McArthur River Operation

Environmental Risk Assessment

2020

Cameco Corporation (Cameco) operates the McArthur River Operation (the Operation), the world's largest high-grade uranium mine. It is located in northern Saskatchewan, in the Athabasca Plain Ecoregion of the Boreal Shield Ecozone, approximately 300 km north of La Ronge and 80 km north of the Key Lake Operation. Exploration of the McArthur River deposit began in 1980, and mining was initiated in 1999. Milling of the McArthur River ore is being conducted at the Key Lake Operation.

In 2020, Cameco completed a detailed quantitative environmental risk assessment (ERA) to align with the standardized requirements found in CSA N288.6-12 *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills* (CSA 2012).

Overall, the results of the 2020 ERA are consistent with previously approved ERAs and demonstrate that the environment and human health in the vicinity of the Operation remain protected. Further, the ERA and routine monitoring results continue to demonstrate that the site remains within the objective of the licensing basis and previous Environmental Assessment predictions.

BACKGROUND INFORMATION

An ERA is a systematic process used to identify and assess the potential risk posed by releases from the Operation to people and the environment. There are two parts to an ERA – 1) an assessment of the exposure and potential risk to people who use the area through a human health risk assessment (HHRA) and 2) an assessment of living things in the environment (such as plants, insects, and animals) through an ecological risk assessment (EcoRA). The McArthur River ERA was completed to address the following question: *Is there potential for significant environmental (i.e., human and/or ecological) effects from current releases associated with the Operation?*

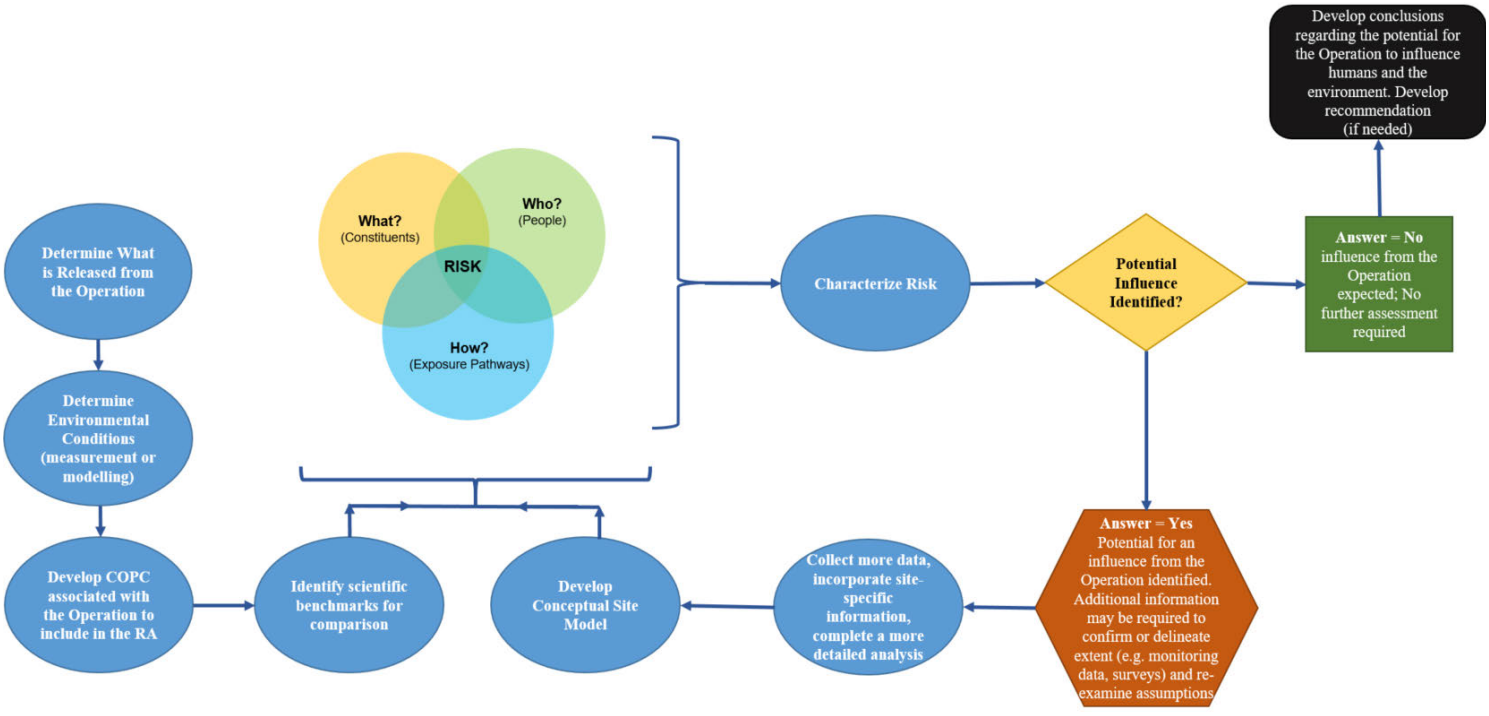
Additionally, the conclusions of the current assessment were compared to those provided in the 2015 ERA.

ERAs follow guidance provided by CSA and various agencies, such as Health Canada (HC), Environment and Climate Change Canada (ECCC), Canadian Council of Ministers of the Environment (CCME) and the Canadian Nuclear Safety Commission (CNSC)

One of the first steps in conducting an ERA is to detail the releases from the Operation and to understand how these move in the natural environment. Data collected through routine monitoring at the Operation helps to inform this step.

Once the releases are understood, the Constituents of Potential Concern (COPCs) need to be identified. This is a list of the key radiological and non-radiological constituents released to air and water from site operations. It is developed from knowledge of the facility, environmental monitoring data, and feedback from regulators, community members and other stakeholders. In developing the list of COPCs, some constituents are removed from further consideration (if they are released in very small quantities, if they are present at or below natural background levels, or if they are determined not to be a concern from a human or ecological health perspective).

The concentrations of COPCs in the environment (e.g., soil, surface water, air) are determined in the natural areas near the Operation using monitoring data, modelling, or a combination of both.

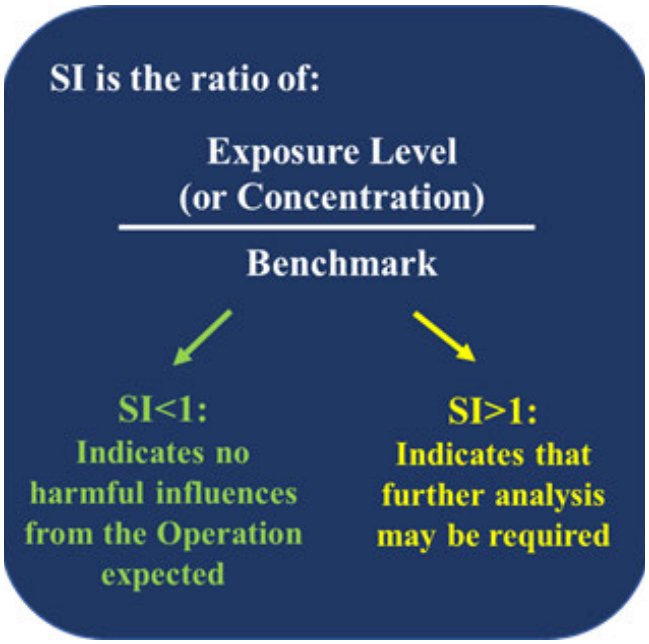


Environmental Risk Assessment Process Overview

The foundation of the risk assessment is the Conceptual Site Model (CSM). The CSM summarizes how the COPCs are released and are expected to move in the environment, as well as identifies who uses the land, including both people and biota (wildlife, plants). This information, together with information on the potential influence of COPCs, are used in the risk assessment. The pathways assessment (also called risk characterization or risk assessment) uses information on What (selected COPCs), Who (identified receptors) and How (exposure pathways) to assess the risk.

The CSA standard N288.6-12 provides a systematic approach and calculations that are used to estimate the exposure of the human or ecological receptor to each of the COPCs. The calculations estimate the uptake of COPCs from the different environmental media and indicate how the COPCs are passed up the food chain. A cautious approach is taken in the assessment using conservative assumptions that are likely to overestimate the exposure. An example of a conservative assumption can be seen regarding the home ranges of the evaluated species. Those species with larger home ranges, such as wolf, moose and woodland caribou, are conservatively assumed to spend a significant amount of time in the exposure area; however, it is expected that they would range over a larger area.

Potential risks to identified human and wildlife receptors are determined using a weight-of-evidence approach. One part of this is to calculate a screening index (SI). In simple terms, an SI is the concentration or exposure level divided by published scientific benchmarks, which are levels that have been deemed unlikely to adversely affect the receptor. These benchmarks can come from research or field studies, regulatory standards and objectives, scientific literature, or other credible sources. If no potential influences are identified (i.e., if SI is less than 1), then changes on the environment are not expected. Due to the cautious nature of the calculations, an SI greater than 1 indicates that further assessment may be required to determine whether there is an influence. This can include more detailed analysis or collecting additional field data and site-specific information.

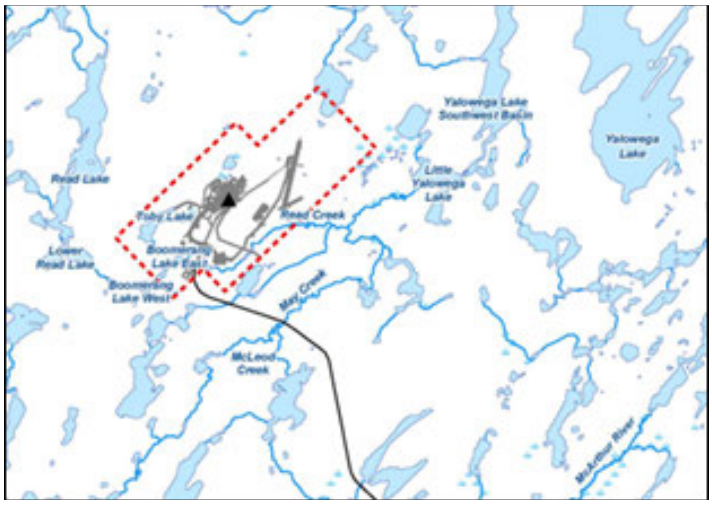


In a weight-of-evidence approach, all information is considered to reach an overall conclusion on the potential for a response. For example, for the assessment of aquatic insects that are in sediment, the calculated SI will be considered along with information collected on the type of insects and how many are present. Once the assessment is complete, a conclusion regarding the potential harm to people or the environment is developed.

The following sections provide more information specifically about the McArthur River Operation, the releases into the environment from the Operation, selection of COPCs and receptors, pathway characterization, and results and conclusions of the ERA. The input from the local communities is also highlighted. For example, ecological receptors were selected based on surveys completed in the Operation area, as well as other considerations, including local resource user interviews and input from local communities.

SITE DESCRIPTION

The McArthur River Operation is situated within the Read Creek watershed of the Waterfound River drainage area, which is a tributary of the Fond-du-Lac River. The Fond-du-Lac River discharges into Slave Lake River via Lake Athabasca and ultimately into the Beaufort Sea. Read Creek passes through Boomerang Lake, flowing eastward into May Creek. May Creek flows east into Little Yalowega Lake which then joins Yalowega Lake. The aquatic environment study area includes Read Creek, Little Yalowega Lake, Yalowega Lake, and downstream Pawliuk Lake. The terrestrial environment study area includes a 100 km_2 area around the McArthur River Operation.



Releases into the Water

Water from the Operation is treated and released into Read Creek. Prior to August 2014, treated mine water was discharged to the muskeg upstream of Boomerang Lake East. Since that time, a conveyance channel was constructed and is used to release the treated mine water directly to Read Creek. Clean groundwater that is diverted from the underground mine is released as Shaft 3 dewatering water via the same conveyance channel.

The amount and quality of water released were based on the measured data from the water treatment system at the site and on an understanding of the expected changes. Two scenarios were considered for the treated water (also called effluent) release: an Expected Loading scenario, which represents the current best estimate of future flows and concentrations; and a more conservative Upper-bound Loading scenario, which considers a potential range of operational performance. To investigate the potential influence of non-routine discharges from inflow events at the Operation, sensitivity case scenarios were run. These sensitivity cases included a non-routine discharge to each of the Expected and Upper-bound Loading scenarios.

The movement of COPCs in the environment was modelled using a computer program called ADEPT (Assessment of the Dispersion and Effects of Parameter Transport), which is a contaminant dispersion and transport model for waterbodies that includes pathways and risk assessment calculations. The model can assess a variety of COPCs and considers numerous lakes/rivers/wetlands/bays and can handle complex watershed systems. As expected, once the operation ceases and treated effluent is no longer released, the concentrations are expected to improve and return to pre-operational conditions.

Releases to the Air

Air dispersion modelling was used to evaluate the potential influences of the Operation on air quality over the life of the mine, including the historical operations, care and maintenance period, future operations, and decommissioning period. The releases from the facility include mine ventilation, waste rock storage, and road dust. The CALMET/CALPUFF modelling package was then used to predict concentrations of various COPCs. Overall, it was predicted that the Operation would have a limited influence on air quality. Within 450 m from the lease boundary, all COPCs concentrations are predicted to return to near background levels.

Selection of COPCs

The final list of COPCs selected for the assessment is provided below:

- Metals (and metalloids): arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc.
- Radionuclides: uranium-238, lead-210, polonium-210, radium-226, and thorium-230
- Total Dissolved Solids (TDS) was included as it represents inorganic salts present in solution in water including calcium, magnesium, sodium, and potassium cations and carbonate, bicarbonate, chloride, sulphate, and nitrate anions.
- Other general chemistry constituents selected for inclusion in the COPCs list are ammonia, calcium, chloride, nitrate, and sulphate.
- Additional COPCs selected for inclusion for air quality are dust (total suspended particulate, TSP, and constituents; and, particulate matter of different sizes including PM_{10}, $PM_{2.5}$), nitrogen oxides, and radon (Rn-222).

These COPCs were assessed in one or more of the following pathways in the ERA:

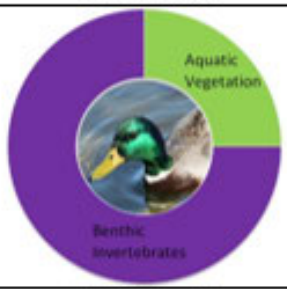
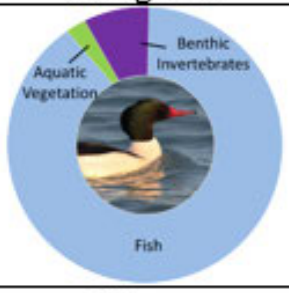
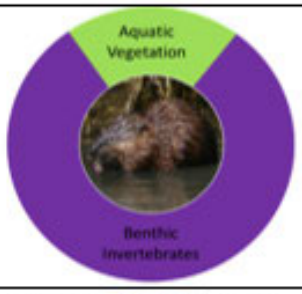
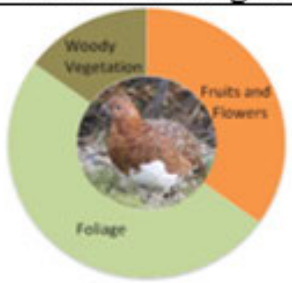
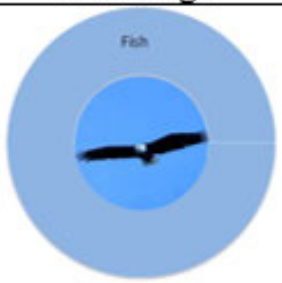
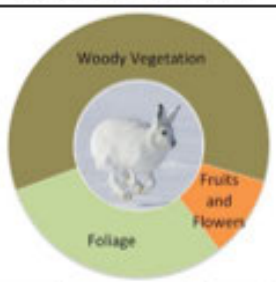
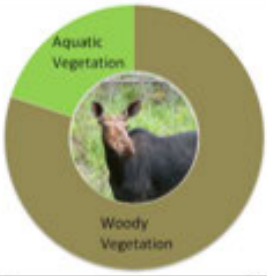
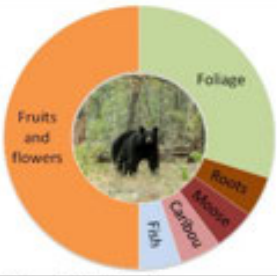
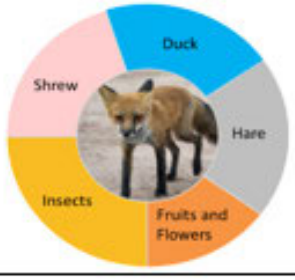
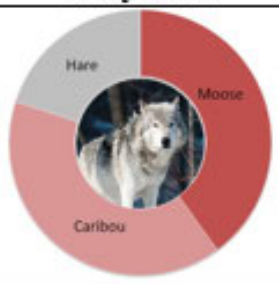
- Soil
- Air
- Surface water
- Sediment
- Human or wildlife food items (e.g., aquatic vegetation, fish)
- Gamma radiation

This assessment was undertaken within a pathways framework, which involves consideration of humans, animals, and plants that may be exposed to releases to water and air from the Operation.

Selection of Receptors

A number of ecological receptors were selected to represent the diversity in the environment around the Operation. In the water, this includes all parts of the community (insects, plants, algae, and fish). Animals that use the water (e.g., waterfowl, muskrat, beaver) are also included. On the land, plants (e.g., grass, lichen), insects and animals (e.g., hare, blackbird, fox, woodland caribou) are included. Biota is a term that is used when discussing all the living things in an area.

Ecological receptors were selected based on surveys in the Operation area, as well as other considerations including local resource user interviews and input from local communities. An overview of the characteristics of the selected mammals and birds is provided on the following page.

Waterfowl	**Mallard**	**Merganser**	**Scaup**
			
Semi-Aquatic Mammals	**Muskrat**	**Beaver**	**Mink**
			
Terrestrial Birds	**Willow Ptarmigan**	**Bald Eagle**	**Rusty Blackbird**
			
Mammals	**Masked Shrew**	**Snowshoe Hare**	**Moose**	**Black Bear**
				
	Red Fox	**Grey Wolf**	**Woodland Caribou**	
				

It is also important to determine the presence or absence of species at risk, which can influence the choice of receptor. This is completed by reviewing results of previous monitoring programs and the Species at Risk Act (SARA) Public Registry database. Woodland caribou was identified as potentially present in the general area, and is listed as threatened in Schedule 1 of SARA. From this review, the common nighthawk (threatened), olive-sided flycatcher (threatened) and rusty blackbird (special concern) were also determined to be potentially present in the Operation area. Consistent with CSA N288.6-12, the rusty blackbird was selected to represent these birds.

The human receptors were selected to capture a range of people who may live and work in the study area. The selected human receptors are consistent with those from the 2015 ERA and include an adult working at the Operation's camp (e.g., cook, security), a trapper family spending three months a year at Little Yalowega Lake, a seasonal resident family living four months a year at Yalowega Lake North, and a permanent resident family living at Little Yalowega Lake once the Operation has been decommissioned. Input from local resource user interviews was important for defining the appropriate scenarios.

For each receptor, exposure estimates are compared to various benchmarks. These benchmarks are taken from regulatory agencies, such as Saskatchewan Ministry of Environment, Health Canada or Environment and Climate Change Canada, or from scientific research that has been published.

Receptor Pathways

Consistent with N288.6-12, the receptor pathways for the ecological and human health assessments are shown in the following tables.

Ecological Exposure Pathways

Receptor Group	Exposure Pathways			
	Soil	Surface Water	Sediment	Food
Terrestrial invertebrates	✓	NR	NR	NR*
Terrestrial plants	✓	NR	NR	NR
Aquatic birds	NR	✓	✓	✓
Terrestrial birds	✓	✓	NR	✓
Semi-Aquatic mammals	NR	✓	✓	✓
Terrestrial mammals	✓	✓	NR	✓
Amphibians[a]	NR	✓	✓	NR*
Reptiles[b]	NA	NA	NA	NR*
Fish	NR	✓	✓	NR*
Aquatic plants	NR	✓	✓	NR
Aquatic invertebrates	NR	✓	✓	NR*

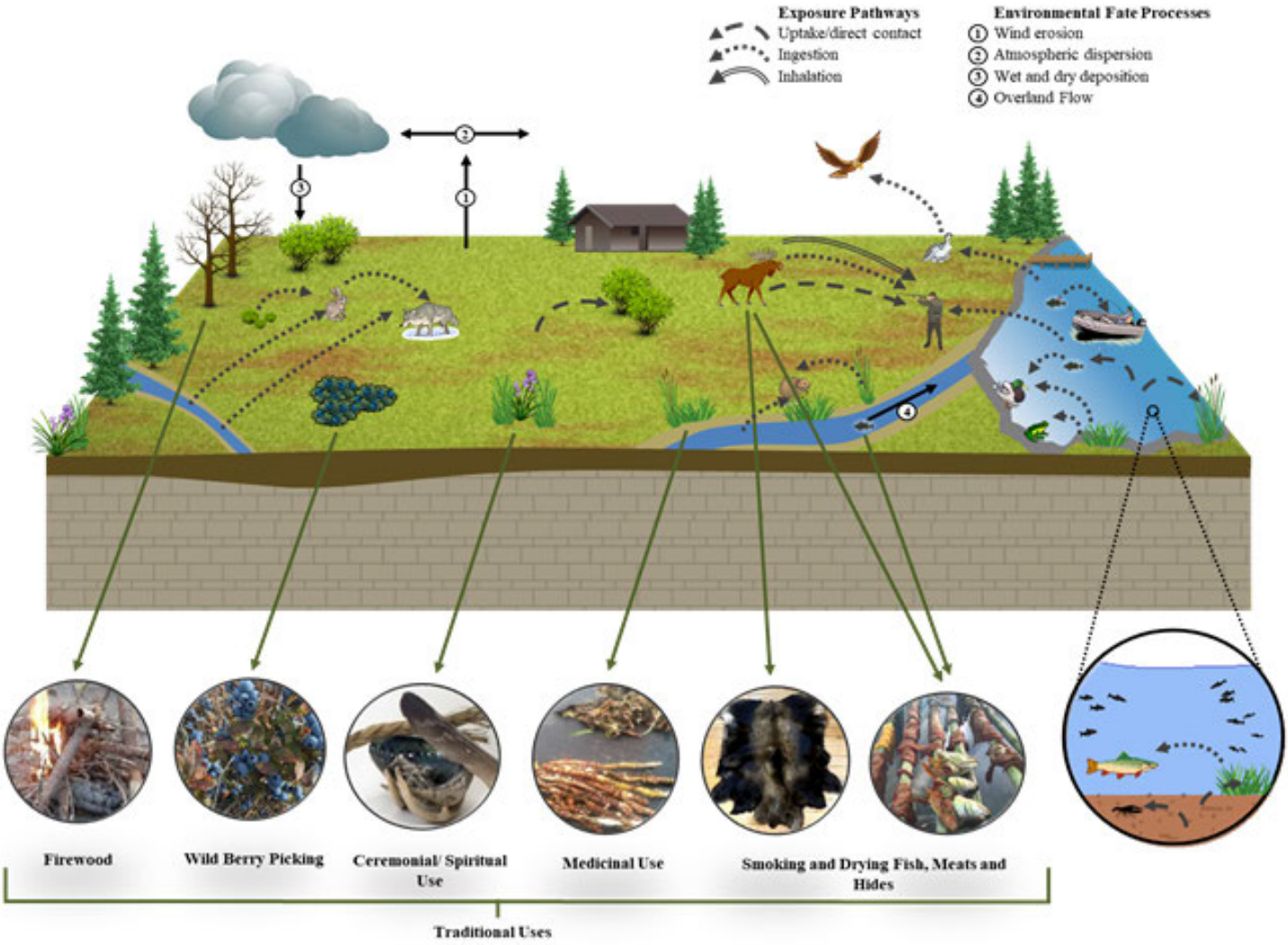
Note: NA – not assessed; NR – not relevant; ⊠ - assessed; * Evaluated by comparing water, sediment or soil concentrations to benchmarks that address all pathways, including food; a - assessed using fish as surrogate; b - no reptiles observed in the area.

Human Health Exposure Pathways

Potential Pathway of Exposure	Members of the Public
Incidental ingestion and direct contact with soil	Yes
Inhalation of air and contact	Yes
Drinking water – surface water	Yes
Drinking water – groundwater	No
Other uses of potable water (e.g., bathing)	Min
Harvest local foods (e.g., berries)	Yes
Hunting / Trapping	Yes
Fishing	Yes
Garden produce ingestion	Min
Irrigation of vegetation (potable / groundwater / surface water)	Min
Livestock	No
External dose from soil (groundshine)	Yes
Recreational use of surface water (e.g., swimming)	Yes[a]
	Min

Note: a – While this pathway is not expected to be a significant pathway of exposure, dermal contact with water while swimming is included in the assessment.

A CSM is a representation of the biological, physical and chemical processes that determine the ways that constituents move from sources through the environment to receptors.



Conceptual Site Model (CSM) for the Operation

ERA CONCLUSIONS

The results of the ERA are summarized for the expected future releases in the tables below . As expected, when the release of treated effluent to Read Creek stops after the operational period, the concentrations of COPCs are predicted to drop.

Sediment	Surface Water	Air
Predicted concentrations for COPCs are expected to remain below the selected sediment benchmarks, with the exception of cadmium and molybdenum in Unknown Pond. Molybdenum concentrations are expected to decrease as the concentrations continue to improve following the minewater treatment plant improvements.	Concentrations of COPCs in surface water are predicted to remain below all surface water quality guidelines.	There was no predicted influences on regional air quality from the McArthur River Operation.

	People	Water	Land
Scenario	*The HHRA evaluated a McArthur River Operation camp worker, a trapper, a seasonal resident, and a permanent resident at Little Yalowega Lake.*	*Assessment for a range of biota that live in water from benthic invertebrates (insects in the sediment at the bottom of the lake) to fish. Wildlife that use the water are also considered*	*Assessment for terrestrial plants, insects and wildlife. Selected species at risk (e.g., woodland caribou and blackbird) are protected on an individual basis (versus population basis).*
Radiological	No expected risks to human health from radioactivity related to the McArthur River Operation.	No potential influence on aquatic biota or wildlife that use the water are anticipated.	No potential influence on terrestrial biota are anticipated.
Non-Radiological	No expected risks to human health from COPCs released from the McArthur River Operation.	No potential influence on populations of aquatic biota or wildlife that use the water are anticipated.	No potential influence on terrestrial biota are anticipated from exposure to non-radionuclides COPC.

The ERA meets the requirements of CSA N288.6-12. The results of the 2020 ERA are consistent with the findings from the 2015 ERA in that there are no significant risks posed to aquatic, terrestrial, or human receptors situated in the area surrounding the Operation. As such, it can be concluded that the environment and human health in the vicinity of the McArthur River Operation will remain protected.

Cameco also completes environment monitoring and summarizes the results in a Comprehensive Aquatic Monitoring Reports. The most recent report found that, consistent with the findings from the 2020 ERA, that the Operation remains within the objective of the licensing basis and that human health and the environment in the vicinity of the Operation remain protected.

Overall, the results of the 2020 ERA are consistent with previously approved ERAs and demonstrate that the environment and human health in the vicinity of the Operation remain protected.

Further, the ERA and routine monitoring results continue to demonstrate that the site remains within the objective of the licensing basis and previous Environmental Assessment predictions.