

Environmental Risk Assessment

Cameco Corporation’s (Cameco) Blind River Refinery (BRR or site) is located about 5 km west of the Town of Blind River, Ontario and adjacent to the Mississauga First Nation (see Figure 1). While the secured CNSC-licensed site has a relatively small footprint, the property owned by Cameco Corporation is significantly larger, bounded to the north by the railway line, to the west by the Mississagi River, and to the south by Lake Huron. Cameco has also leased from the Town of Blind River additional lands to the east of the existing property boundary as a buffer. The nearest residence is located approximately 1 km NE of the refinery.



Figure 1: Cameco Blind River Refinery

In accordance with its licence requirements, Cameco has completed an environmental risk assessment (ERA) to align with the standardized requirements found in Canadian Standards Association (CSA) N288.6-12, Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills. An ERA is a systematic process used to identify and assess the potential risk posed by contaminants and physical stressors in the environment on biological receptors. There are two parts to an ERA – an assessment of the facility’s operations on human receptors through a human health risk assessment (HHRA) and an assessment on non-human environmental receptors through an ecological risk assessment (EcoRA).

The BRR ERA was completed to address the following question:

Is there potential for significant environmental (i.e. ecological and human health) effects from current emissions associated with Cameco’s BRR facility operations?

This summary provides the ERA methodology and results, which conclude there are no radiological or non-radiological human health risks expected to members of the public. Similarly, there are no radiological or non-radiological ecological risks to any of the terrestrial or aquatic receptors

Environmental risk assessment follows a general tiered-approach methodology supported by CSA and various regulators and agencies, such as Health Canada (HC), Canadian Council of Ministers of the Environment (CCME) and the CNSC. Potential impacts on humans or the environment are measured in terms of “screening indices”. In simple terms, a screening index (SI) is the concentration or exposure level divided by a published criteria that has been deemed unlikely to have a significant effect on the receptor. These criteria can come from research or field studies, regulatory standards and objectives, scientific literature or other credible sources.

SI is the ratio of

Exposure Level (or Concentration)
Criterion

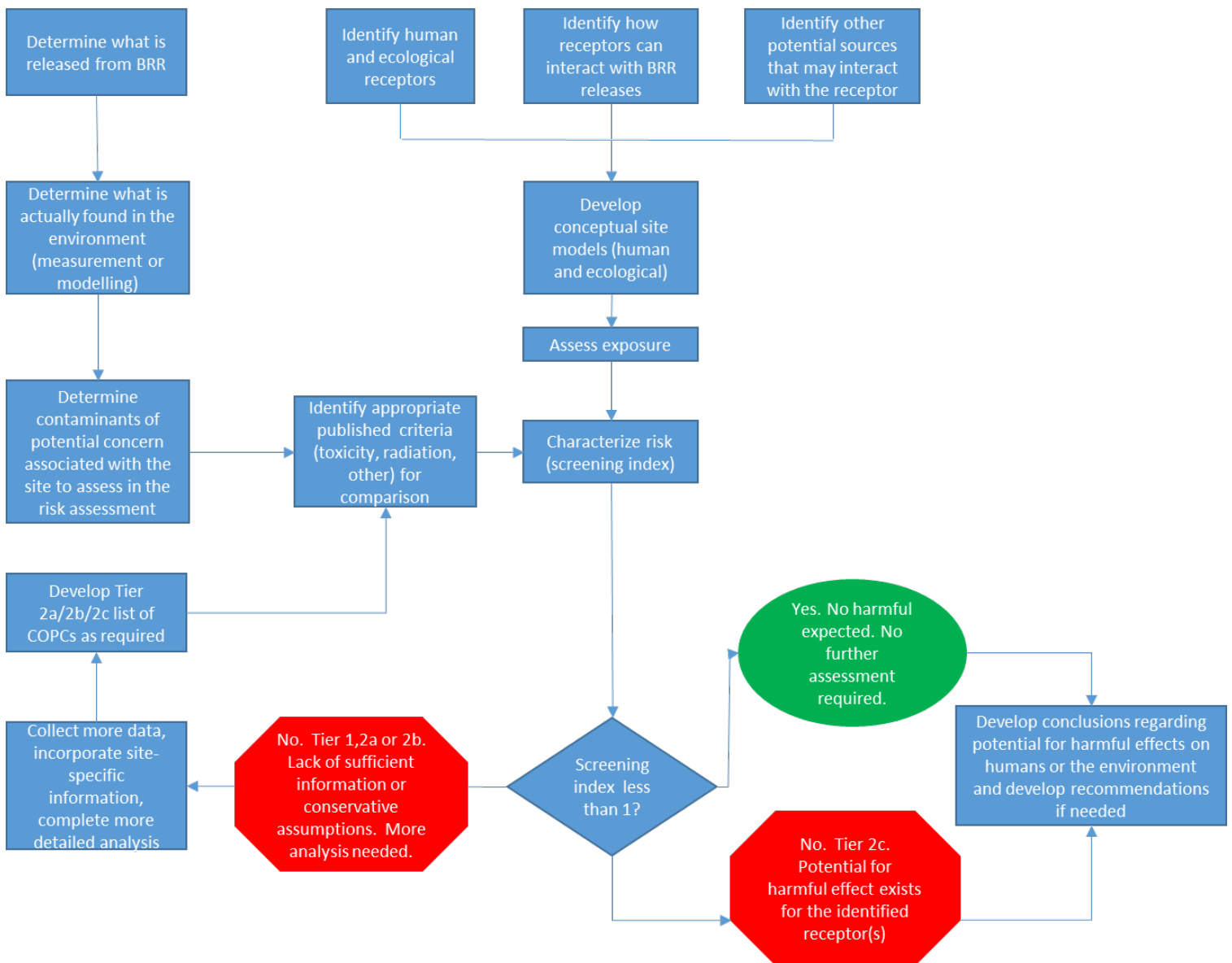
SI **below one** indicates that no harmful effects on living things are expected.

SI **above one** indicates that further analysis is required.

As depicted in Figure 2, the first level or tier of the assessment starts with very broad, very conservative assumptions designed to uncover any potentially significant environmental effects. If no potential effects are identified (SI is less than 1), the assessment stops. If a potential effect is identified (SI greater than 1), then analysis continues to determine whether that potential effect is due to lack of sufficient information or assumptions that are too conservative. Another tier or step of analysis (in Tiers 2a, 2b and 2c as required) would follow with

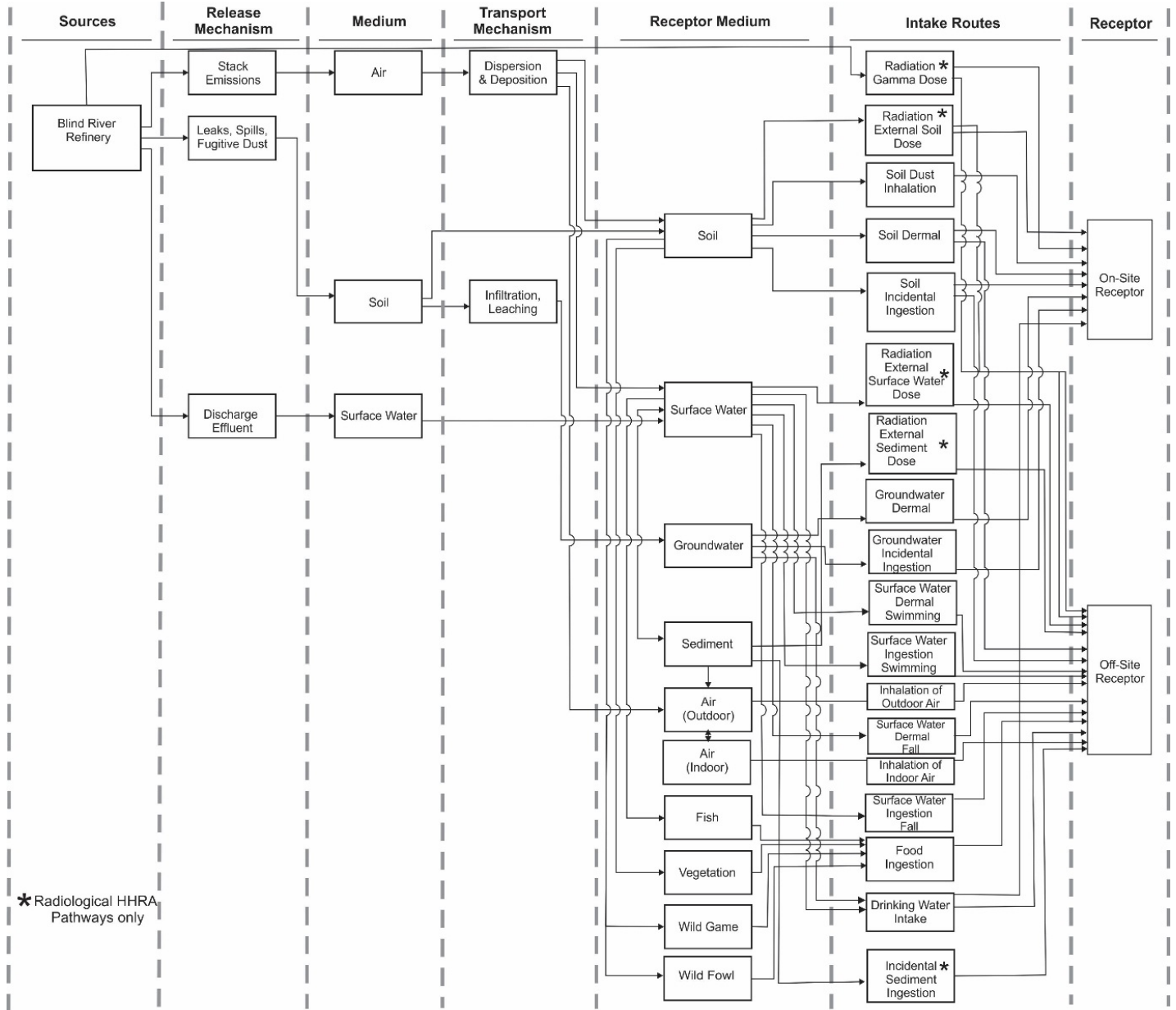
more detailed analysis, additional field data, and more site specific information. As data gaps are closed and assumptions become more realistic, it becomes possible to determine if a stressor is actually having an effect. Each step results in increasing levels of certainty about environmental risk factors. Once the assessment is complete, a conclusion with associated recommendations to address potential harm to people or the environment is developed.

Figure 2: Environmental Risk Assessment Overview



The first step in conducting an ERA is to understand how materials released from Cameco's operations may enter the natural environment. This is illustrated in Figure 3.

Figure 3: Transport Pathways



Once this is understood, the Contaminants of Potential Concern (COPCs) need to be identified. This is a list of all radiological and non-radiological contaminants released to air and water from site operations. It is developed from operational knowledge of the facility, routine monitoring data, other available monitoring data and field investigations. Screening for COPCs at BRR included the following broad categories: BRR routine monitoring parameters; general chemistry parameters; metals; radionuclide and organics analysis. Data from both Cameco and non-Cameco sources were utilized. In developing the list of COPCs, some contaminants are removed from further consideration if they are released in very small quantities, are present at or below natural background levels, or are determined not to be a concern from a human or ecological health perspective. The concentration(s) in the environment are then determined for each source (i.e. soil, groundwater, surface water, air emissions) in the natural areas near the facility using field measurements, modelling or a combination of both. Where multiple samples are available, the maximum concentration or “worst-case” is used for the first or screening level assessment in the ERA.

The pathways assessment (also called risk characterization or risk assessment) is a series of calculations following the standardized requirements of N288.6-12 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 how the COPCs are passed up the food chain. The calculated exposure levels are compared to scientifically accepted benchmarks to determine whether there is a potential for an effect to human health or biota which results in a screening index.

It is important to understand the first tier of the assessment begins with conservative assumptions about both estimated exposure and the criteria used to assess the risks of that exposure, especially where information is not readily available.

The assumptions used to derive the SI are conservative to ensure that if the index is estimated to be less than 1, there’s a high level of confidence that, despite any uncertainty in the data, the index value won’t exceed 1. If the screening index is estimated to be greater than 1, however, follow-up work is required in a higher tier assessment to determine whether this is due to conservatism in the assumptions, lack of sufficient data or a real impact. Tier 1 assessments are typically based on literature reviews. Higher tier assessments require field studies.

Human Health Risk Assessment

The HHRA component of the ERA included the following COPCs:

- Uranium
- Ammonia (in groundwater)
- Tri-butyl phosphate (TBP)
- Chromium
- Vanadium
- Radionuclides and gamma radiation

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

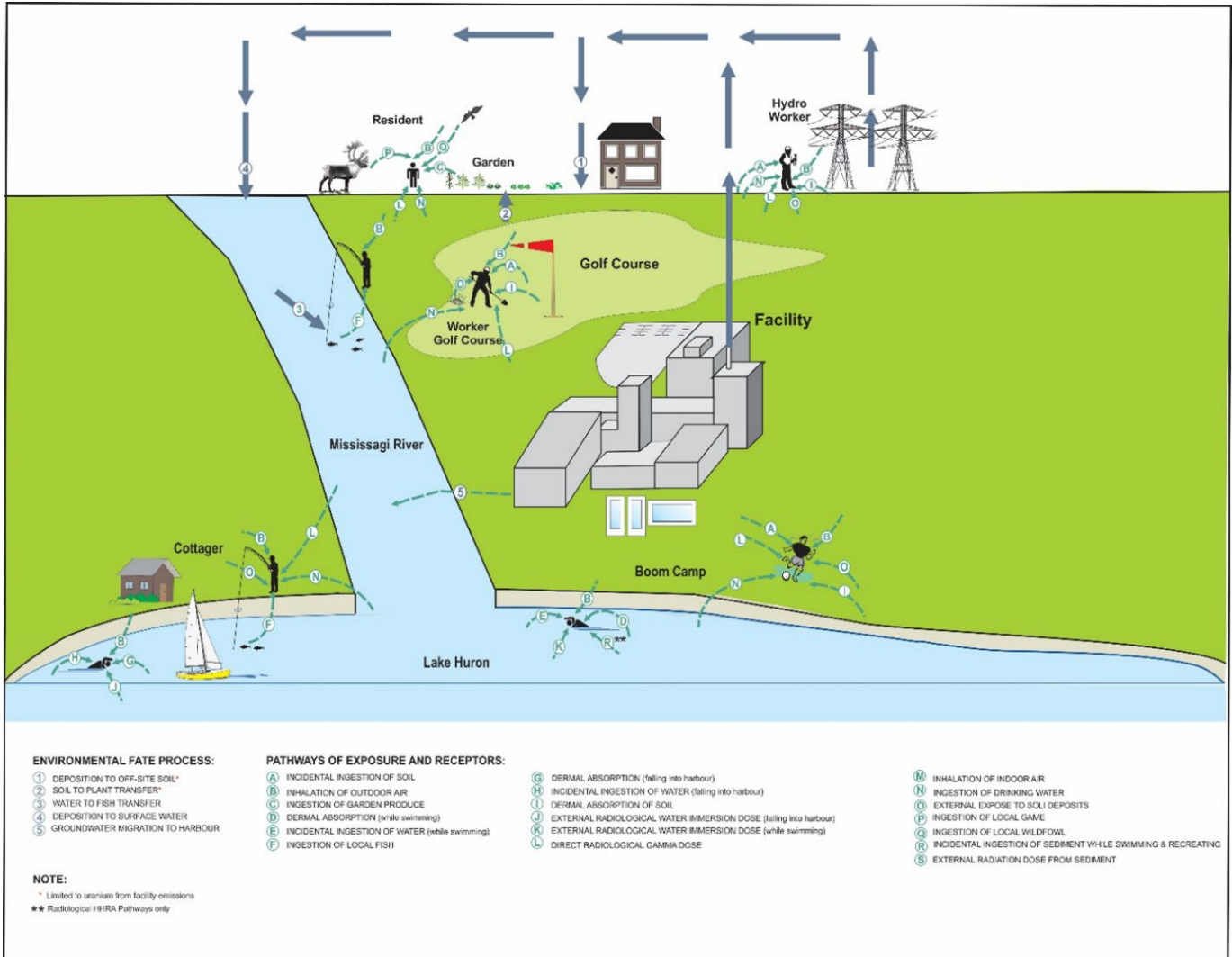
- Groundwater
- Soil
- Air
- Surface water
- Sediment
- Gamma radiation



The human receptors and receptor characteristics are defined for the HHRA based on the members of the public who reside or use the natural areas near the facility who may be affected by the release of contaminants. Different scenarios are considered to assess nearby residents, such as their age, whether they work near the facility, consume local produce or wild game or participate in recreational activities such as

fishing or swimming. The different routes of exposure, or pathways (i.e. how the contaminants travel through the natural environment and ultimately interact with the human or biological receptors) are determined and are collectively referred to as the conceptual site model (CSM), as shown in Figure 4.

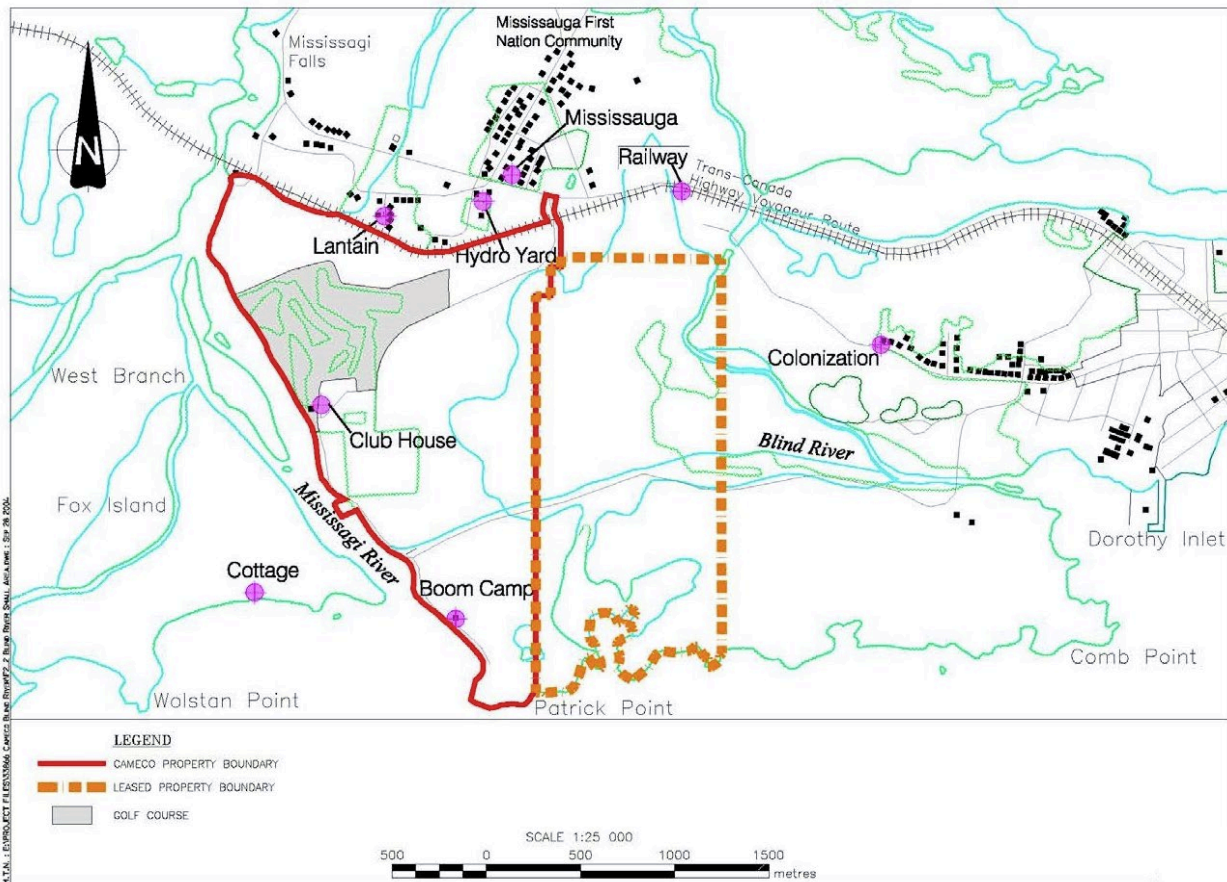
Figure 4: Human Health Risk Assessment Conceptual Site Model



The BRR receptors considered are illustrated in Figure 5 and Table 1 for the HHRA.

Table 1: Human Receptor Exposure Locations and Environmental Media

Receptor(s)	Location(s)	Environmental Media	Uptake/Exposure Route
1 Resident	(A) <i>Lantain Subdivision</i>	Soil	Consumption - Backyard Produce
			Consumption - Wild Game
			External Exposure from Soil (<i>Rad. Only</i>)
	(B) <i>Mississauga First Nation</i>	Surface Water	Consumption - Fish
			Air
	(C) <i>Railway</i>	Groundwater	Consumption - Drinking Water
	(D) <i>Colonization Rd.</i>	Gamma	<i>External - Direct (Rad. Only)</i>
2 Cottager	<i>Lake Shore, SW of River.</i>	Soil	Incidental Ingestion
			External Exposure from Soil (<i>Rad. Only</i>)
		Surface Water - Lake	Fall into water - Dermal
			Fall into water - Incidental Ingestion
			Consumption - Fish
			Consumption - Drinking Water
	Air	<i>External - Immersion (Rad. Only)</i>	
Air	Inhalation (indoor air)		
	Inhalation (outdoor air)		
Gamma	<i>External - Direct (Rad. Only)</i>		
3 Boom Camp	<i>River Shore</i>	Soil	Dermal
			External Exposure from Soil (<i>Rad. Only</i>)
		Surface Water - Lake	Incidental Ingestion
			Swim - Dermal
			Swim - Incidental Ingestion
			<i>External - Immersion (Rad. Only)</i>
	Air	Consumption - Drinking Water	
Gamma	Inhalation (outdoor)		
Sediment	<i>External - Direct (Rad. Only)</i>		
4 Golf Course Worker	<i>Golf Course Club House</i>	Soil	External Dose (<i>Rad. Only</i>)
			Incidental Ingestion
			External Exposure from Soil (<i>Rad. Only</i>)
		Surface Water - Lake	Dermal
		Gamma	Consumption - Drinking Water
5 Hydro Worker	<i>In-Town Hydro Site</i>	Soil	Inhalation (outdoor)
			Incidental Ingestion
			External Exposure from Soil (<i>Rad. Only</i>)
		Surface Water - Lake	Dermal
		Gamma	Consumption - Drinking Water
Air	Inhalation (outdoor)		
Gamma	<i>External - Direct (Rad. Only)</i>		

Figure 5: Human Receptor Locations


Results

The radiological human health risk component involved dose calculations based on maximum measured radionuclide levels in environmental media (wherever such measured data were available), as well as estimated levels of radionuclides (wherever measured data are absent) using radionuclide ratios. The resulting estimated doses are well below the dose limit to a member of the public (1 mSv/a) and, therefore, no undue impacts are expected to workers or members of the public.

The non-radiological human health risk component involved exposure calculations based on maximum concentrations measured in a particular media. Further analysis is completed for receptor-media combinations that exceed benchmark

values. In this assessment, resident receptors are not expected to have access to on-site groundwater, and therefore, the receptor-media combination is not feasible and therefore, no undue risk is anticipated.

Table 2 summarizes the results of the HHRA for the BRR. For both radioactive and non-radioactive parameters, there are no effects expected to humans as a result of BRR operations. The Tier 1 assessment did indicate the potential for effects from uranium and TBP; however, subsequent Tier 2a (U and TBP) and 2b analysis (TBP only) carried out following the guidance of N288.6-12 confirmed that no potential health effects are expected.

Table 2: Results of the Human Health Risk Assessment

Receptor Name	Rec. ID#	Age Group	HHRA TIER 1 – Exceedances				HHRA TIER 2a - Exceedances				HHRA TIER 2b - Exceedances
			<i>Air</i>	<i>Soil</i>	<i>SW</i>	<i>GW</i>	<i>Air</i>	<i>Soil</i>	<i>SW</i>	<i>GW</i>	
Resident	1	<i>Infant</i>		U		U, TBP				TBP	<i>No residual exceedances</i>
		<i>Toddler</i>		U		U, TBP				TBP	
		<i>Child</i>		U		U, TBP				TBP	
		<i>Teen</i>				U, TBP				TBP	
		<i>Adult</i>				U, TBP				TBP	
Cottager	2	<i>Infant</i>			TBP	n/a			TBP	n/a	<i>No residual exceedances</i>
		<i>Toddler</i>			TBP	n/a			TBP	n/a	
		<i>Child</i>			TBP	n/a			TBP	n/a	
		<i>Teen</i>			TBP	n/a			TBP	n/a	
		<i>Adult</i>			TBP	n/a			TBP	n/a	
Boom Camp	3	<i>Infant</i>			TBP	n/a			TBP	n/a	<i>No residual exceedances</i>
		<i>Toddler</i>		U	TBP	n/a			TBP	n/a	
		<i>Child</i>			TBP	n/a			TBP	n/a	
		<i>Teen</i>			TBP	n/a			TBP	n/a	
		<i>Adult</i>			TBP	n/a			TBP	n/a	
Golf Worker	4	Adult			TBP	n/a			TBP	n/a	
Hydro Worker	5	Adult			TBP	n/a			TBP	n/a	

Ecological Risk Assessment

The EcoRA component of the ERA included the following COPCs:

- Uranium
- Ammonia (in groundwater)
- TBP
- Chromium
- Vanadium
- Radionuclides

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

- Groundwater
- Soil
- Surface water
- Sediment

The biological receptors and receptor characteristics are defined for the EcoRA based on the plants, invertebrates, mammals and birds who use the natural areas near the facility and may be affected by the release of contaminants. The CSM for the EcoRA, illustrating the different routes of exposure, or pathways (i.e. how the contaminants travel through the natural environment and ultimately interact with the biological receptors) is shown in Figure 6 and Table 3.

Figure 6: Ecological Risk Assessment Conceptual Site Model

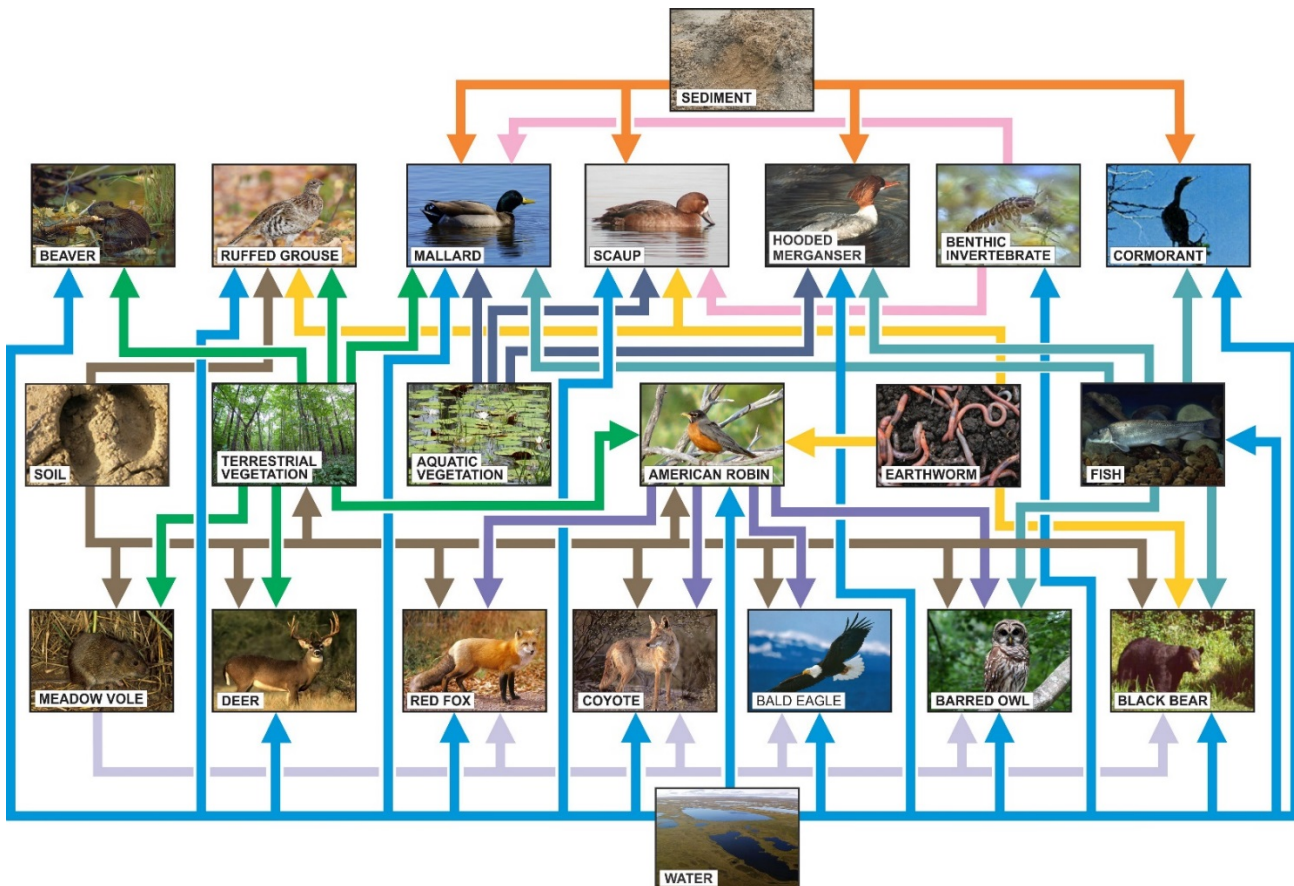


Table 3: EcoRA Exposure Pathways Summary

Receptor	Environmental Media Exposed	Modes of Exposure
<i>Fish</i>	<ul style="list-style-type: none"> • surface water • sediment 	<ul style="list-style-type: none"> • uptake from water; • immersion in water; • exposure to sediment (benthic fish, radiological only).
<i>Benthic Invertebrates</i>	<ul style="list-style-type: none"> • surface water • sediment 	<ul style="list-style-type: none"> • uptake from water; • immersion in water (radiological only); • immersion in sediment (radiological only).
<i>Aquatic Plants</i>	<ul style="list-style-type: none"> • surface water 	<ul style="list-style-type: none"> • uptake from water; • immersion in water (radiological only).
<i>Terrestrial Invertebrates</i>	<ul style="list-style-type: none"> • soil • groundwater 	<ul style="list-style-type: none"> • uptake from soil; • immersion in soil (radiological only); • uptake from groundwater; • immersion in groundwater (radiological only).
<i>Terrestrial Birds</i>	<ul style="list-style-type: none"> • soil • surface water 	<ul style="list-style-type: none"> • ingestion: <ul style="list-style-type: none"> - terrestrial vegetation; - terrestrial invertebrates; - soil; - surface water; - mammals and birds (owl; eagle). • direct exposure to soil (radiological only).
<i>Terrestrial Mammals</i>	<ul style="list-style-type: none"> • soil • surface water 	<ul style="list-style-type: none"> • ingestion (as appropriate): <ul style="list-style-type: none"> - terrestrial invertebrates; - terrestrial vegetation; - soil; - surface water; - mammals and birds (fox, bear, coyote). • direct exposure to soil (radiological only).
<i>Terrestrial Plants</i>	<ul style="list-style-type: none"> • soil 	<ul style="list-style-type: none"> • uptake from soil; • exposure to soil (radiological only).
<i>Aquatic Birds</i>	<ul style="list-style-type: none"> • surface water • sediment 	<ul style="list-style-type: none"> • ingestion (as appropriate): <ul style="list-style-type: none"> - surface water; - fish; - benthic invertebrates; - aquatic vegetation; - sediment. • immersion in surface water (radiological only).
<i>Aquatic Mammals</i>	<ul style="list-style-type: none"> • surface water • sediment • Soil 	<ul style="list-style-type: none"> • ingestion: <ul style="list-style-type: none"> - surface water; - benthic invertebrates; - aquatic vegetation; - soil. • immersion in surface water (radiological only).

Results

Table 4 summarizes the results of the EcoRA for the BRR. For radioactive parameters, there are no effects expected on ecological (terrestrial and aquatic) receptors as a result of BRR operations. With respect to non-radioactive parameters, the

Tier 1 assessment did indicate the potential for effects from TBP, however subsequent Tier 2 analysis carried out following the guidance of N288.6-12 confirmed that no ecological effects are expected.

Table 4 Results of the Ecological Risk Assessment

Receptor Type	Receptor	HHRA TIER 1 - Exceedances	HHRA TIER 2 - Exceedances
Terrestrial	<i>American Robin</i>		<i>No residual exceedances</i>
	<i>Bald Eagle</i>		
	<i>Barred Owl</i>		
	<i>Black Bear</i>		
	<i>Coyote</i>		
	<i>Deer</i>		
	<i>Earthworm</i>		
	<i>Meadow Vole</i>		
	<i>Red Fox</i>		
	<i>Ruffed Grouse</i>		
<i>Terrestrial Vegetation</i>			
Aquatic	<i>Amphibian</i>	TBP	
	<i>Aquatic Vegetation</i>	TBP	
	<i>Beaver</i>		
	<i>Benthic Fish</i>	TBP	
	<i>Benthos</i>	TBP	
	<i>Cormorant</i>		
	<i>Hooded Merganser</i>		
	<i>Mallard</i>		
	<i>Pelagic Fish</i>	TBP	
	<i>Scaup</i>		

Conclusions

In summary, as indicated in Table 5, there are no potential radiological or non-radiological human health risks expected to members of the public. Similarly, there are no potential radiological or non-radiological ecological risks to any of the terrestrial or aquatic receptors.

Table 5: Summary of ERA Results

Stressor Type	Members of the Public	Aquatic Biota	Terrestrial Biota
Radiological	No adverse effect expected from COPCs associated with BRR operations.	No adverse effect expected from COPCs associated with BRR operations.	No adverse effect expected from COPCs associated with BRR operations.
Non-Radiological	No adverse effect expected from COPCs associated with BRR operations.	No adverse effect expected from COPCs associated with BRR operations.	No adverse effect expected from COPCs associated with BRR operations.

This ERA satisfies the CSA N288.6-12 standard.

As a result of this ERA, Cameco has:

- Reduced its analytical detection limit for TBP from 0.6 mg TBP/L to 0.13 mg TBP/L. The previous detection limit was above toxicological reference values used in the ERA.
- Implemented a new environmental protection program that considers this risk assessment, its conclusions and meets the requirements of additional CSA environmental standard for monitoring program.

The next scheduled update of this ERA is in 2021 in accordance with the CSA N288.6-12 recommended update cycle.

