Review of the Environmental Risk Assessment for the Blind River Refinery

In Support of the Renewal of the Blind River Refinery Operating Licence FFOL-3632.00/2022

September 30, 2020

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1.0 Introduction

In accordance with its licence requirements, the Blind River Refinery (BRR) maintains an environmental risk assessment (ERA) in accordance with the standardized requirements of CSA N286.6-12: *Environment Risk Assessments at Class 1 Nuclear Facilities and Uranium Mines and Mills* (N288.6-12). 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).

BRR completed its ERA in November 2016 (ARCADIS, 2016), which found there were no undue risks to the environment or to human health as a result of refinery operations. A summary of the ERA and a redacted version of the ERA are available on the Cameco community website (www.camecofuel.com/library/media-library). Under Clause 11 of N288.6-12 Cameco is required to review the ERA for the BRR every five years. The 2016 ERA was completed November 2016, and therefore is required to be reviewed by November 2021. This review was undertaken in 2020 to support the licence renewal application for BRR's Fuel Facility Operating Licence (FFOL-3632.0/2022) being submitted in September 2020.

1.1 Scope of Review

As per N288.6-12 (R2017) Clause 11.1:

> *A nuclear facility shall review its ERA to verify its applicability, and shall update it as necessary, consistent with the overall iterative process for ERAs.*
>
> *The purpose of the periodic review of the ERA is to identify and assess any risks that might have emerged since the last ERA review. This review can indicate that the potential for risks is substantively the same and therefore that the ERA does not require changes. Conversely, the review can identify new risks or highlight changes in the risk assessment variables that need to be updated to reflect the new risk profile. In either case, the review process and findings shall be thoroughly documented. A full or partial update of the ERA may be completed, as needed, to reflect important changes since the last ERA review.*

The present review of the ERA is to identify:

(a) changes that have occurred in site ecology or surrounding land use;
(b) changes to the physical facility or facility processes that have the potential to change the nature of facility effluent(s) and the resulting risks to receptors;
(c) new environmental monitoring data collected since the last ERA update;
(d) new or previously unrecognized environmental issues that have been revealed by the EMP;
(e) scientific advances that require a change to ERA approaches or parameters; and
(f) changes in regulatory requirements pertinent to the ERA.

In addition, specific comments (CNSC, 2017) from CNSC staff regarding the November 2016 ERA have been considered and addressed in the current review. The purpose of the review is evaluate the applicability of the final conclusions of the 2016 ERA for the ongoing operations of the refinery.

1.2 Available Data and Information Sources

The following facility data and information were used in the current review of the ERA.

1. Environmental monitoring data 2015-2019
2. 2019 Emission Summary Dispersion Model
3. Facility Design Change records 2015-2019
4. 2016 Environmental Risk Assessment
5. 2018 Derived Release Limit report
6. 2015 Plume modelling, delineation and sediment study
7. Applicable provincial and federal guidelines for environmental protection
8. Literature reviews to support specific disposition of CNSC staff questions

1.3 Report Organization

This report is structured as follows, based on the guidance in N288.6-12 (R2017) Clause 11.1 for review of an ERA:

Section 2 provides a review of site changes (physical facility and facility processes), site ecology, and surrounding land use. It also identified opportunities for enhancing the site characterization.

Section 3 provides a review of the environmental monitoring data collected since the 2016 ERA. An updated screening of contaminants of potential concern (COPC) is provided.

Section 4 provides a review of environmental issues revealed by the 2016 ERA and a review of other issues identified with the methodology of the 2016 ERA.

Section 5 provides a review of scientific advances and changes in regulatory requirements that may impact the ERA approaches or parameters.

Section 6 provides a review of the information presented in Sections 2-5 and the impact of these issues on problem formulation in the ERA.

Section 7 provides an evaluation of the ongoing applicability of the final conclusions and recommendations of the 2020 ERA review.

2.0 Review of Site Characterization

This section provides a description of the review completed to identify changes that have occurred to site ecology or surrounding land use, changes to the physical facility or facility processes that have the potential to change the nature of facility effluents(s) and the resulting risks to receptors as recommended by Clause 11.1 (a) and (b) of N288.6-12. It also provides a description of information requested by CNSC staff to enhance the overall robustness of the site characterization and the conceptual site model.

2.1 Site Ecology and Surrounding Land Use

As described in the 2016 ERA, Cameco owns and/or leases 1117 acres on which the 28-acre secured area of the refinery is situated. No changes in access or use of this land has occurred since the 2016 ERA. There have been no major changes within 25 km of the facility as noted by refinery personnel who reside in the area. The Official Plan for the town of Blind River (2015) emphasizes the importance of the environment, including forested areas and wetlands in future development in the area.

2.2 Changes to the Physical Facility and Facility Processes

In order to assess the changes to the refinery between 2015 and 2019, a review of the facility design control files, annual reports and management review reports was carried out. In this review only one change was identified which should be noted in the ERA. This was the installation of a berm outside the refinery perimeter along the south, east and west fence lines in order to mitigate the impact to refinery operations in the extremely unlikely event of a worst-case flood scenario. While this change has no direct impact on discharges from the refinery, it will alter stormwater flow around the site which may impact the volume of the liquid effluent discharge. However, no appreciable difference in effluent quality was identified as discussed in section 3.

2.3 Opportunities for Enhancement of Site Characterization

Site characterization information was documented in Section 2 of the 2016 ERA. Additional information is provided to enhance the site characterization as part of this review of the 2016 ERA.

2.3.1 Information Regarding Site Selection

The refinery was built on a greenfield site in the early 1980s by Eldorado Resources Ltd. (ERL) and began producing uranium trioxide (UO_3) in 1983. Prior to the construction of the refinery in the 1980's, the property was undeveloped, with no permanent residences. Much of the general surrounding area is vegetated or wet lands with little agricultural activity as is typical for northern Ontario. The natural landscape in the Blind River area has environmental and social value to northern Ontario (Eldorado, 1978).

Present day, there are few permanent residences directly to the east or west of the property; however, there are small rural communities located along Highway 17 to the north. The nearest residence is located approximately 1 km northeast of the UO_3 plant. There is an 18-hole golf course constructed on the Cameco property to which the public has access (ARCADIS, 2018).

2.3.2 Information Regarding Topography

The topography is generally flat, rising from the shoreline inland, with a general elevation range of about 177m to 180m (Geodetic Datum) and the plant site is nominally at least 2m above the water level in the nearby river (Cameco, 2016).

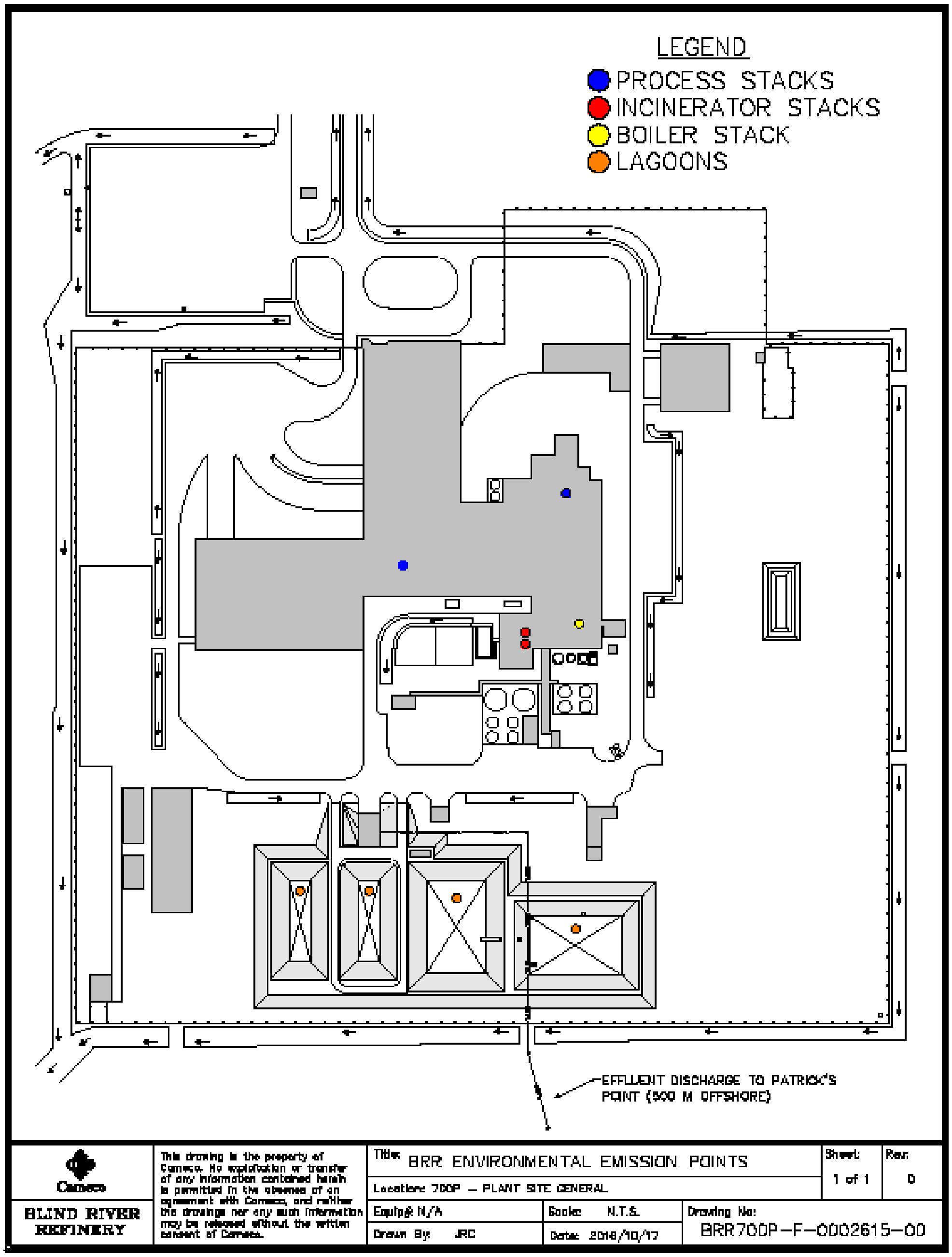
2.3.3 Releases to the Environment

The primary air emissions associated with the BRR are uranium and oxides of nitrogen. These contaminant emissions are measured using source monitoring and/or estimated using available monitoring data. There are two process stacks and three utility stacks in use at the refinery. Routine sampling is carried out at the two process stacks for uranium and total particulate when operating. The incinerator stack is also sampled routinely for uranium and total particulate when operating. The other two utility stacks are the boiler stack and the calciner flue gas stack, both of which discharge combustion products from natural gas.

There is one point of liquid effluent discharge from the property. Liquid effluent from the process and utilities (including the sewage treatment plant) is pumped to one of three holding lagoons where it is sampled to ensure it meets all regulatory requirements prior to discharge. The facility also has a storm water lagoon to collect surface water run-off from the site. All liquid effluent is combined prior to being discharged into the North Channel of Lake Huron via an outfall pipe diffuser. A flow proportional sampler is located on the discharge line and collects a composite sample of effluent as it is being discharged.

The environmental emission points from the refinery are shown in Figure 1.

Figure 1 Environmental Emission Points from BRR



Corresponding monitoring for COPCs in the environment was described in section 2.5 of the 2016 ERA.

2.3.4 Meteorological Statistics and Climate Setting

A review of available climatic data was carried out as part of this review. Gore Bay is located approximately 49 km southeast of Blind River and is situated on the North Channel of Lake Huron. It is the most representative meteorological station due to its proximity to Lake Huron. However, climate normal data for Gore Bay meteorological station is only available up to the 1971 to 2000 time period.

Cameco reviewed the Environment Canada and Climate Change (ECCC) database and identified three meteorological stations with climate normal data for 1981 to 2010. These stations are Sudbury (approximately 166 km east of Blind River), Sault Ste. Marie (approximately 145 km west of Blind River) and Massey (approximately 70 km east of Blind River). It is important to note that none of these meteorological stations are situated on Lake Huron which may impact their ability to represent the climatic normal of Blind River.

In comparing data for temperature (Figures 2 and 3) and precipitation (Figure 4) climate normals, no appreciable difference was determined between the datasets.

Figure 2 Daily Minimum Temperatures

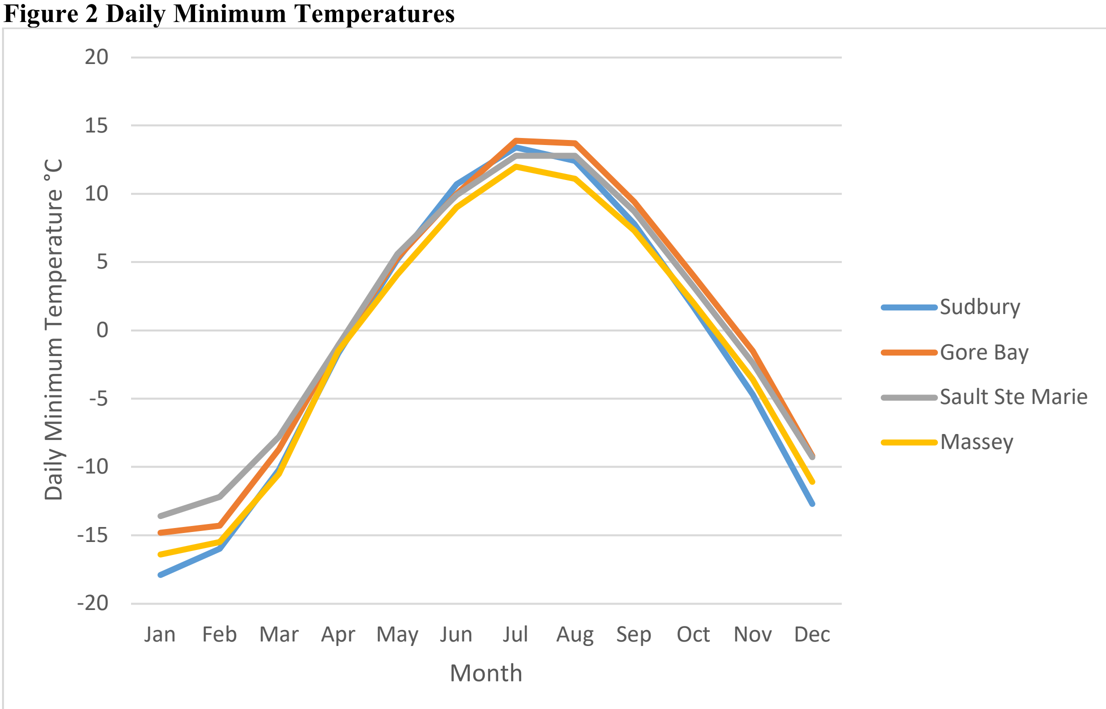


Figure 3 Daily Maximum Temperatures

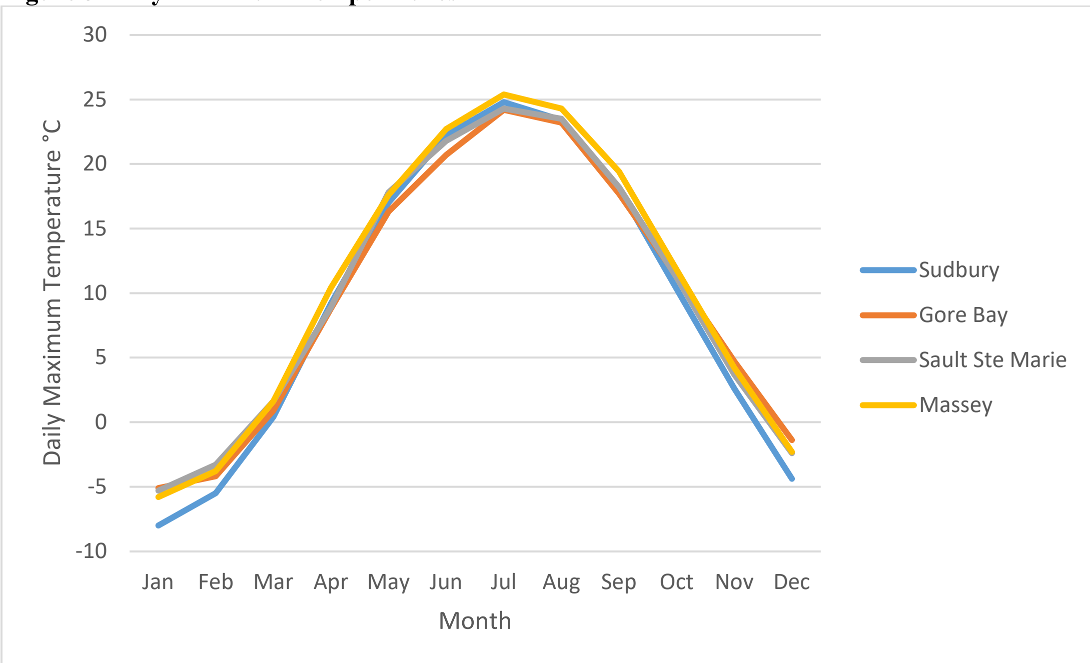
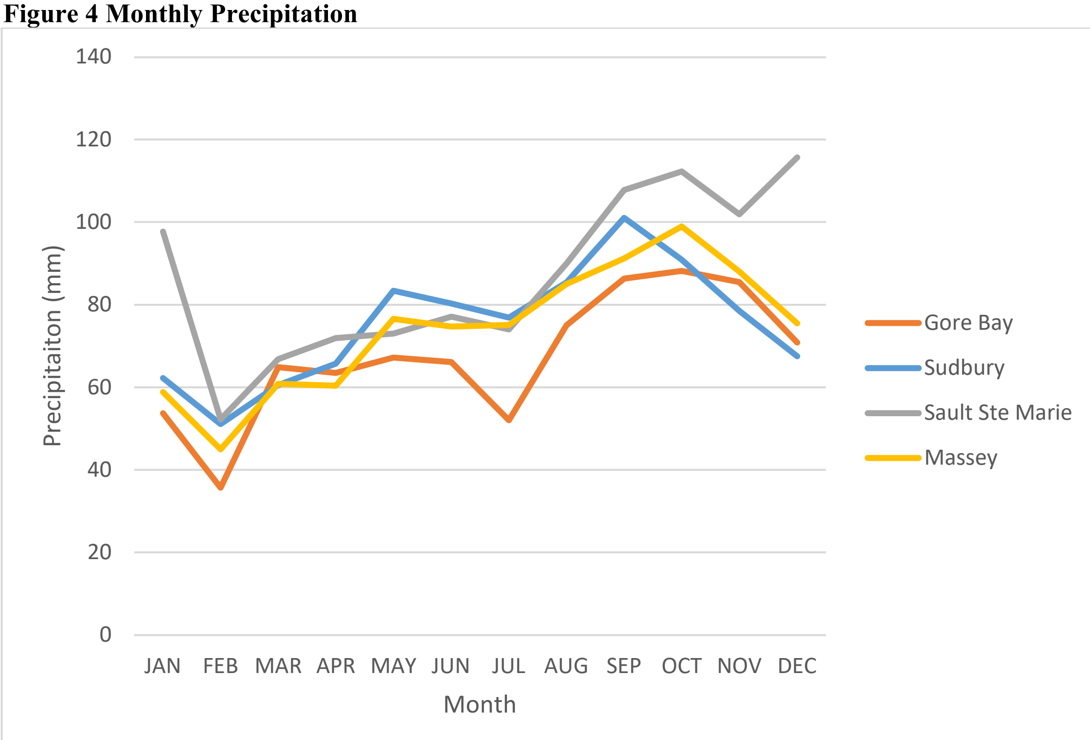


Figure 4 Monthly Precipitation



For completeness of the site characterization, the climate normal data for both the Gore Bay (1971-2000) and the Massey (1981-2010) data are presented below. It is important to note that the climate normal are only used to describe the climate setting and do not affect meteorological data used in dispersion modelling or assessment in the ERA.

As it can be seen from Tables 1 and 2, differences in average daily temperatures, daily maximum and minimum temperatures and extreme temperatures throughout the seasons are small between the two stations and periods.

As it can be seen from Tables 3 and 4, similar precipitation patterns and seasonal distribution may be observed in these two stations.

A further discussion of meteorological data as it pertains to air dispersion modelling is provided in section 3.2.1.

Table 1 Temperature Climate Normals, Gore Bay, Ontario, 1971 to 2000

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily Average Temperature (°C)	-10.0	-9.3	-3.9	3.9	10.8	15.4	19.1	18.5	13.6	7.7	1.6	-5.3	5.2
Daily Maximum Temperature (°C)	-5.1	-4.2	0.9	8.8	16.3	20.7	24.2	23.2	17.7	11.3	4.7	-1.4	9.8
Daily Minimum Temperature (°C)	-14.8	-14.3	-8.7	-1.1	5.3	10.0	13.9	13.7	9.4	4.0	-1.5	-9.2	0.6
Extreme Maximum Temperature (°C)	8.3	8.3	16.7	27.5	29.5	31.7	**36.2**	34.4	33.3	23.9	18.3	14.3	36.2
Extreme Minimum Temperature (°C)	**-36.9**	-36.5	-30.6	-20.6	-5.6	-7.3	5.6	2.3	-2.0	-5.0	-22.8	-30.5	-36.9

Table 2 Temperature Climate Normals, Massey, Ontario, 1981 to 2010

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily Average Temperature (°C)	-11.1	-9.6	-4.5	4.4	10.9	15.9	18.7	17.8	13.4	6.9	0.3	-6.7	4.7
Daily Maximum Temperature (°C)	-5.8	-3.8	1.6	10.4	17.6	22.7	25.4	24.3	19.4	11.8	4.2	-2.3	10.5
Daily Minimum Temperature (°C)	-16.4	-15.5	-10.5	-1.5	4.1	9	12	11.1	7.3	2	-3.6	-11.1	-1.1
Extreme Maximum Temperature (°C)	8	10	19	27	30	33.5	**37**	36	32.5	27.5	18.5	14.5	37
Extreme Minimum Temperature (°C)	-41	**-41**	-36	-24.5	-5	-1.5	2	0	-7.5	-8.5	-29	-38.5	-41

Table 3 Precipitation Climate Normals, Gore Bay, Ontario, 1971 to 2000

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Average Monthly Rainfall (mm)	11.7	4.8	37.7	50.6	66.6	66.1	52.0	75.0	86.3	86.3	62.4	25.5	625.0
Average Monthly Snowfall (cm)	67.1	47.3	34.5	14.1	0.7	0.0	0.0	0.0	0.0	2.0	29.0	72.6	267.3
Average Monthly Precipitation (mm)	53.7	35.7	64.9	63.5	67.2	66.1	52.0	75.0	86.3	88.2	85.5	70.8	808.9
Extreme Daily Rainfall (mm)	26.8	46.2	35.8	41.4	39.4	51.1	49.0	**83.1**	61.5	49.0	44.2	41.7	83.1
Extreme Daily Snowfall (cm)	36.0	23.1	37.3	25.4	8.1	0.0	0.0	0.0	0.0	9.7	**50.0**	39.1	50.0
Extreme Daily Precipitation (mm)	45.8	46.2	35.8	41.4	39.4	51.1	49.0	**83.1**	61.5	49.0	51.6	41.7	83.1
Extreme Snow Depth (cm)	**109.0**	**109.0**	107.0	36.0	3.0	0.0	0.0	0.0	0.0	6.0	37.0	90.0	109.0

Table 4 Precipitation Climate Normals, Massey, Ontario, 1981 to 2010

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Average Monthly Rainfall (mm)	8.1	8.7	32.2	52.8	76.1	74.7	75.1	85	91.2	96.7	65.8	23	689.2
Average Monthly Snowfall (cm)	50.7	36.3	28.7	7.7	0.5	0	0	0	0	2.3	22.2	52.6	200.9
Average Monthly Precipitation (mm)	58.8	45	60.8	60.4	76.6	74.7	75.1	85	91.2	99	88	75.5	890.1
Extreme Daily Rainfall (mm)	18.8	16.6	40.2	49.4	52.6	44.2	68.4	**85**	50	45.6	54.2	37.2	85
Extreme Daily Snowfall (cm)	20	24	23	18.6	9	0	0	0	0	14	**34**	22	34
Extreme Daily Precipitation (mm)	20	24	40.2	49.4	52.6	44.2	68.4	**85**	50	45.6	54.2	37.2	85
Extreme Snow Depth (cm)	67	74	**90**	58	9	0	0	0	0	4	27	49	90

3.0 Review of Environmental Monitoring Data

This section provides a description of the review of the environmental monitoring data collected since the 2016 ERA as recommended by Clause 11.1 (c) of N288.6-12. It also provides a review of modelling information relevant to the determination of contaminants of potential concern (COPC). An updated COPC screening is provided.

3.1 Overview of Available Data

The Environmental Protection Program (EPP) for BRR describes the effluent and environmental monitoring programs. The data from this program is used in the 2020 Review of the ERA.

The following discharge data and environmental monitoring data were included in the ERA review.

3.1.1 Air Quality Data

Uranium emissions from the Dust Collection Exhaust Vent (DCEV), absorber and incinerator stacks are sampled nearly continuously during operations using a TSI sampler. Nitrogen oxides (NOx) emissions from the absorber stack are continuously monitored by an on-line analyzer. Additional monitoring from the incinerator stack as required by the Environmental Compliance Approval (ECA) includes continuous emission monitoring is completed for oxygen concentration, carbon monoxide and nitrogen oxides in the undiluted flue gas.

Monitoring data from the process stacks is summarized in the quarterly and annual compliance monitoring and operational performance reports which are available on the Cameco community website (www.camecofuel.com/library/media-library) and are summarized in Table 5. All emissions in the review period 2015 – 2019 were below all action levels and/or regulatory limits.

Table 5 Comparison of 2014 Effluent Quality Data with 2015-2019 Data

Constituent	Unit	2016 ERA		2015-2019			
		2014 Average	2014 Maximum	5-year Average	Range of Annual Averages		5-year Maximum
					Min	Max	
DCEV - Uranium	g/h	0.05	0.6	0.048	0.04	0.05	0.28
Absorber - Uranium	g/h	0.01	0.05	0.01	0.01	0.01	0.04
Incinerator - Uranium	g/h	0.01	0.01	0.01	0.01	0.01	0.01
Absorber - NOx	kg/h	2	4.8	2.3	1.6	3.3	5.6
All - Particulate	kg/h	0009	0.041	0.0008	0.006	0.012	0.137

The refinery maintains an Emission Summary and Dispersion Modelling Report (ESDM) documents the air emissions sources at the BRR and maintains the most current listing of all stacks/sources, their specifications and parameters emitted as required by Ontario Regulation 419/05 *Air Pollution – Local Air Quality* (O. Reg. 419/05). The 2016 ERA used air quality data extracted from the 2015 ESDM. The information for nitrogen oxides, carbon monoxide, uranium, suspended particulate matter, fluorides and magnesium was summarized and screened for COPCs in the 2016 ERA. For the 2020 Review of the ERA, the 2019 Consolidated ESDM (ARCADIS,

2020) was used in the same screening process as described in section 3.3. All contaminants not considered negligible under s.8 of O. Reg. 419/05 were included in the screening. From this screening, although it was below applicable criteria, uranium was carried forward as a COPC due to the refinery operations and observations in environmental endpoints.

3.1.2 Water Quality Data

There is one waterborne effluent from the BRR. Once the lagoon is full it is sampled, analyzed and is deemed to meet release criteria, the drain valve is opened and the lagoon drains by gravity into the lake discharge sump which is discharged to the North Channel of Lake Huron via an outfall pipe and diffuser. The diffuser is designed to ensure a minimum 100-fold dilution at the point of entry into the lake under normal conditions. Effluent discharged to the lake is sampled as it is discharging by a flow proportional sampler. A flow meter accurately measures the flow rate from the effluent discharge sump.

Monitoring data from the effluent discharge is summarized in the quarterly and annual compliance monitoring and operational performance reports which are available on the Cameco community website (www.camecofuel.com/library/media-library). All emissions in the review period 2015 – 2019 were below all action levels and/or regulatory limits.

In the 2016 ERA, measured liquid effluent concentrations from 2014 were used. Table 6 presents the comparison of the 2014 data used in the 2016 ERA with the more recent effluent data collected from the BRR for the 2015 to 2019 timeframe. The table shows that in general, the averages of the 2015-2019 measured effluent concentrations are consistent and lower than the 2014 data used in the 2016 ERA. Nickel and ammonia concentrations are marginally higher in the more recent data. Radium-226 was added recently and measurements were not available for the 2016 ERA. Based on this effluent data comparison, the conclusions made in the 2016 ERA regarding the effluent quality remain valid.

Table 6 Comparison of 2014 Effluent Quality Data with 2015-2019 Data

Constituent	Unit	2016 ERA		2015-2019			
		2014 Average	2014 Maximum	5-year Average	Range of Annual Averages		5-year Maximum
					Min	Max	
Uranium	mg/L	0.020	0.066	0.012	0.008	0.016	0.060
Radium-226	mBq/L	-	-	5.9	4.9	8.6	25
Arsenic	mg/L	0.0006	0.0014	0.0004	0.0003	0.0006	0.0018
Copper	mg/L	0.008	0.129	0.0055	0.0038	0.0078	0.032
Lead	mg/L	0.0005	0.0045	0.0005	0.0004	0.0007	0.013
Nickel	mg/L	0.0017	0.0033	0.0020	0.0016	0.0023	0.0096
Zinc	mg/L	0.031	0.062	0.027	0.024	0.030	0.076
Ammonia as N	mg N/L	0.32	1.1	0.37	0.24	0.40	1.1
Nitrate as N	mg N/L	20.3	42.1	17.8	12.6	22	41.3
Nitrite as N	mg N/L	0.70	2.0	0.70	0.60	0.84	2.4
Chloride	mg/L	40	99.7	37.5	31.9	42.5	142
TBP	mg/L	0.99	3.8	0.61	0.48	0.80	2.9
TSS (at 103°C)	mg/L	9.2	25.1	8.9	7.0	10.4	85.1
TSS (at 300°C)	mg/L	4.7	10.4	3.4	2.7	3.7	27.3
TOC	mg/L	11.8	32	11.3	10.8	12.2	42

Constituent	Unit	2016 ERA		2015-2019			
		2014 Average	2014 Maximum	5-year Average	Range of Annual Averages		5-year Maximum
					Min	Max	
Cyanide	µg/L	1.4	11	1.4	1.1	2.2	7
Hydrogen Peroxide	mg/L	1.1	30	1.2	0.14	1.8	100
Flowrate	m^3/hr	103	115	101	99	104	127
pH	-	7.8	8.4	7.8	7.7	7.9	8.6

3.1.3 Environmental Monitoring Data

The environmental monitoring program is intended to collect data to monitor the impact of the airborne and aqueous discharges into the offsite receiving area in the vicinity of the refinery by verifying concentrations of contaminants of potential concern in the airborne, terrestrial and aquatic receiving environments. This data is used to determine exposure point concentrations for comparison to screening criteria from available standards to confirm COPCs.

The atmospheric environmental monitoring program is intended to collect data for uranium to assess whether airborne emissions from the BRR may be detected at offsite locations in the vicinity of the refinery. Data from the high volume (hi-vol) air samplers were used in the validation of the model in the ESDM.

The 2016 ERA assessed groundwater data, soil data, surface water data, sediment data and gamma measurement data. The 2020 Review of the ERA assessed groundwater data, soil data and surface water data available for the period 2015-2019. A discussion of the 2015 Effluent Plume Study (ARCADIS, 2015) is included for completeness. Gamma measurement data was not included in the 2020 ERA review, as this was recently assessed in the 2018 Derived Release Limit report (ARCADIS, 2018).

3.2 Updated Modelling

3.2.1 Air Dispersion

As part of the 2020 Review of the ERA, updated air dispersion modelling was completed for uranium (IEC, 2020) using emissions data and model setup files from the 2019 Consolidated ESDM Report (Arcadis, 2020). The meteorological data set used in the ESDM Report was prepared by the Ontario Ministry of Environment, Conservation and Parks (MECP) using AERMET. The surface station used to develop the data set (Killarney) had missing data and required substitution using data from two other stations (Gore Bay and Sudbury). As the meteorological data set was prepared by the MECP and is acceptable for determining compliance with Ontario Regulation 419/05 (O.Reg. 419/05), this lends confidence to the meteorological data. Furthermore, any uncertainty with the data set can be examined through model validation, which is discussed in Section 4.3.

The uranium emission rates from the ESDM Report are replicated in Table 7, along with the source parameters used in the model. The building setup in the existing model files was used to run the building downwash model, BPIP-Prime. The emission rates from the incinerator stack, absorber stack, and DCEV were based on the highest emission rates from the last three years of stack testing results (i.e., 2017, 2018 and 2019), which is an acceptable method for assessing compliance with O.Reg. 419/05 standards. The emissions from the HVAC units are estimated based upon in-plant air monitoring and filter efficiency factors applied to the HVAC.

Table 7: Model Source Parameters and Uranium Emission Rates

Model ID	Flow Rate (m^3/s)	Exit Temperature (˚C)	Stack Diameter (m)	Stack height above grade (m)	Release Type	Stack UTM Coordinates[1] (X,Y) (m)	Uranium Emission Rate (g/s)
ABSORBER	4.2	38	0.76	24.1	Vertical	344360, 5116188	3.00E-06
DCEV	17.2	34	1.2	31.1	Vertical	344265, 5116152	4.65E-05
INC	3.7	46	0.61	27.45	Vertical	344338, 5116131	1.32E-06
HVAC1A	8.4	20	2.87	24.5	Horizontal	344256, 5116158	1.10E-05
HVAC1B	8.4	20	2.87	24.5	Horizontal	344258, 5116156	1.10E-05
HVAC2A	14	20	1.63	15.8	Horizontal	344275, 5116188	4.73E-06
HVAC3A	8.4	20	2.87	27	Horizontal	344352, 5116161	1.21E-05
HVAC3B	8.4	20	2.87	27	Horizontal	344354, 5116158	1.21E-05
BOILER	21	269	1.22	36	Vertical	344354, 5116140	0
FIREPUMP	0.6	523	0.15	4.6	Vertical	344140, 5115972	0
GEN	1.6	523	0.25	11.8	Vertical	344356, 5116125	0

Notes:
[1] Universal Transverse Mercator (UTM) coordinates are defined in the North American Datum of 1983 (NAD83).

To support the use of the model in the 2020 Review of the ERA, additional assessments were undertaken to validate the model and provide additional information regarding uranium deposition (IEC, 2020). Uranium was modelled using adjusted emission rates for HVAC emissions and the particle size distribution from the 2007 LEHDER stack test report (IEC, 2020).

Figure 5 presents the contour plot for maximum annual uranium concentrations predicted by AERMOD. The highest annual concentration is predicted to occur at a fenceline receptor on the west side of the facility and has a value of 2.5E-03 µg/m³. This prediction is consistent with the 2018 DRL report, which predicted a maximum annual concentration of 2.6E-03 µg/m³ after adjustment (Arcadis, 2018); however, it is a factor of five greater than the annual uranium concentration considered in the 2016 ERA (5.0E-04 µg/m³). As discussed in Section 6.2, this difference does not change the conclusion of the 2016 ERA as the air pathway only represents a minor pathway of exposure (CanNorth, 2020).

Figure 6 presents the contour plot for maximum annual uranium deposition rates predicted by AERMOD. The highest annual deposition rate has a value of 3.5E-04 g/m². This prediction is within the range of deposition rates shown in Figure 3.2 of the 2016 ERA, but it almost 25 times lower than the maximum deposition rate (8.8E-03 g/m²). Additionally, it appears that the maximum deposition rate in the 2016 ERA occurs on the west side of the facility, whereas in the updated model run, the maximum is on the east side. Since the ERA is lacking detail, it is uncertain as to what is causing the differences and it is difficult to draw any conclusions from this exercise. However, it is important to note that the uranium deposition rates were not used in the 2016 ERA and these differences do not affect the conclusion of the ERA (IEC, 2020).

Figure 5 Maximum Annual Uranium Concentration

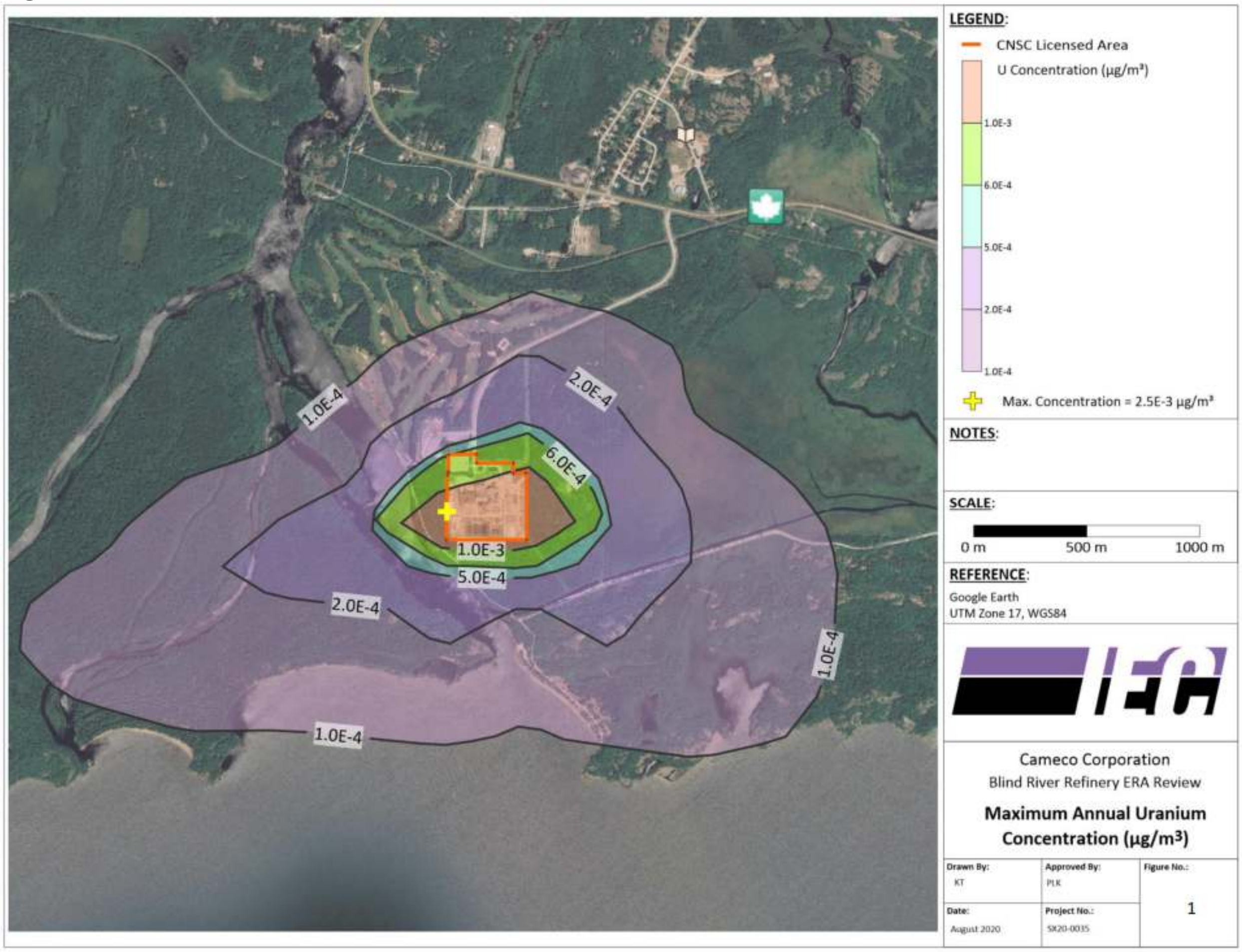
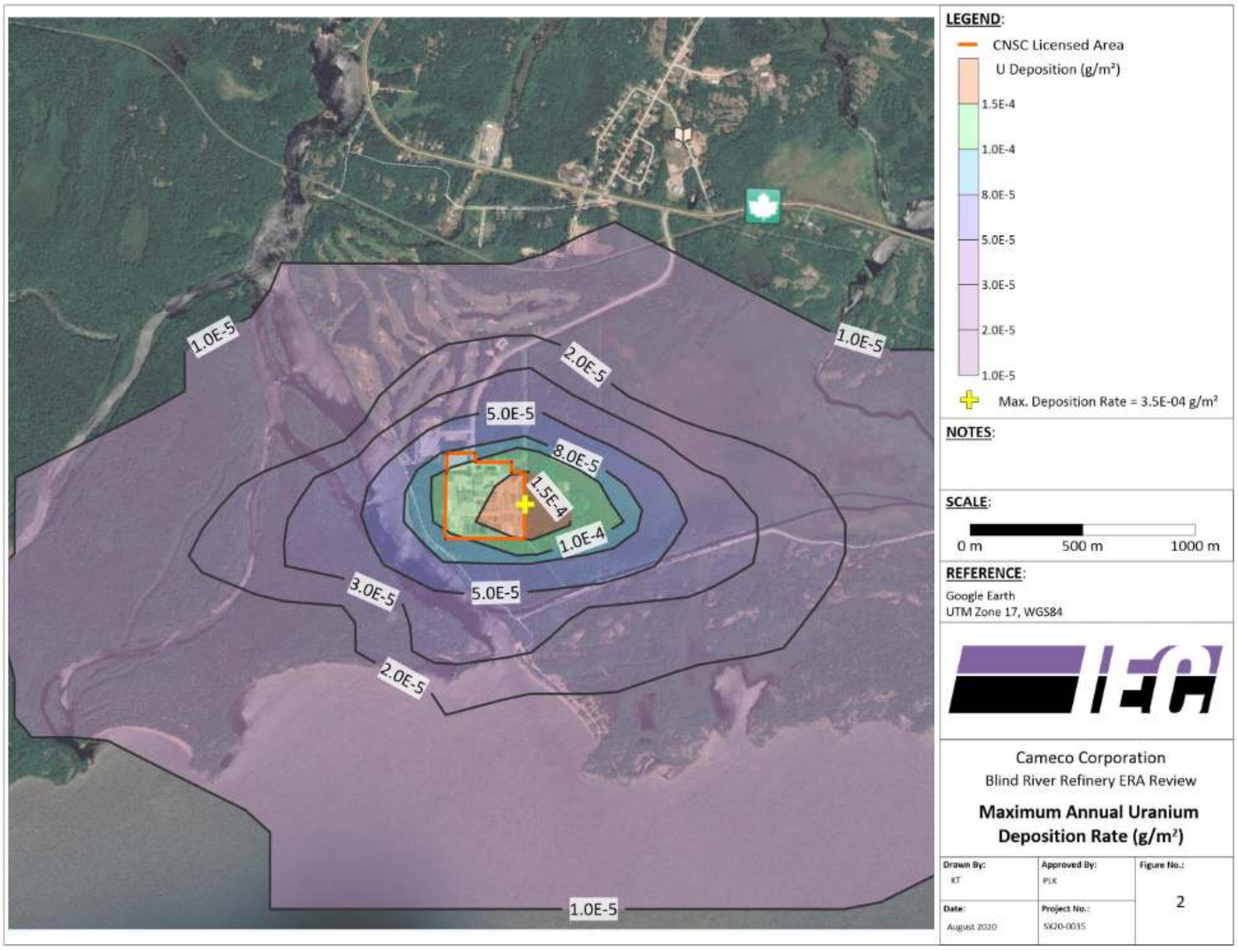


Figure 6 Maximum Annual Uranium Deposition Rate (g/m^2)



3.2.2 Liquid Effluent Release Modelling

Liquid effluent release modelling was completed as part of the ARCADIS (2015) *Plume Modelling, Delineation & Sediment Study,* based on liquid effluent quality data from 2014. The 2015 study was an update to the 2006 Effluent Plume Delineation and Sediment Quality study (SENES 2006) and used the same diffuser characteristics, the same surface water measurement locations, the same upgradient and downgradient sediment sampling locations along with updated sediment screening criteria and updated version of the model. Overall, modelling predicts the effluent plume that results from release of liquid effluents from the submerged diffuser into the Lake Huron North Channel.

To model the Cameco effluent plume using Cornell Mixing Zone Expert System (CORMIX) several input parameters are needed to characterize the effluent, the outfall diffuser, and the ambient aquatic receiving environment. Parameters characterizing the effluent and the outfall diffuser exhibit little variation in comparison to those characterizing the receiving aquatic environment. Since the receiving aquatic environment experiences a wide range of conditions (e.g. varying temperatures, wind velocities, water current velocities, etc.), six different scenarios were modelled (ARCADIS, 2015). Each scenario is based on changes in one parameter, such as minimum current velocity versus maximum current velocity. In all scenarios, the parameters characterizing the effluent and the outfall diffuser remain the same. It is important to note that in all 6 scenarios, all parameters used to represent effluent characteristics and diffuser geometry (and release rates) are the same as those used in the prior SENES (2006) plume study. For completeness, a detailed table of all parameters used in all scenarios (including redundancies between scenarios) is available in Table 8.

A summary of modelling results for each of the 6 scenarios is provided in Table 5, comparing the distances at which certain dilutions are achieved. A field verification activity followed the modelling where field measurements of surface water conductivity were obtained at specific locations (upgradient and downgradient of the diffuser) in order to perform a comparison of empirical measurements to CORMIX predicted levels in surface water. This is one of the techniques approved by Environment Canada (2002) in Aquatic Environment Effects Monitoring (EEM) programs.

Data obtained from verification field measurements show a relationship between conductivity and downstream distance from the diffuser, where surface water has overall higher conductivity to the west, which gradually decreases as the current travels east, past the diffuser. The relationship also extends upgradient beyond the diffuser, though this likely results from flows from the nearby Mississagi River into the lake. The Mississaugi River typically experiences high flow rates in late May.

Overall, CORMIX plume modelling results indicate that a dilution of 50x is achieved essentially immediately upon release from the diffuser, with 100x dilution being achieved within 11 m, for all but the worst-case scenario (minimal current). A summary of all modelled scenarios is shown in Table 9. A comparison of measured versus modelled results was performed using the method outlined in the prior SENES (2006) study, by first calculating the conductivity of a 1% effluent solution (i.e. a dilution of 100x) from measured data, then comparing this value to its corresponding location in the modelled plume. The comparison shows that in reality, the concentration at this location is much less than predicted; and from this it is reasonable to infer that a dilution of 100x is being achieved not only at the predicted 11 m distance, but also at distances much closer to the diffuser (ARCADIS, 2015).

The resulting plume prediction for 'Scenario 1' (near-worst-case lake current velocity; conservative wind velocity; and, stratified lake temperature profile) is shown in Figure 7.

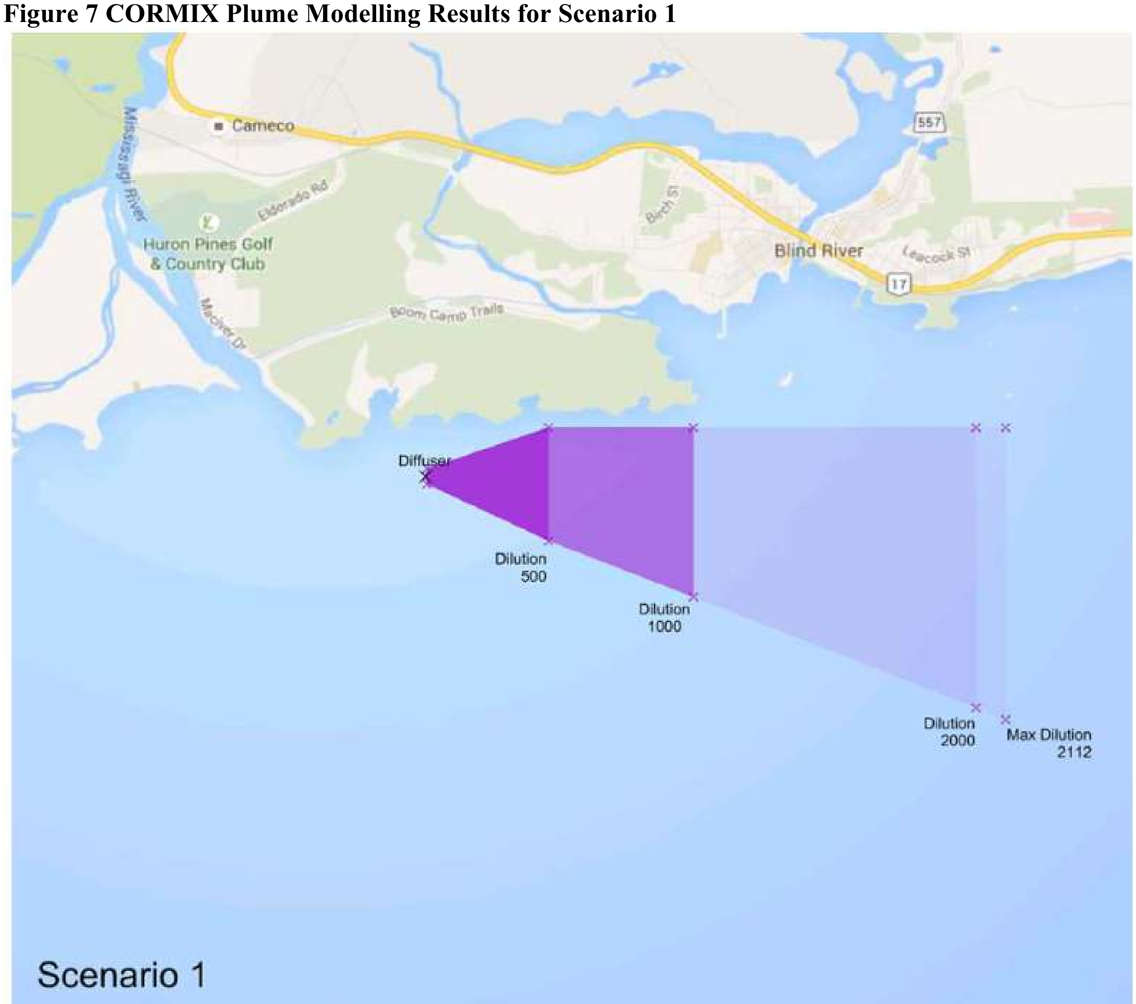
Table 8 Plume Modelling Source Parameters (From ARCADIS, 2015)

Scenario No.	Scn 1 (Base)	Scn 2 (Uniform Temp)	Scn 3 (Min. Current)	Scn 4 (Max. current)	Scn 5 (Wind Velocity)	Scn 6 (Wind and Current)	Comments
Parameters							
1) Effluent Characteristics	-	-	-	-	-	-	-
1.1 - Assume conservative effluent (i.e. no decay/loss/degredation across release time)	Yes	Yes	Yes	Yes	Yes	Yes	All scenarios conservatively assume no loss or degradation of the effluent. In other words, all of the effluent is assumed to be released to the environment.
1.2 - Discharge concentration (mg/L above background)	1 (unit concentration)	1 (unit concentration)	1 (unit concentration)	1 (unit concentration)	1 (unit concentration)	1 (unit concentration)	All scenarios are based on a unit-concentration of effluent
1.3 - Flow Rate (m3/sec)	0.028	0.028	0.028	0.028	0.028	0.028	All scenarios are based on a 100 m3/hr release rate, for approximately 20 hrs, as per SENES (2006)
1.4 - Effluent temperature (°C)	19.7	19.7	19.7	19.7	19.7	19.7	SENES (2006), for all scenarios
2) Ambient Environment Characteristics	-	-	-	-	-	-	-
2.1 - Average Depth (m)	4	4	4	4	4	4	SENES (2006), for all scenarios
2.2 - Depth at discharge (m)	4	4	4	4	4	4	SENES (2006), for all scenarios
2.3 - Wind Speed (m/s)	2	2	2	2	5	5	CORMIX recommended default is 2 m/s. 5 m/s is the maximum average daily wind speed, based on data from 2000-2012 (Weatherspark.com, 2015).
2.4 - Lake current type (unitless)	Steady	Steady	Steady	Steady	Steady	Steady	SENES (2006), for all scenarios
2.5 - Lake current velocity (m/s)	0.025 (rep. velocity)	0.025 (rep. velocity)	0.02 (min. velocity)	0.05 (max velocity)	0.025 (rep velocity)	0.05 (max velocity)	0.025 m/s is a representative, near-worst-case current velocity. 0.02 m/s is minimum, worst-case (near-stagnant) current velocity. 0.05 m/s is maximum typical current velocity. SENES (2006)
2.6 - Bounded/Unbounded (unitless)	Unbounded	Unbounded	Unbounded	Unbounded	Unbounded	Unbounded	Assumed unbounded for all cases (i.e. lake, not confined river
2.7 - Freshwater/Marine (unitless)	Freshwater	Freshwater	Freshwater	Freshwater	Freshwater	Freshwater	Lake Huron
2.8 - Lake Temperature & distribution (°C)	Stratified Surface: 18.1°C Bottom: 15.5°C	Uniform (16.5°C; SENES 2006)	Stratified Surface: 18.1°C Bottom: 15.5°C	Stratified Surface: 18.1°C Bottom: 15.5°C	Stratified Surface: 18.1°C Bottom: 15.5°C	Stratified Surface: 18.1°C Bottom: 15.5°C	If modelling based on uniform temperature, the difference in surface water temperatures across all depthsshould be less than 1 °C. Average of SENES 2006 measured temperature data at reference locations indicates that a difference of up to 2.5°C exists between average surface and average bottom layer temperatures. (SENES 2006)
2.9 - Mannings Coefficient (unitless)	0.03	0.03	0.03	0.03	0.03	0.03	Upper end of CORMIX default range for clean/straight natural rivers, and earth channels with some stone and weed. Qualitative comparison to USGS (2015) verified example manning's coefficients for select river sites shows good overall similarities.
3) Diffuser/Discharge Characteristics	-	-	-	-	-	-	-
3.1 - CORMIX Module Type (unitless)	Multiple Ports	Multiple Ports	Multiple Ports	Multiple Ports	Multiple Ports	Multiple Ports	SENES (2006), for all scenarios
3.2 - Nearest shore/bank (unitless)	Left	Left	Left	Left	Left	Left	SENES (2006), for all scenarios
3.3 - Diffuser length (m)	61	61	61	61	61	61	SENES (2006), for all scenarios
3.4 - Distance to 1st port (from shore) (m)	500	500	500	500	500	500	SENES (2006), for all scenarios
3.5 - Distance to last port (from shore) (m)	561	561	561	561	561	561	SENES (2006), for all scenarios
3.6 - Port height (above bottom) (m)	0.63	0.63	0.63	0.63	0.63	0.63	SENES (2006), for all scenarios
3.7 - Port diameter (m)	0.025	0.025	0.025	0.025	0.025	0.025	SENES (2006), for all scenarios
3.8 - Contraction Ratio (unitless)	1	1	1	1	1	1	CORMIX recommended default for well rounded nozzle/opening. SENES (2006), for all scenarios
3.9 - Number of ports (unitless)	15	15	15	15	15	15	SENES (2006), for all scenarios
3.10 - Alignment Angle (GAMMA) (°)	90	90	90	90	90	90	Angle between diffuser line and ambient current, measured counter-clockwise from ambient current direction. SENES (2006)
3.11 - Port/Nozzle configuration (unitless)	Single	Single	Single	Single	Single	Single	Each riser leads to a single port/nozzle. In other words, there are not multiple nozzles on each riser SENES (2006)
3.12 - Port/Nozzle overall direction (unitless)	Unidirectional	Unidirectional	Unidirectional	Unidirectional	Unidirectional	Unidirectional	All nozzles generally point in the same direction. SENES (2006) indicates overall south-east facing nozzle direction; though each nozzle alternates by a slight (10°) angle.
3.13 - Angle (THETA) (°)	10	10	10	10	10	10	Angle between the nozzle centreline and the horizontal plane. 0° represents horizontal-facing nozzles. SENES(2006)
3.14 - Angle (SIGMA) (°)	270	270	270	270	270	270	Horizontal angle between the direction of discharge and the direction of ambient current flow, measured counter-clockwise from the ambient current direction. 270° represents all nozzles pointing perpendicular (i.e. to the right) of the current direction, from the point of view of an observer facing downstream. SENES (2006)
3.15 - Angle (BETA) (°)	0	0	0	0	0	0	Nearest angle between the horizontal projection of the average port/nozzle centreline direction, and the diffuser axis. 0° represents all nozzles oriented along the diffuser line (i.e. a staged diffuser arrangement).
3.16 - Nozzle Direction	Same direction	Same direction	Same direction	Same direction	Same direction	Same direction	All nozzles generally point in the same direction. SENES (2006) indicates overall south-east facing nozzle direction.
4 Mixing Zone	-	-	-	-	-	-	-
4.1 - Mixing Zone (m)	n/a	n/a	n/a	n/a	n/a	n/a	Applicable only to US facilities where mixing zone size criteria apply.
4.2 - Water Quality Standards (unitless)	n/a	n/a	n/a	n/a	n/a	n/a	No water quality standards specified. Comparison to water quality standards can be accomplished post-modeling
4.3 - Region of Interest (m)	5000	5000	5000	5000	5000	5000	Town of Blind River is located approximately 5 km downgradient (BRR DRL; SENES 2013).
4.4 - Output Steps per Module	20	20	20	20	20	20	

Table 9 Modelling Results – Distance vs. Dilution, Scenario Comparison

Dilution	Scenario 1 (Base)	Scenario 2 (Uniform Temp. Distribution)	Scenario 3 (Minimum Current)	Scenario 4 (Maximum Current)	Scenario 5 (Base Current and Wind)	Scenario 6 (Max. Current and Wind)
10	< 1 m	< 1 m	< 1 m	< 1 m	< 1 m	< 1 m
50	1 m	< 1 m	1 m	2 m	1 m	2 m
100	11 m	3 m	20 m	5 m	10 m	5 m
500	1,061 m	363 m	1,140 m	657 m	371 m	371 m
1000	2,311 m	681 m	2,585 m	1,303 m	668 m	719 m
2000	4,747 m	949 m	-	2,455 m	1,331 m	1,262 m
Maximum Achieved Dilution	2,112 (at 5,000 m)	22,077 (at 5,000 m)	1,940 (at 5,000 m)	4,002 (at 5,000 m)	8,966 (at 5,000 m)	8,669 (at 5,000m)

Figure 7 CORMIX Plume Modelling Results for Scenario 1



3.3 Updated COPC Screening

The environmental monitoring data collected since the last ERA in 2016 was reviewed to determine whether additional contaminants of potential concern (COPC) need to be considered. The 2016 ERA used the maximum concentrations in soil, groundwater, surface water and sediments in the screening process. COPC screening followed the methodology set out in the 2016 ERA (ARCADIS, 2016). Analytes were carried forward for further evaluation in the ERA review if the analyte satisfied one of the following three conditions:

1. The maximum concentration exceeds the corresponding screening criterion; or
2. a) There are measurable concentrations; and

   b) corresponding screening criteria are not available; and

   c) toxicity benchmarks are available; or
3. They were identified in other relevant connected environmental media as COPCs (i.e., at levels exceeding screening criteria in those connected media) and are related to current site operations.

3.3.1 Air

Air screening follows the overall screening procedure outlined above using concentrations at the point of impingement (POI), all contaminants not considered negligible under s.8 of O. Reg. 419/05 were included in the screening. The results of air screening are shown in Table 10.

Only uranium was identified as a COPC due to its relevance to current site operations.

Table 10 Air – COPC Screening (From 2019 ESDM – ARCADIS (2020)

Contaminant	CAS No.	Aggregate Emission Rate (g/s)	Averaging Period	AERMOD Maximum Ground-level Concentration (µg/m^3)	Screening Criteria (µg/m^3)	% of Criteria (%)	Evaluate as COPC?	Comments
Nitrogen Oxides (NOx)	10102-44-0	2.17	1-hr	180.6	400	45%	No	Less than screening criterion
Nitrogen Oxides (NOx)	10102-44-0		24-hr	47.2	200	24%	No	Less than screening criterion
Carbon Monoxide (CO)	630-08-0	0.63	½-hr	24.4	6000	1%	No	Less than screening criterion
Uranium (U)	7440-61-1	0.000102	Annual	0.00063	0.03	2%	Yes	Less than screening criterion. Identified as a COPC in other relevant connected media. Directly relevant to site operations.
Suspended Particulate Matter (SPM)	-	0.08	24-hr	1.39	120	1%	No	Less than screening criterion
Cadmium	7440-43-9	0.000006	24-hr	0.00013	0.025	1%	No	Less than screening criterion
Hexavalent chromium	7440-47-3	0.000019	Annual	0.000074	0.00014	53%	No	Less than screening criterion
Iron	15438-31-0	0.0008	24-hr	0.0170	4	0%	No	Less than screening criterion
Manganese	7439-96-5	0.00022	24-hr	0.0144	0.4	4%	No	Less than screening criterion
Magnesium	7439-95-4	2.80E-04	24-hr	5.10E-03	0.2	3%	No	Less than screening criterion
Nickel	7440-02-0	0.00025	Annual	0.00195	0.04	5%	No	Less than screening criterion
Phosphorus	7723-14-0	0.00062	24-hr	0.0136	0.5	3%	No	Less than screening criterion
Potassium	7440-09-7	0.00055	24-hr	0.0131	1	1%	No	Less than screening criterion

3.3.2 Soil

Table 11 provides a summary of the updated screening for soil. The maximum uranium concentration in the recent measured data is lower than the 2016 ERA maximum value and remains well below the screening criteria for soil. However, as indicated in the 2016 ERA, since it is related to site operations, uranium is still retained as a COPC in soil (CanNorth, 2020).

Table 11 Soil: Updated Screening

Parameter	Units	Screening Criteria		2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	2020 Review COPC?	Comments
		CCME	MOE					
Uranium	µg/g	23	33	22.1	9.7	Yes	Yes	Below screening criteria but is an operational parameter

3.3.3 Groundwater

Table 12 provides a summary of the updated screening for groundwater. As indicated in Table 12, the groundwater screening should only consider uranium for the groundwater evaluation. A further screening of the ammonia and TBP concentrations which is typically done in risk assessments will demonstrate that these constituents do not represent a risk and do not need to be evaluated further. It should be noted that there is no ammonia source from current operations. The increase of the uranium concentration in groundwater from the 2016 ERA does not change the COPC identification as uranium was identified and evaluated in the 2016 ERA. The increase in the uranium concentration in the groundwater does not affect human health as people do not drink groundwater from the site. From an ecological standpoint, the results are unchanged as the screening values are very low (CanNorth, 2020).

Table 12 Groundwater: Updated Screening

Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Ammonia	mg-N/L	NA	4.1	6.2	Yes	No	See secondary screening
Chloride	mg/L	790	210	590	No	No	Below screening criteria
Nitrite	mg-N/L	NA	0.31	0.6	No	No	Previous conclusions apply
Nitrate	mg-N/L	NA	7.4	4.9	No	No	Previous conclusions apply
Sulphate	mg/L	NA	540	110	No	No	Previous conclusions apply
Arsenic	µg/L	25	5.7	4.6	No	No	Below screening criteria
Uranium	µg/L	20	8.9	27	Yes	Yes	Above screening criteria
Radium-226	Bq/L	NA	0.03	0.04	Yes	No	Below screening criteria

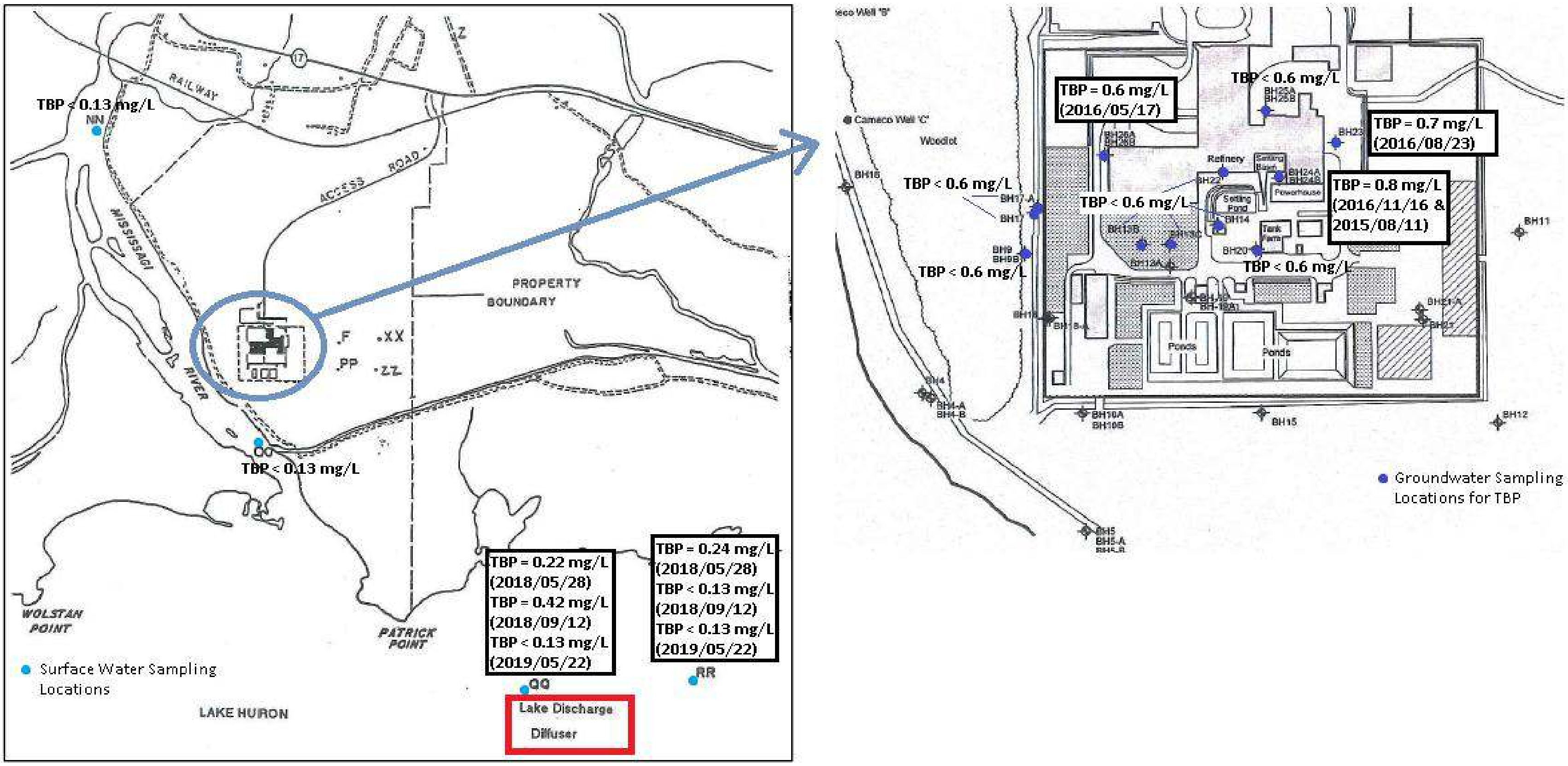
Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
TBP	mg/L	NA	3	0.8	Yes	No	See secondary screening

Note – NA not available. For simplicity, not all parameters considered in the 2016 ERA screening Table 4.1 were included here (i.e., non-COPC parameters like pH, conductivity, hardness and some general chemistry parameters)

Groundwater generally upwells into surface water and Table 13 demonstrates that the uranium concentration in surface water is actually lower in the current time period. Thus the increase in the uranium concentration in groundwater does not change the conclusions of the 2016 ERA. Since there is no screening criterion for ammonia in groundwater, a conservative approach can be used whereby the groundwater concentrations are screened against the more conservative surface water guideline. The use of the surface water guideline is deemed appropriate as groundwater generally upwells into a surface water body. Based on the temperature and pH of the surface water, a surface water quality guideline of 12.6 mg-N/L (Based on a pH of 7.0 and temperature of 5°C, converted to mg-N/L using a conversion factor of 0.8224) for total ammonia based on the CCME (2020) guideline was considered to be the appropriate value. The maximum measured total ammonia concentration in the recent groundwater data of 6.2 mg-N/L is below the surface water quality guideline; therefore, ammonia in groundwater is considered not to represent a risk and should not be evaluated quantitatively. This approach is also corroborated by examining the surface water data where the ammonia concentrations between the 2016 ERA and the more recent data range between 1 and 2 mg/L and is below the surface water guideline and does not represent a risk (CanNorth, 2020).

Similarly, there is no screening criterion for TBP in groundwater; therefore, the groundwater data was evaluated further to determine whether TBP in groundwater should be considered as a COPC for the site. TBP has only been detected in groundwater within the site complex and only at two specific locations in the 2015 to 2019 data. Most groundwater monitoring locations have nondetectable concentrations of TBP (<0.6 mg/L) and TBP has not been detected in groundwater outside of the site complex. The general direction of groundwater flow is from the site to the Mississagi River. Figure 8 shows that the surface water data collected from the Mississagi River does not have a detectable TBP concentration; the upstream sampling location NN has a TBP concentration of <0.13 mg/L, as does downstream sampling location OO (<0.13 mg/L). Considering the limited detected concentrations of TBP in groundwater and the lack of evidence of any impact within the receiving surface water body, TBP in groundwater does not represent a risk and should not be selected for further consideration in the risk assessment (CanNorth, 2020).

Figure 8 Measured TBP in groundwater



3.3.4 Surface Water

Table 13 provides a summary of the updated screening for surface water. As indicated, the maximum measured uranium concentration in surface water is now lower than the 2016 value used in the ERA and is below the screening criterion. However, given that uranium is a concern at the site, it is still retained for further assessment.

For TBP, a secondary screening for ecological and human health was considered which is a common approach used by risk assessors. The screening criteria for TBP presented in Table 13 is an interim provincial water quality objective (PWQO) from the then Ontario Ministry of Environment and Energy (OMOEE) (1994). It is noted that the OMOEE provides no basis for how the PWQO was derived.

The maximum measured value of 420 µg/L in surface water was measured at the lake discharge diffuser (QQ, Figure 8). At this location concentrations have also been measured below the detection limit. The average of the 2015 to 2019 data is 180 µg/L. The measured data also shows lower concentrations at distances removed from the diffuser. From a human health standpoint, it is unreasonable to assume that human receptors drink water at the diffuser location and therefore a more reasonable drinking water concentration is derived based on the CORMIX model presented in the 2016 ERA (Also see Section 3.2.2). Using very conservative assumptions of lake velocity and wind velocity, the model derived a dilution factor of about 500 which is considered to be appropriate for human exposure. Applying this dilution factor to the average concentration measured at the diffuser results in a concentration of 0.36 µg/L which is below the interim PWQO and therefore TBP is not considered to represent a risk for human receptors and should not be considered further (CanNorth, 2020).

Table 13 Surface water: updated screening

Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Ammonia (total)	mg-N/L	12.5	2	1.6	No	No	Below screening criteria
Nitrate	mg-N/L	13	2	0.5	No	No	Below screening criteria
Uranium	µg/L	5	7.4	2.9	Yes	Yes	Is an operational parameter
Radium-226	Bq/L	1	0.02	0.04	Yes	No	Below screening criteria
TBP	µg/L	0.6	<600	420	Yes	No (HH) Yes (Eco)	See secondary screening

Note: For simplicity, not all parameters considered in the 2016 ERA screening Table 4.2 were included here (i.e., non-COPC parameters like pH, conductivity, hardness and some general chemistry parameters
HH-Human Health; Eco-Ecological health

For the consideration of ecological health, more recent work on the toxicity of TBP to aquatic organisms has been conducted by the European Chemicals Agency (ECHA). They derived a predicted no-effect concentration (PNEC) for TBP of 35 to 82 µg/L for freshwater aquatic organisms (ECHA 2020). Since the maximum measured concentration at the diffuser is above this value, TBP in surface water should be evaluated in the assessment for aquatic receptors (CanNorth, 2020) as discussed in Section 6.4.1.

3.3.5 Sediments

No new sediment data was available for the 2020 Review of the ERA. The available sediment data for COPCs from the 2015 plume study (ARCADIS, 2015) is provided in Table 14. The five reference/upgradient locations were located to the west of the mouth of the Mississaugi River, The fifteen exposure locations were downgradient to the diffuser which is to the east of the mouth of the Mississaugi River.

Table 14

Constituent	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
Chromium	µg/g	26	29	N/A	Yes	N/A	Above screening criteria. Noted that the exceedences occurred at reference (upstream) locations
Uranium	µg/g	32	0.64	N/A	Yes	N/A	Below screening criteria but operational parameter
Vanadium	µg/g	27.3	98	N/A	Yes	N/A	Above screening criteria. Noted that the exceedences occurred at reference (upstream) locations

3.3.6 Comparison of EMP with 2016 ERA Predictions

From looking at the data in the 2016 ERA in comparison with the more recent monitoring data at the BRR, it appears that concentrations in the various media are declining and therefore the more recent data does not have a significant impact on the screening process for the COPC. The more recent monitoring data were compared to the exposure point concentrations (EPCs) used in the 2016 exposure assessment to determine the impact on the conclusions of the 2016 ERA. This comparison found that that most of the recent data remain consistent with the EPCs, except that the maximum uranium level in groundwater is higher than that used in the 2016 assessment. This increase does not have a significant effect on the conclusion of the 2016 ERA (CanNorth, 2020).

4.0 Review of Environmental Issues Identified in 2016 ERA

This section provides a review of environmental issues revealed by the 2016 EMP and a review of other issues identified with the methodology of the 2016 ERA and the impact of these issues on problem formulation in the ERA.

4.1 Follow-up to Recommendations in the 2016 ERA

The 2016 ERA made four recommendations:

1. Presently there is no information on local background levels of Ra-226, which may be naturally elevated. Completing a study to determine local background levels of radionuclides in environmental media would be beneficial, as it would help to provide perspective on the levels of radionuclides measured in surrounding environmental media in comparison to facility effluents.

2. It is recommended to update this ERA at least every 5 years, consistent with CSA N288.6 (2012) recommended update cycle.

3. The detection limit of 0.6 mg/L TBP in surface water samples is higher than the EcoRA toxicity reference values (TRVs) for aquatic vegetation, fish and benthic invertebrates. It is recommended that TBP to be analyzed by a procedure with a lower detection limit, if possible.

4. It is recommended to include porewater sampling for ammonia in any future sediment sampling program so that field data will be available for future updates of the EcoRA. Furthermore, a lower ammonia detection limit than the one reported in the 2015 sediment sampling program (20 µg/g) should be utilized in future studies.

4.1.1 Background levels of Ra-226

This recommendation was reviewed by Cameco and determined not to warrant further investigation. While Ra-226 is part of the U-238 decay chain, it is frequently measured at or below the method detection limit in the liquid effluent discharge. The screening for COPCs in the 2016 ERA identified it as a COPC due to its relation to the refining process. However, this review did not carry Ra-226 forward as a COPC.

4.1.2 Update of the ERA

This review meets the requirements of a review of the ERA as per Clause 11 of N288-6-12.

4.1.3 Detection Limit for TBP

The 2016 ERA identified tributyl phosphate (TBP) as a COPC due to the fact that there were no guidelines in sediments and in surface water the method detection limit was above the interim PWQO. It was recommended following the 2016 ERA to reduce the method detection limit for the laboratory analysis of TBP, and this was achieved in 2017 with a change from a detection limit of 0.6 mg/L to 0.13 mg/L for surface water samples. The lower detection limit is the best that can be achieved while maintaining confidence in the results. TBP has not been measured in the groundwater at the BRR since 2016, though total organic carbon and phosphate are monitored as indicators for TBP. Cameco issued updates to the groundwater monitoring program in 2017 to reflect the changes. Reported concentrations in surface water continue to be mostly at the detection limit; however, detectable concentrations have been observed at the diffuser (QQ, max of 0.42

mg/L) and in the vicinity of the diffuser (RR, max of 0.24 mg/L), as shown in Figure 1. The 0.13 mg/L detection limit represents the lowest achievable level from a technical point of view and while this number remains above the PNEC (0.035 mg/L) and the PWQO (0.006 mg/L), further evaluation in surface water demonstrates that the detection limit for TBP does not represent a risk to aquatic life (CanNorth, 2020).

For TBP, the European Chemicals Agency provides a recent evaluation of aquatic toxicity data for the derivation of the predicted no-effect concentration for aquatic life (ECHA 2020). A summary of the most sensitive endpoints from the aquatic toxicity data considered for the PNEC is provided in the following table.

Receptor	Effects Concentration (mg/L)	Test Species	Effects Endpoint/Test Type
Fish	0.82	*Oncorhyncus mykiss*	NOEC for fish ELS
Aquatic invertebrate	1.3	*Daphnia magna*	NOEC 21-day reproduction test
Aquatic plant	1.1	*Scenedesmus subspicatus*	EC50 96-hr (biomass)

These concentrations are well above the maximum measured concentration of TBP (0.42 mg/L) at the diffuser and indicates that negative effects on even the most sensitive receptor (fish) are not expected based on the measured TBP concentrations. The comparison with the maximum measured concentration at the diffuser is conservative, especially for the assessment of fish, since fish are mobile and would not be located exclusively at the diffuser.

4.1.4 Porewater sampling for ammonia

Sediment monitoring was assessed in a study in 2006 (SENES, 2006) and another in 2015 (ARCADIS, 2015). The conclusions of the 2015 study stated that based on the results of the study and the previous SENES (2006) study, there is a good understanding of station effluents their dilution in the North Channel (given that both modelled results and field measurements are available, along with verification and comparison between them). As such, unless conditions change significantly, there seems to be no need to routinely repeat this study. While future revalidation of the ongoing applicability of these results is appropriate, with no change to the diffuser design of effluent parameters, this is expected to be undertaken at the 10-year point, at which point enhancements to sediment monitoring will be completed.

With respect to ammonia, the use of anhydrous ammonia in the refining process was eliminated prior to 2010, and as such there is not a source of ammonia at BRR and ongoing monitoring and assessment is not required. In the 2020 Review of the ERA, an independent review stated that since ammonia is not considered a COPC the recommendation to collect ammonia porewater may no longer be necessary (CanNorth, 2020). Ammonia will not be included in the design of the follow-up sediment and plume modelling study when completed.

4.2 Follow-Up to Issues raised in Regulatory Review of the 2016 ERA

CNSC staff raised a number of areas for follow-up with the 2016 ERA. Those not previously discussed in this review are included in this section. This included a discussion of uncertainties associated with the ERA, opportunities for improvement to the site characterization and other assumptions made in the 2016 ERA.

4.2.1 Discussion of Uncertainties

Additional information regarding uncertainties should have been included in the 2016 ERA and was provided to CNSC staff in separate correspondence (Cameco, 2018). It is represented in this section.

<u>The following text should have been included at the end of section 1.3 of the 2016 ERA</u>

Many areas of uncertainty attend a risk assessment. This is due to the fact that assumptions have to be made throughout the assessment either due to data gaps, environmental fate complexities or in the generalization of receptor characteristics. To be able to place a level of confidence in the results, an accounting of the uncertainty, the magnitude and type of which are important in determining the significance of the results, must be completed. In recognition of these uncertainties, conservative assumptions were used throughout the assessment to ensure that the potential for an adverse effect would not be underestimated. In each of the major sections listed above, a sub-section describing uncertainty and conservatisms is provided.

<u>The following text should have been included as section 2.6 of the 2016 ERA</u>

2.6 Uncertainties in Site Characterization
Due to the large number of environmental studies conducted by Cameco, site is well-characterized and there are few uncertainties or data gaps with respect to site description. This is supplemented by a relatively short operating history with no other industrial influences. The following data gaps were identified for potential uncertainty:

- There is limited selection of radionuclide measurement data. As discussed in Section 2.6.9 above, in the absence of radionuclide measurements, the levels of U-234, U-235 and U-238 were estimated based on measured uranium concentrations. *Degree of uncertainty: Medium*
- Limited soil data (primarily uranium concentration) is available through the facility soil monitoring program and site specific soil characteristics are not available. Conservative assumptions were used in calculations, such as using the maximum concentration from all depths of sample. *Degree of uncertainty: Low*
- The detection level tor tributyl phosphate (TBP) used during analysis of samples was much higher than the screening criteria. TBP was carried forward as a COPC at all tiers of the risk assessment. *Degree of uncertainty: Medium*

Other data gaps (such as air, or surface water at off-site receptor locations) were addressed by undertaking modelling activities.

<u>The following text should have been included as section 4.8 in the 2016 ERA</u>

4.8 Uncertainties in Preliminary COPC Screening

- The screening methodology has been set up to minimize uncertainty: in the absence of screening criteria, contaminants are 'screened-in', i.e., retained as COPCs.
- The main uncertainties in the preliminary screening process are likely to be gaps in the data and gaps in the available screening criteria. As discussed earlier, large gaps were not identified in the ERA data set. In the absence of MOECC [now Ministry of Environment, Conservation and Parks (MECP)] screening criteria, other values such as background levels were used for screening. *Degree of uncertainty: Low*

Secondary screening, based on human health and ecological component values, is conducted and discussed in later sections of this report.

4.2.2 Information Gaps in Site Characterization

Multiple comments from CNSC staff related to the level of detail in the information provided in the Site Characterization in the 2016 ERA. This included recommendations for additional details regarding the known releases to the environment from the BRR, previous studies referenced in the ERA and Meteorological Data. This information has been included in Section 2.3.

4.2.3 Validation of the Air Dispersion Model

Model validation was not undertaken as part of the 2016 ERA; however, it was completed as part of the 2018 Derived Release Limits (DRL) report (Arcadis, 2018), which found that modelled annual uranium concentrations were lower than monitored concentrations at all five hi-vol stations. The validation was based on data from 2014. A similar validation exercise was completed as part of the 2020 Review of the ERA, which compared the updated uranium model results to hi-vol monitoring data from 2015-2019.

The default MECP nested receptor grid utilized in the 2019 ESDM Report was used in the model, along with the locations of the five high-volume air samplers (hi-vols) listed in table 15. Modelled uranium concentrations at the hi-vol receptors were used for model validation. Terrain was considered flat in the model files and was assumed to be acceptable and therefore maintained for the updated model runs.

Table 15 BRR Hi-Vol Stations

Hi-Vol Station ID	Description	UTM Coordinates [1]	
		X (m)	Y (m)
40000	Blind River Sewage Plant	349255	5116339
40010	Ontario Hydro Yard	344787	5117427
40020	Golf Course	343864	5116381
40030	South East Yard	344483	5115956
40036	East Yard	344481	5116163

Notes:
[1] Universal Transverse Mercator (UTM) coordinates are defined in the North American Datum of 1983 (NAD83).

The updated validation results are provided in the following table and are compared to the results from the DRL report. As can be seen in table 16 the results from the updated validation are consistent with the findings in the 2018 DRL report; modelled annual uranium concentrations are below the 5-year annual average concentrations measured at each of the hi-vol stations. The ratios of modelled vs. monitored data range from 0.02 at station 40000 (Blind River sewage plant) to

0.39 at station 40030 (southeast yard). A model is considered to perform well if modelled concentrations are within a factor of ± 2 of observed values (U.S.EPA, 2003).

Table 16 Comparison of Modelled vs. Monitored Annual Uranium Concentrations at the Hi-Vol Stations

Hi-Vol Station ID	Description	Annual Uranium Concentration (µg/m³)			2018 DRL Ratio Model vs. Monitor
		Monitored[1]	Modelled[2]	Ration Model vs. Monitor	
40000	Blind River Sewage Plant	1.77E-04	4.09E-06	0.02	0.03
40010	Ontario Hydro Yard	1.67E-04	1.91E-05	0.11	0.10
40020	Golf Course	2.23E-04	7.51E-05	0.34	0.22
40030	South East Yard	7.21E-04	2.79E-04	0.39	0.34
40036	East Yard	2.99E-03	3.78E-04	0.13	0.14

Notes:
[1] Based on the five-year annual average of hi-vol data (2015-2019). Concentrations at the detection limit (0.0001 µg/m³) were assumed equal to the detection limit.
[2] Based on the modelled five-year annual average concentration

As noted in the 2018 DRL report (Arcadis, 2018), differences between modelled and monitored concentrations can be attributed to air dispersion model uncertainty (i.e., emission rates, source parameterization, meteorology) or measurement uncertainty (i.e., values below the detection limit). The DRL report also noted that differences can be due to variability in background uranium concentrations; however, it is expected that background levels of uranium in the area are negligible. To address the uncertainty in the model predictions, the DRL report adjusted the uranium emission rates from the HVAC sources following the same method applied in the 2013 DRL (SENES, 2013). This method was able to produce acceptable model results (i.e., modelled uranium concentrations within a factor of two of observed values). As a result, the same adjustment method was applied here, which is outlined in table 17.

Table 17 Adjustment Factor Calculation for HVAC Emissions

Monitor	Description	Annual Average U Concentration (µg/m³)				Adj. factor for HVAC $(C_{air}-C_{stack})/C_{HVAC}$
		Measured[1] (C_{air})	Stack Contribution [2] (C_{stack})	$(C_{air}-C_{stack})$	HVAC Contribution [2] (C_{HVAC})	
40020	Golf Course	2.23E-04	1.70E-05	2.06E-04	5.16E-05	4.0
40030	South East Yard	7.21E-04	3.89E-05	6.82E-04	2.27E-04	3.0
40036	East Yard	2.99E-03	3.68E-05	2.96E-03	3.31E-04	8.9
					Average Adj. Factor:	5.3

Notes:
[1] Based on the five-year annual average of hi-vol data (2015-2019). Concentrations at the detection limit were assumed equal to the detection limit.
[2] Based on the modelled five-year annual average concentration

The revised adjustment factor was calculated to be 5.3. For comparison, the adjustment factor used in the 2018 DRL report was 7.1. The updated adjustment factor was then applied to HVAC uranium emissions and the revised emission rates were evaluated using the same AERMOD setup discussed above. The adjusted five-year annual uranium concentrations predicted at the hi-vol stations are provided in Table 18 and are compared to the monitoring data. It should be noted that AERMOD can predict annual concentrations averaged over the entire five year meteorological data set (i.e., the five-year annual average) or the maximum annual concentration (i.e., the worst-case annual concentration out of five years of meteorological data). To be conservative, the maximum annual average concentration out of five years of meteorological data is presented.

As Table 18 shows, the ratio of modelled vs. monitored concentrations are within an acceptable factor of two at the golf course and two yard stations; however, modelled concentrations are still below measured concentrations at station 40000 (Blind River sewage plant) and station 40010 (Ontario Hydro Yard). This suggests that model uncertainty may increase with distance from the facility.

Table 18 Comparison of Modelled vs. Monitored Annual Uranium Concentrations at the Hi-Vol Stations (after HVAC emissions adjustment)

Hi-Vol Station ID	Description	Annual Uranium Concentration (µg/m³)		
		Monitored[1]	Modelled[2]	Ratio Model vs. Monitor
40000	Blind River Sewage Plant	1.77E-04	1.42E-05	0.1
40010	Ontario Hydro Yard	1.67E-04	5.87E-05	0.4
40020	Golf Course	2.23E-04	2.96E-04	1.3
40030	South East Yard	7.21E-04	1.22E-03	1.7
40036	East Yard	2.99E-03	1.99E-03	0.7

Notes:
[1] Based on the five-year annual average of hi-vol data (2015-2019). Concentrations at the detection limit were assumed equal to the detection limit.
[2] Based on the modelled maximum annual concentration out of five years of meteorological data

It is noted that the provision of this information does not impact the conclusions of the ERA.

4.2.4 Uranium deposition

Uranium deposition was modelled using AERMOD as part of the 2016 ERA; however, there was insufficient information provided in the documentation to determine what methodology was followed. The model setup files from the 2019 ESDM Report contained particle size information for the absorber, DCEV, and incinerator stacks, but the origin of the data is unknown. Particle size data based on testing that was completed in 2007 (LEHDER, 2007) was obtained but it did not match the particle size distributions in the existing model files. As a result, both distributions were modelled to understand the effect on uranium deposition rates (IEC, 2020). The particle size distributions that were modelled are summarized in the Table 19.

Table 19 Particle Size Distributions for the Absorber, DCEV and Incinerator Stacks

Model ID	2019 ESDM Report Model Files			2007 LEHDER Stack Testing		
	Particle Diameter (µm)	Mass Fraction	Particle Density (g/cm^3)	Particle Diameter (µm)	Mass Fraction	Particle Density (g/cm^3)
Absorber	0.5	0.18	1.8	0.97	0.063	1.8
	3	0.38	1.8	2.0	0.063	1.8
	7	0.14	1.8	3.1	0.188	1.8
	10	0.08	1.8	6.7	0.063	1.8
	15	0.22	1.8	0.43	0.126	1.8
	-	-	-	10.7	0.5	1.8
DCEV	0.5	0.03	1.8	5.8	0.071	1.8
	3	0.26	1.8	9.3	0.429	1.8
	7	0.18	1.8	2.7	0.143	1.8
	10	0.11	1.8	1.7	0.071	1.8
	15	0.42	1.8	0.83	0.071	1.8
	-	-	-	0.37	0.214	1.8
INC[1]	0.5	0.03	1.8	0.37	0.214	1.8
	3	0.26	1.8	0.83	0.071	1.8
	7	0.18	1.8	1.7	0.071	1.8
	10	0.11	1.8	2.7	0.143	1.8
	15	0.42	1.8	5.8	0.071	1.8
	-	-	-	9.3	0.429	1.8

Notes:
[1] In the 2019 ESDM Report model files, the particle size distribution for the incinerator stack was equal to the DCEV stack. In the absence of data from the 2007 stack testing report (LEHDER, 2007), the same assumption was applied.

The model files that were provided did not include a particle size distribution for the HVAC sources. For these sources, it was assumed that majority of the particulate is less than 10 microns (µm) in diameter, so dry deposition Method 2 was applied in AERMOD for the HVAC sources. Method 2 requires the fine particle fraction and the mass mean particle diameter, which were assumed to be 0.8 and 0.4 µm, respectively. These variables were selected based on the recommended values for radionuclides published in Appendix B of Wesely et al. (2002). It should be noted that dry depletion and wet depletion were turned off in accordance with the Ontario Air Dispersion Modelling Guideline (MECP, 2017).

As described above, AERMOD was run using two different particle size distributions to understand the effect on uranium deposition rates. The results are summarized in Table 20, which shows that the maximum annual deposition rate predicted using the existing particle size distribution was 3.6E-04 g/m² and the maximum annual rate using the distribution from LEHDER (2007) was 2.5E-04 g/m². In both cases, the maximum deposition rates were predicted at receptors along the fenceline on the east side of the facility.

Table 20 Comparison of Uranium Deposition Rates using Different Particle Size Distributions

Particle Size Distribution Source	Max. Annual U Deposition Rate (g/m²)	Location of Maximum [1]	
		UTM X (m)	UTM Y (m)
2019 ESDM Report	3.6E-04	344527	5116129
2007 LEHDER Test Data	2.5E-04	344507	5116129

Even though the deposition rate is higher using the existing particle size distribution, the difference in the results is considered small enough to support using the 2007 LEHDER test data rather than using particle size data with an unknown origin. As a result, the LEDHER particle size distribution was used in the modeling described in Section 3.2.1.

4.3 Review of 2016 ERA Compliance with N288.6-12

As part of the 2020 Review of the ERA, an independent accounting of the 2016 ERA compliance with N288.6-12 was completed (CanNorth, 2020). There were technical deficiencies identified, including in the problem formulation for human receptors and the lack of consideration of species at risk for the assessment.

4.3.1 Species at Risk

Section 6.1.1 of the 2016 ERA identifies the ecological receptors considered in the assessment. Receptors were based on previous assessments. Species at risk were not considered in the 2016 assessment.

The 2016 ERA selected ecological receptors based on SENES (2006). According to ARCADIS (2016), indicator species were selected based on knowledge of the site and surrounding environment, relevant environmental studies, accessibility of the environmental media, and potential species present in the area. However, there is no indication that potential species at risk (SAR) were considered and ecological significance is a component of CSA N288.6 receptor selection and characterization (CSA 2012, Clause 7.2.3.5 Table 7.1). A thorough identification of Species at Risk Act (SARA) species potentially present at the site should be completed, along with a rationale for including or excluding the identified SAR for the assessment. As SAR species are subject to change it is important to conduct the identification at the time of the assessment. For example, a scan of the MNR Natural Heritage Information Centre in 2018 indicated that the painted turtle was a SAR species; however, a more recent scan indicated that Blanding's turtle is a SAR in the area and not the painted turtle. In terms of the risk assessment, SAR species are evaluated at the individual level (CSA 2012, Clause 7.2.4.3), and this evaluation influences the selection of TRVs, which is discussed in the Problem Formulation Update for TRVs (Section 6.4).

4.3.2 Levels of Conservatism

The 2016 assessment incorporated Tier 1 and Tier 2 assessments, which builds on the database of environmental and operations data, while also, to the extent possible and where appropriate, maintaining consistency with past assessments. Since it was built on current assessments it was not necessary to use the extremely conservative assumptions that necessitated a Tier 1 and Tier 2 assessment. In addition, the exposure point concentrations and the doses calculated for the HHRA were extremely conservative values of potential exposures. The importance of reasonable exposure scenarios is discussed in the Problem Formulation Update for Exposure Assumptions (Section 6.2).

5.0 Review of Changes to Scientific and Regulatory Information

The review process considered the potential for changes to scientific and regulatory information.

5.1 Scientific Advances

Screening criteria used in risk assessment are selected from appropriate standards and guidelines published by federal and/or provincial government agencies. These standards and guidelines are established on the basis of review of scientific literature and other sources of information regarding health or environmental impacts from exposure to a contaminant. Standards and guidelines are periodically reviewed to incorporate new information. As the 2020 Review of the ERA utilized the current standards and guidelines in the COPC screening, relevant advances in scientific information was included in the review.

Under O. Reg. 419/05, BRR is required to use AERMOD to demonstrate compliance with the provincial regulatory requirements. AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. The model code and supporting documents are regularly updated to incorporate the best available science

5.2 Regulatory Requirements

There have been no significant changes to environmental legislation applicable to the BRR operations since the 2016 ERA. The only change to site-specific environmental regulatory requirements is the routine update to the provincial Environmental Compliance Approval (ECA) that was underway at the time of the 2020 Review of the ERA. A review of the draft ECA identified no changes to requirements.

6.0 Problem Formulation Updates

6.1 Conceptual Site Model

From a human health perspective, the 2016 ERA provided two conceptual site models one for onsite workers and the other for off-site members of the public. The off-site members of the public included residents, cottagers, people spending time at Boom Camp as well as workers at the nearby golf course and the in-town hydro yard. Various exposure pathways were also discussed including, direct soil exposure, consumption of local food (wild game, wild fowl and fish), drinking water, consumption of backyard produce, inhalation, and gamma exposure. These are typical receptors and exposure pathways considered within an ERA. However, it should be noted that the location of the soil exposures and drinking exposures for off-site receptors is not considered to be reasonable as discussed below.

The ecological CSM considered a wide range of receptors including fish, benthic invertebrates, frogs, aquatic and terrestrial plants, terrestrial invertebrates, aquatic and terrestrial birds, aquatic and terrestrial mammals. These are typical ecological receptors and the pathways presented are also typical to an ERA. CNSC staff requested the use of site-specific soil characterization data instead of the use of generic soil parameters. The 2016 ERA used measured data for uranium soil in the assessment as it was the only COPC identified. Radionuclide concentrations were estimated from the ratio of Unat to other radionuclides measured in airborne emissions. Generic soil parameters (such as soil type, soil texture, etc.) were not used. This comment does not appear to influence the conclusions of the risk assessment (CanNorth, 2020).

6.2 Exposure Assumptions

Table 5.4 of the 2016 ERA provided the exposure locations and media assumptions for the human receptors selected for the assessment. This risk assessment is an update of the 2006 ERA and should represent a detailed quantitative risk assessment (DQRA) where reasonable and not highly conservative implausible estimates of exposure are used. The selection of the consumption of groundwater as drinking water by the 1(A-D) off-site resident at the maximum measured concentration (Tier 1) and 95th percentile concentration (Tier 2) measured on the BRR site is an implausible and unreasonably conservative assumption. This resulted in risks that were eliminated by resorting to a Tier 2b discussion. The Tier 2b discussion concluded that resident receptors would not be exposed to on-site groundwater concentrations in drinking water and no adverse effects are expected. The ingestion of site groundwater is not an operable pathway for resident receptors and should have been eliminated in the problem formulation for the assessment. While this assumption does not change the ultimate conclusions for the risk assessment (no risks for TBP via groundwater), it is an implausible scenario and unnecessarily complicated the assessment and created an inconsistent message. Similarly using the maximum concentration of COPC in the surface water at the diffuser outfall as a drinking water source is also an unreasonably conservative assumption and also resulted in an inconsistent message. It is very important at the Problem Formulation Stage to set up the foundation for the risk assessment and to ensure that reasonable exposure scenarios are being evaluated.

The new air quality modelling predicts an air concentration of uranium 0.0025 µg/m³ which is 5 times higher than the uranium concentration of 0.0005 µg/m³ that was used in the 2016 ERA. It is noted that the new modelled uranium concentration is consistent with the 2018 DRL report. The change in air concentrations does not change the conclusion of the 2016 ERA as the air pathway only represents a minor pathway of exposure (CanNorth, 2020). While uranium deposition rates were determined as part of the air modelling exercise, they were not used in the 2016 ERA as measured uranium in soil concentrations were available.

6.3 Receptor Selection and Characterization

6.3.1 Aquatic Receptors

The 2016 ERA identified fish, benthic invertebrates, aquatic vegetation, and amphibians as the major biota groups (ARCADIS 2016, Table 6.1). Potential indicator species were also specified. The brown bullhead catfish was selected as the indicator species for forage/benthic fish. Since fish are assessed generally for both radiological and nonradiological effects (ARCADIS 2016, Table 6.1 footnote), the consideration of brown bullhead catfish has no influence on the assessment or conclusions of the 2016 ERA. Additional discussion is provided in the TRV evaluation in section 6.4.

6.3.2 Terrestrial Receptors

The problem formulation updates for terrestrial receptors pertains to species at risk which is described in section 4.3.1.

6.3.3 Human Receptors

The 2016 ERA established exposure factors for the HHRA based on the most conservative values between Health Canada (2012, as recommended by CSA 2012) and the Blind River Refinery Derived Release Limit (SENES 2013, BRR DRL), which were based on Health Canada (1994). The selected values used in the 2016 ERA are summarized in Table 5. Although the Mississauga First Nation (MFN) community was identified as a community living near the Blind River Refinery, the 2016 ERA did not appear to consider that unique populations of First Nations/Inuit or Métis populations engage in hunting and harvesting of traditional foods. The 2016 ERA indicated that the fish ingestion rate (ARCADIS 2016, Table 5.5) were specific to First Nations, but it was unclear if other ingestion rates were specific to First Nations populations. Therefore, the original literature sources were reviewed to determine the applicability of the specified ingestion rates presented in Table 5.

Following CSA N288.6 guidance, the 2016 ERA specified ingestion rates and age groups for the non-radiological and radiological assessment separately. The values presented in Table 21 are specific to the non-radiological assessment; however, the values were consistent with the radiological assessment with the exception of produce rates, which were higher in the radiological assessment and based on CSA N288.1 (2014).

Table 21 Human Receptor Characterization

Pathway	Total Ingestion Rate (g/d)					Reference
	Infant	Toddler	Child	Teen	Adult	
Fish	0	95	170	200	220	Richardson (1997, generic for Canadian Native fish eaters, Table 6.2) [Ref. 7]
Produce	155	172	259	347	325	Richardson (1997, generic for males and females combined, Table 5.4, root vegetables + other vegetables)
Game	0	85	125	175	270	Richardson (1997, generic for Canadian Native wild game consumption, Table 6.5), includes small game, large game, and waterfowl
Fowl	0	12.6	15.9	20.2	20.2	Health Canada (1994), according to ARCADIS (2016, Table 5.5)

As indicated in Table 21, the fish and game rates were specific to Canadian Native populations (Richardson 1997). To our knowledge there are no specific studies for the MFN; however, other references are available to characterize ingestion rates for First Nations populations in Ontario (e.g., Chan et al. 2014). It appears that the assumptions used in the 2016 ERA are conservative based on other studies for First Nations populations.

The First Nations Food, Nutrition, and Environment Study (FNFNES) for Ontario (Chan et al. 2014) surveyed 18 First Nations communities in Ontario. The MFN were not included; however, from the report, Ecozone 2 where the BRR is located is the best representation for the MFN. According to Chan et al. (2014, Table 6), of the 344 adult respondents from Ecozone 2, 40%

consumed deer meat and 57% consumed moose meat. For wild birds, grouse (blue, ruffed, sharp-tailed) had a 7% consumption rate. Grey partridge had a higher prevalence (23%); however, for the purposes of the ERA, partridge and grouse could be combined. Table 10a of the report also indicates the daily consumption of food for adults and the values provided in this table are lower than the values used in the 2016 ERA. As such, the assumptions in the 2016 ERA for the dietary patterns for First Nations are reasonable and possibly conservative, in the absence of specific information for the MFN.

6.4 TRVs

The 2016 ERA used the methodologies of the time as well as the toxicity reference values (TRVs). This review examines the TRVs and determines whether any values have been changed since the 2016 ERA and indicates the impact of these changes. For the radiological assessment, the selected dose coefficients and dose limits in the 2016 ERA were based on CSA N288.6-12 (2012).

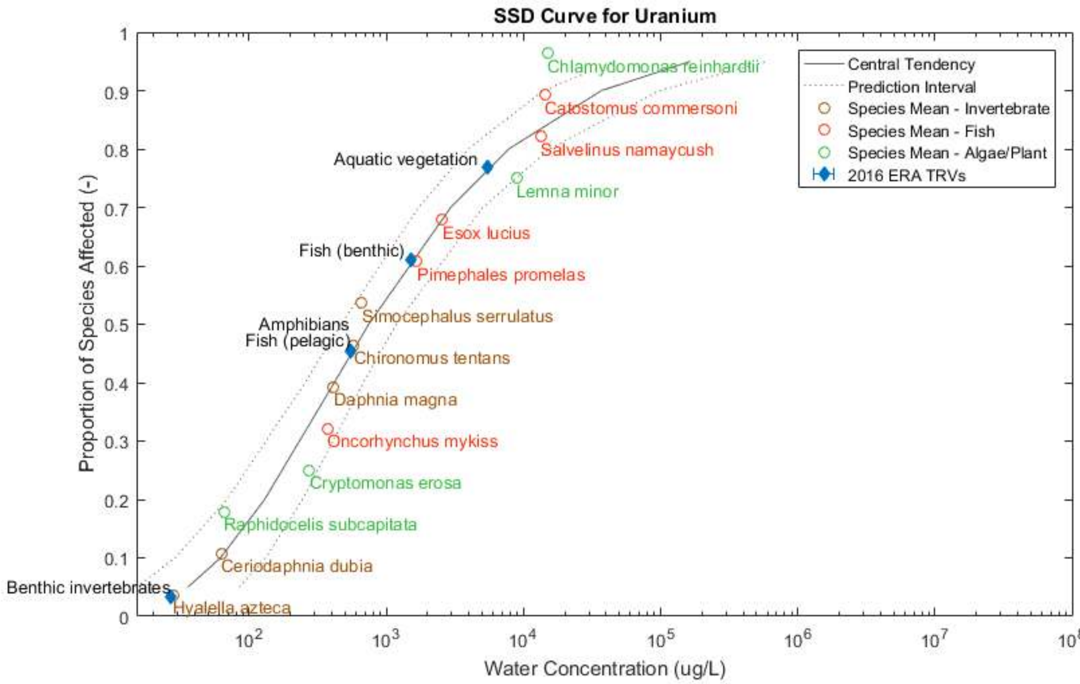
6.4.1 Aquatic Receptors

From an aquatic environment perspective, individual TRVs for benthic invertebrates, aquatic plants, and fish were used. In more recent ERAs for example for Cameco in Northern Saskatchewan, a Species Sensitivity Distribution (SSD) approach, which considers the aquatic environment as a holistic community, has been used. This approach is used by the CCME for the setting of water quality guidelines and is currently the approach used by many in the risk assessment community to evaluate risks in the aquatic environment. Based on the SSD approach, potential effects on aquatic receptors are evaluated on a community basis rather than individual receptor types. Figure 9 provides the uranium SSD with the 2016 ERA TRVs (ARCADIS 2016, Table 6.20) indicated in relation to the SSD curve. As seen from the curve, a number of the TRVs used in the 2016 ERA are on the curve and thus it is unlikely that the conclusions of the aquatic assessment would change.

The 2016 ERA assumption for amphibians used the toxicity value of fish as a surrogate. As seen from the SSD curve there are no available toxicity data for amphibians, so the use of fish is a reasonable approach and is used by the risk assessment community. There are more sensitive species of aquatic vegetation and fish considered in the SSD curve (Figure 9) than the TRVs selected in the 2016 ERA; however, the TRV for benthic invertebrate is consistent and the most sensitive aquatic receptor. The maximum concentration of uranium at 7.4 µg/L is at the lower end of the curve and below the toxicity data for benthic invertebrates. Therefore, the conclusions of the 2016 ERA for uranium remain valid.

The use of the SSD approach for uranium incorporates all available toxicity data, provided these data pass quality control and applicability criteria. For uranium specifically, the SSD curve (Figure 9) is based on CCME (2011 Table 11), with additional data from U.S. EPA ECOTOX and a literature review including Goulet et al.(2015).

Figure 9 Uranium species sensitivity distribution



For TBP, ECHA provides a recent evaluation of aquatic toxicity data for the derivation of the PNEC for aquatic life (ECHA 2020). This is discussed in Section 4.1.3.

As mentioned previously, the 2016 ERA did not identify or consider SAR in the assessment. Per CSA N288.6-12 (2012, Clause 7.2.4.3), the assessment of SAR influences the selection of TRVs. The use of the SSD curve can assist in the evaluation of potential aquatic SAR species for nonradiological effects. The painted turtle or Blanding's turtle have been noted to be SAR species in the area; however, there is no available toxicity information and a surrogate species could be used or the measured water concentration could be plotted on the curve to demonstrate that the concentration is lower that any species for which toxicity data are available. Based on this analysis, it is unlikely that SAR species will experience adverse effects.

For radiological dose, there are no available dose limits for the assessment of aquatic SAR species. However, from the results presented in the 2016 ERA (ARCADIS 2016, Table 6.22), the SI values calculated using a dose limit of 9.6 mGy/d are very low (<0.1), which indicates that there is a wide margin of safety for the protection of individual aquatic receptors, including amphibians, fish, and aquatic plants and thus SAR species would not experience adverse effects (CanNorth, 2020)

6.4.2 Terrestrial Receptors

The TRVs for mammals and birds in the 2016 ERA were primarily obtained from the U.S. EPA ecological soil screening levels (Eco-SSLs) (U.S. EPA 2005) and from Sample et al. (1996). A similar approach was used for more recent ERAs for Cameco in Northern Saskatchewan, with an updated approach for surrogate selection. Table 22 provides a comparison of the TRVs selected for the 2016 ERA and updated TRVs in more recent ERAs for Cameco in Northern Saskatchewan.

Table 22 Comparison of TRVs – terrestrial receptors - uranium

Receptor		2016 ERA TRV (mg/kg-d)	Updated TRV (mg/kg-d)	Conclusion
Mammals	Beaver	5.6	8.8	No change
	Black Bear	5.6	8.8	No change
	Coyote	5.6	8.8	No change
	Deer	5.6	8.8	No change
	Meadow Vole	5.6	8.8	No change
Birds	American Robin	16	16	No change
	Bald Eagle	16	16	No change
	Barred Owl	16	16	No change
	Cormorant	16	16	No change
	Hooded Merganser	16	16	No change
	Mallard	16	16	No change
	RuffedGrouse	16	16	No change
	Scaup	16	16	No change

Note: Coyote and deer were not selected as terrestrial receptors in the most recent ERAs for Cameco in Northern Saskatchewan; therefore, LOAEL TRVs for coyote and deer were selected using the surrogate selection approach. The selection process relies on receptors having a match with test species, either exactly, or at the order and family level. With this selection process, the default (calculated bird or mammal) TRVs are selected for most of the ecological receptors. Since the default TRVs are a representation of all the available toxicity data for a particular COPC, this is considered to be a stronger approach than an arbitrary selection of a specific test species. The coyote and deer do not have a match at the order and family level and were therefore assigned the default LOAEL TRV.

For mammals, the updated TRV is based on lowest observable adverse effects levels (LOAELs) from 6 studies, rather than the single LOAEL value considered in the 2016 ERA. The updated TRV is greater than the 2016 ERA value, which would result in lower screening index (SI) values than were presented in the 2016 ERA (ARCADIS 2016, Table 6.25). Since these values were all well below 1, the conclusions of the assessment remain unchanged for the mammals and potential exposures to uranium. There is no change in the uranium TRV for birds, which due to a lack of available data, is based on a no observable adverse effects level (NOAEL).

There were no available TRVs for mammals and birds for TBP identified in the 2016 ERA; this reflects the current information available for TBP. As indicated in previous sections TBP should not be identified as a COPC in the terrestrial environment.

As mentioned previously, the 2016 ERA did not identify or consider SAR in the assessment. Per CSA N288.6-12 (2012, Clause 7.2.4.3), the assessment of SAR influences the selection of TRVs. The approach for the assessment of avian and mammalian SAR in the more recent ERAs completed for Cameco in Northern Saskatchewan includes the consideration of NOAEL TRVs. Since the uranium TRV identified for avian receptors in Table 7 is based on a NOAEL, the assessment of avian SAR would be similar to the receptors considered in the 2016 ERA. For mammalian SAR receptors, the default TRV for uranium is 4 mg/kg-d, based on 5 studies. The highest SI calculated for a mammalian receptor in the 2016 ERA (ARCADIS 2016, Table 6.25) was 0.012 for the meadow vole. Scaling this SI for consideration of the NOAEL value results in an SI value of 0.017, which remains well below the SI benchmark value of one. Therefore, it is unlikely that the additional consideration of SAR receptors would change the conclusions of the 2016 ERA for uranium, assuming that the indicator species selected for the 2016 ERA are reasonable surrogates for the SAR receptors.

For radiological dose, a dose threshold value of 1 mGy/d can be used to assess species at risk as IAEA (1992) determined this was the dose rate with no observable effects to biota. The results for the radiological assessment for terrestrial receptors in the 2016 ERA (ARCADIS 2016, Table 6.22) appear to use an incorrect dose limit of 9.6 mGy/d for cormorant, merganser, mallard, and scaup (dose limit of 2.4 mGy/d as presented in Table 6.21 should have been used). The calculated doses for these receptors are low enough that the SI values remain below one if the correct dose limit of 2.4 mGy/d is used. However, the scaup has the highest estimated radiological dose of 1.1 mGy/d. The scaup is not a SAR, however if the scaup provides surrogate exposure for other aquatic-based SAR at the site, the calculated dose would exceed the dose limit considered for no observable effects to biota. Doses for the other terrestrial receptors considered in the assessment would remain well below one.

6.4.3 Human Receptors

The TRVs specified for the HHRA in the 2016 ERA (ARCADIS 2016, Table 5.21) for uranium are consistent with TRVs used in more recent ERAs for Cameco in Northern Saskatchewan. As illustrated in the updated selection of COPC, ammonia is not identified as a COPC for the site and would not be considered in an HHRA. TBP is also not identified as a COPC for human health in surface water. Based on consideration of the site groundwater data, TBP was also not identified as a COPC in groundwater. Furthermore, the ingestion of groundwater at the site is not an operable pathway for off-site receptors and should not have been considered in the assessment.

7.0 Conclusion

The 2016 ERA was generally conducted using the framework outlined in N288.6-12 and using the available toxicity information at that time (CanNorth, 2020). There are a few issues that have been noted:

- Approach to screening of ammonia and TBP for human health.
- Assumptions used for locations of drinking water and soil exposures for off-site human receptors.
- Use of extremely conservative measures of exposure (maximum concentrations and 95%tile concentrations) instead of the more reasonable and acceptable exposure of a 95%UCLM.
- The human health calculations for the carcinogenic effects of TBP are not correct as they do not represent incremental risks. Background needs to be subtracted from the calculations.
- Lack of evaluation of Species at Risk.
- Incorrect application of radiation benchmarks in the ecological assessment.

Since the completion of the 2016 ERA, additional monitoring has been completed resulting in decreases in some concentrations, for example uranium in soil. In addition, the approach to the evaluation of aquatic receptors has evolved and some toxicity values have changed. The changes in monitoring data and changes in toxicity values and approaches to evaluation of aquatic receptors do not result in changes to the 2016 ERA conclusions.

7.1 Recommendations

Based on this review completed in accordance with Clause 11.1 of N288.6-12, there are no identified risks that have emerged since the last ERA review. The review also assessed opportunities to improve the information presented in the ERA which is provided in this report. There were no changes identified which required a full update of the ERA before the 5-year timeframe.

The 2020 Review of the ERA was completed by Cameco subject matter experts with support from third-party experts in the areas of risk assessment and environmental modelling. Three areas for follow-up were identified prior to the next review of the ERA:

1. It was identified that available sediment data does not include analysis for TBP. In order to fully assess TBP, sediment sampling should be completed to ensure all pathways for TBP are considered. It is recommended that this activity be completed in Spring 2021 so that the information is available prior to the licence renewal hearing anticipated in September 2021.
2. It was identified that an adjustment factor is required to be applied to HVAC uranium emissions in the AERMOD model validation. Differences between modelled and monitored concentrations is attributed to air dispersion model uncertainty and/or measurement uncertainty. To support continual improvement, this uncertainty should be investigated and documented. It is recommended that this activity be completed prior to the scheduled update of the DRL, which is due for resubmission to CNSC staff in 2023.
3. It was identified in this review and the recent review of the DRL that a detailed example of the derivation of the radionuclide concentration ratios at the refinery and their application to environmental media would enhance interpretation of monitoring results. It is recommended that this activity be completed prior to the scheduled update of the DRL, which is due for resubmission to CNSC staff in 2023.

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