activities as collection of currently-produced scrap metal, size reduction of scrap metal, decontamination of scrap metal and monitoring of scrap metal so it can be released from the site. Non-routine activities include removal of out of service equipment, dismantling of processes, removal of structures, decontamination of items for operating plants and supply of manpower to other groups when requested.

The CUP crew is responsible for decontaminating scrap so it can be released from the facility. Fixed objects such as floor and walls will also be cleaned to as low as reasonably achievable (ALARA), social and economic factors taken into account levels.

Clean-Up Program – Safety Systems

The following safety systems are used for CUP activities to ensure that workers, the public and the environment are protected.

Engineering Barriers:

- Fire protection systems
- Emissions control
    - Dust collection systems with filtration and pressure monitoring indication
    - Monitoring for uranium in air

Administrative Barriers:

- Quality assurance program
    - Change management
- Operator training and qualification
- CUP procedures
- Preventative maintenance
- Onsite emergency response capability 24/7
    - Testing and drills
- Coordination with community emergency plans

Power Plant

The power plant produces steam and compressed air for various uses throughout the PHCF. Power plant shift engineers also operate the cooling water intake system and the two refrigeration systems in the UF_6 plant used to chill the UF_6 cold traps.

Natural gas is used as the primary fuel for the steam boilers. No. 2 fuel oil is used as a backup fuel for the boilers and for the power plant's emergency electrical power generator.

Power Plant – Safety Systems

The following safety systems are used for the power plant to ensure that workers, the public and the environment are protected.

Engineering Barriers:

- Fire protection systems
- Design controls
    - Extensive safety relief valve protection in place
    - Overpressure prevention devices
    - Pipe specifications
    - Pressure boundary program for vessels and piping
    - Instrumentation systems
    - Interlocks are in place to minimize potential for error
    - Strainer filter room has level probes in the sump that will generate an alarm in the UO_2 plant and in the guardhouse
- Leak detection systems
    - pH monitors at the effluent tank and weir overflow
    - Freon detectors in the area
    - Conductivity alarm on discharge from heat exchanger
    - Area specific
    - Chemical pumps are enclosed
    - Sulphuric acid is stored in a sealed storage area
    - Fuel oil is stored in a dyked enclosure
    - Effluent tank overflows to the lime bed which provides some neutralization of acidic water

Administrative Barriers:

- Quality assurance program
    - Change management
    - TSSA registered steam and compressed air systems
- Operator training and qualification
- Powerhouse operating procedures
    - Defined operating parameters
- Preventative maintenance for safety significant systems
- NDE program
- Monitoring programs
    - Freon inventory monitored by power plant personnel
- Routine sampling to inspect for Freon leak to water
- Condensate quality monitoring

- Onsite emergency response capability 24/7
  - Testing and drills
  - Spill kits available throughout the area
- Coordination with community emergency plans

Waste Recovery

Waste recovery operations take place in the waste recovery building located at the north end of the facility. Operations consist of the following activities:

- Waste water (laundry water, groundwater, laboratory waste water, truck wash waste water, plant waste water) treatment and evaporation
- Material decontamination and equipment washing

Waste Recovery – Safety Systems

The following safety systems are used for the waste recovery operations to ensure that workers, the public and the environment are protected.

Engineering Barriers:

- Fire protection systems
- Design controls
  - Liquid containment & management
  - Pipe specifications
  - Overpressure prevention/safety relief devices
  - Pressure boundary program for vessels and piping
- Instrumentation systems
  - Level, conductivity and/or other indicators and alarms throughout the process
  - Interlocks are in place to minimize potential for error
  - Uranium in air monitoring

Administrative Barriers:

- Quality assurance program
  - Change management
- Operator training and qualification
- Operating procedures
  - Defined operating parameters
- Process monitoring
  - Operator care rounds
  - Facility fire inspections
- Preventative maintenance program for safety significant systems
- NDE program
- Onsite emergency response capability 24/7
  - Testing and drills
- Coordination with community emergency plans

Liquid Hydrogen Supply Facility

The liquid hydrogen supply and storage facility provides gaseous hydrogen to the UF_6 and UO_2 plants. The liquid hydrogen station is located near the northeast corner of the original UF_6 building. The system is owned by a vendor.

The vendor is responsible for the operation and maintenance of all equipment containing or using liquid hydrogen. Cameco is responsible for the gaseous hydrogen distribution system.

Liquid Hydrogen – Safety Systems

The following safety systems are used for the liquid hydrogen facility to ensure that workers, the public and the environment are protected.

Engineering Barriers:

- Design controls
  - Overpressure prevention devices
  - Pressure boundary program for vessels and piping
- Instrumentation systems
  - Level, pressure, temperature, flow and other indicators and alarms to production operating system
  - Flame detectors
  - Interlocks are in place to minimize potential for error
  - Interlocks are in place to maintain a safe state

- Leak detection systems
  - Hydrogen detection
  - Pressure and flow used to detect leak and/or leak-by

Administrative Barriers:

- Only qualified employees of the vendor fill and service this equipment.
- Filling is only done during daylight hours
- Enclosure designed to meet NFPA50B
- Change management
- Onsite emergency response capability 24/7
  - Testing and drills
- Coordination with community emergency plans

Other Support Services

To provide a complete overview of activities on site, the Safety Reports includes the following miscellaneous utilities and active buildings:

- The pipe rack carrying process chemicals, gases and utilities
- Analytical and Science & Technology laboratories
- North and south electrical substations
- Truck wash station
- Maintenance oil stores
- Oil storage building
- Groundwater pumping system
- Non-destructive examination (NDE) program

These activities are carried out safely under the same engineered and/or administrative barriers described above.

Safety Analysis and Planning for Emergencies

Assessment of Potential Releases for Emergency Planning

The Safety Report evaluated all of the major processes at the PHCF to identify potential process upsets and credible accident scenarios that could result in releases to the environment. Both liquid and air release scenarios were evaluated and assessed.

Air releases are more likely to have an impact on the community. Therefore, to better understand the potential extent of public exposures associated with the identified release scenarios, an air dispersion modelling assessment was undertaken to support Cameco's emergency planning.

Air Modelling for Emergency Planning

More than 20 worst-case scenarios for process upsets and credible accidents associated with the UO_2 and UF_6 plants that were identified in the safety report were assessed in the subsequent modelling exercise and compared against the Emergency Response Planning Guidelines (ERPG) for air concentration by the American Industrial Hygiene Association.

EPRGs are for single exposures to agents and are intended for use as tools to assess the adequacy of accident prevention and emergency response plans, including transportation emergency planning, community emergency response plans and incident prevention and mitigation. ERPGs are only available for one hour exposure duration, and are not designed for hypersensitive individuals.

The scenarios consisted of an in-plant release that disperses within the room and exits via plant ventilation either directly through an exhaust fan and/or through an emissions control system. Operator or automated response systems were assumed to be operational to isolate the release source and then minimize the discharge to the environment by redirecting the release through emissions control systems where applicable. Air dispersion modelling was undertaken assuming these releases would occur during the worst case weather conditions (i.e. this assumes the release would occur during the worst single hour from a five-year meteorological data set). This is a highly conservative approach, as the likelihood of an unplanned release occurring during the worst-case meteorological condition is very small (i.e.; 1 hour in 44,000 hours, or <0.01%). It was further assumed that each release would occur for a full hour, though most of the releases would likely occur for less than 15 minutes. The results of the modelling exercise are summarized below:

UF_6 Plant

Scenarios evaluated resulted in maximum predicted off-site air concentrations that were very close to Cameco's northern fenceline. Potential exposure of people at these levels should not result in serious health effects that would inhibit their ability to move to a safe location. Based on predicted elevated offsite concentrations, the worst case was further evaluated using more detailed air dispersion modelling and considering 10 minute average meteorology. For this scenario, the maximum air concentrations are predicted to be within the PHCF fenceline. Cameco provides extensive training and drills to site personnel so that they are familiar with the shelter-in-place response to chemical releases within the fenceline.

UO_2 Plant

Scenarios evaluated resulted in maximum predicted off-site air concentrations that were very close to Cameco's south-west fenceline, with the maximum predicted air concentrations predicted to occur within the Cameco fenceline. All but one model scenario had maximum predicted air concentrations, beyond the fenceline, that were below the level where the potential exposure should not result in serious health effects that would inhibit their ability to move to a safe location. For all scenarios, potential effects were limited to the southern portion of the PHCF and would not extend north of the PHCF.

This information will be used to assist Cameco in prioritizing its efforts to further reduce the potential for and potential impact of a release. Emergency response planning and continual improvement projects may include the improved detection of and/or response time to a release or engineered controls to prevent or mitigate a release.

Emergency Planning

Emergency planning is required for responding to hazards, actual or potential, that are identified in the safety report. Depending on type and magnitude of an incident, the site may activate any or all of the following response organizations for the protection of human health, the environment and property:

- Emergency Response Team;
- Emergency Medical Team;
- Emergency Response Organization;
- Local Crisis Management Team;
- Corporate Crisis Management Team; and,
- Crisis Assistance Team (Transportation events).

These organizations include personnel from all levels of the operations and support departments. In the event of an emergency, personnel will leave their normal assigned duties and assume their role in the appropriate response organization.

Emergency preparedness and response is broken down into two components: a planning function and a response function. Planning is responsible for the development and maintenance of the emergency planning and control program. This includes the preparation and periodic review of documentation, ensuring that the program meets regulatory and internal Cameco requirements, periodic testing of the procedures, personnel and equipment to ensure that the facility is in a state of readiness. The response function is initiated only in the event of an actual or potential emergency.

One aspect of emergency planning is a component that ensures that members of the public are kept informed of developments in the event of an emergency at the PHCF with the potential for off-site impacts. The designated public information officer is responsible for liaising with the media and providing necessary information to the public to ensure that the impact of the emergency on the public is minimized.

In the event that urgent information needs to be communicated to the public, Cameco will request that the Municipality of Port Hope activate the Rapid Notify system, which automatically delivers a pre-recorded message to residents in the municipality. At the same time, the local radio stations will be notified and asked to provide the same information to its listeners.

Conclusion

Based on this report, Cameco believes that the risk to the public and the environment arising from the unplanned release of hazardous materials stored, processed and transported to and from PHCF has been mitigated. The current safety systems, procedural controls and abatement equipment in place mitigates risk effectively.

Cameco is committed to ongoing improvement to minimize the risk to the public and the environment in keeping with the as low as reasonably achievable or ALARA practices.