Review of the Environmental Risk Assessment for Cameco Fuel Manufacturing

In Support of the Renewal of the Cameco Fuel Manufacturing Operating Licence FFOL-3641.00/2022

May 11, 2021

Table of Contents

1.0 Introduction

In accordance with its licence requirements, Cameco Fuel Manufacturing (CFM) 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).

CFM 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 manufacturing 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 CFM every five years. The 2016 ERA was completed November 2016, and therefore is required to be reviewed by November 2021. This review was undertaken to support the one-year licence renewal application for CFM's Fuel Facility Operating Licence (FFOL-3641.0/2022) submitted in December 2020 (Cameco, 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, 2017a) from CNSC staff regarding the November 2016 ERA have been considered and addressed in the current review. The purpose of the review is to 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 2015-2020
2. 2019 Emission Summary Dispersion Model
3. Facility Design Change records 2015-2020
4. 2016 Environmental Risk Assessment
5. 2021 Derived Release Limit report
6. Applicable provincial and federal guidelines for environmental protection
7. 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 2021 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 16 hectares on which the 4.1-hectare secured area of CFM is situated in the Municipality of Port Hope (MPH). No changes in access or use of this land has occurred since the 2016 ERA. The only major change in the surrounding area has been the commencement of the Port Hope Area Initiative (PHAI), and the clean-up of low-level radioactive waste within the MPH. There are no direct impacts of the PHAI on CFM. CFM is located in the general employment zoned area of the MPH.

2.2 Changes to the Physical Facility and Facility Processes

To assess the changes to CFM between 2015 and 2020, a review of the facility design control files, annual reports and management review reports was carried out. The following changes were made at the facility which had an impact on environmental performance. All these changes moved performance in a positive direction.

- Installation of real time alpha in air monitors in various production areas
- Installation of automated grinding, washing and drying production line
- Increase sewer sampling frequency to ensure continuous coverage of liquid emissions
- Changed to ICP-MS analysis for hi-vol sample analysis
- Improved turn-around for sewer samples
- Noise abatement improvements
- Installation of stack timers to include operational run time in emission calculations
- Installation of a berm for gamma emission reduction in the northwest portion of the site

While these changes have no direct impact on air and liquid discharges from CFM, they do impact data collected under the routine monitoring program. The noise abatement and gamma shielding activities improve the physical impact of CFM on the surrounding area as discussed in section 2.3.4 and 2.3.5.

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

Construction of the Port Hope plant commenced in 1956 by AMF Atomics to build fuel elements (aluminum clad uranium alloy metal rods and flats) for the Atomic Energy of Canada Limited (AECL) research reactors NRX and NRU at Chalk River, Ontario. The site was comprised of 3 parcels of land purchased from individual citizens and is believed to be a greenfield site located along Highway 2. Though the site has had multiple owners and site developments since, all activities have centered around the development and production of fuel for nuclear reactors.

Present day, the licensed area is zoned for general employment, with commercial/industrial buildings to the east of the facility and south of Peter Street to the south. Immediately to the south of the site, a triangular section of land bounded by Dorset Street East, Peter Street and Rose Glen Road is zoned as open space. The unlicensed portion of the site associated with the Gages Creek tributary is zoned as environmental protection/flood plain. The northern property limit is bounded by a narrow general employment parcel abutting the Canadian Pacific Railway (CPR) right-of-way. There are several private residences and a private institution directly west of the property on a small strip zoned low density residential (Arcadis, 2021).

2.3.2 Releases to the Environment

The primary contaminant in air emissions associated with CFM is uranium. These contaminant emissions are measured using source monitoring and/or estimated using available monitoring data. For the 14 stacks available for operation in the uranium processing portion of the facility, a stack sampling collection strategy is used for determination of uranium emissions. Routine sampling is carried out at the process stacks for uranium when operating. For the 9 HVAC emission points from the uranium processing portion of the facility, a source area monitoring strategy is used for the determination of uranium emissions. Under provincial jurisdiction, there are boilers and comfort heating system which discharge combustion products from natural gas and volatile organic compounds (VOCs), namely trichloroethylene and associated chlorinated VOCs, from the groundwater treatment system located outside the licensed area.

The waterborne effluent from the CFM facility is discharged to the MPH sanitary sewer system and is monitored in accordance with operating licence requirements and the municipal sewer use by-law. The monitoring location is at the final tie-in to the MPH sanitary sewer system and is representative of combined effluent from the uranium processing area of the plant and the groundwater treatment system. Stormwater runoff is directed to intermittent drainage features to the Gages Creek tributary. Sampling occurs thrice annually.

There is a known source of trichloroethylene and associated chlorinated VOCs in the subsurface in the north portion of the production facility. This contamination was identified in 1993 and a groundwater treatment system has been in operation since 2000.

The environmental emission points and liquid sampling points from the CFM facility are shown in Figure 1 and Figure 2.

Figure 1 Air emission sources for CFM

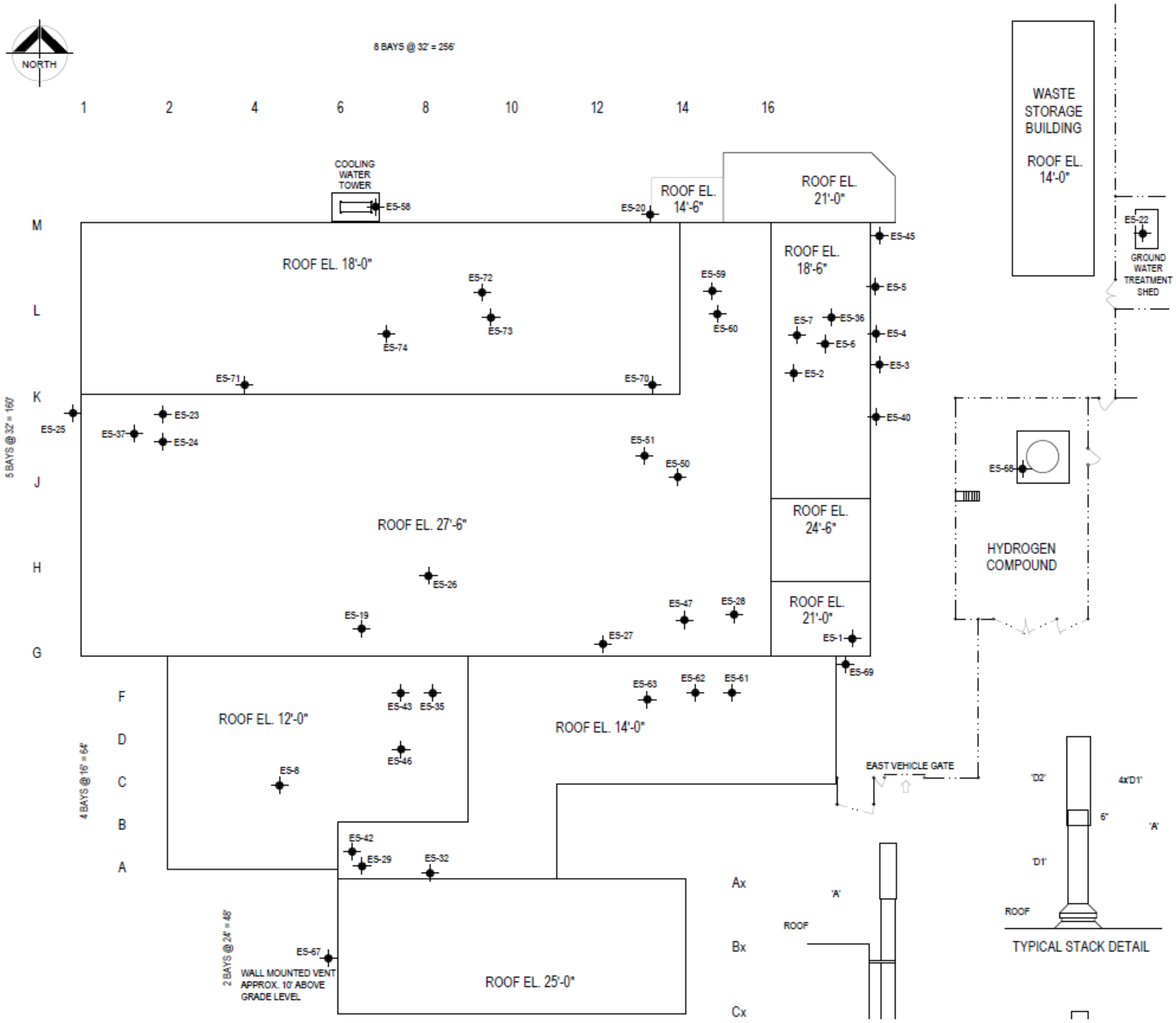
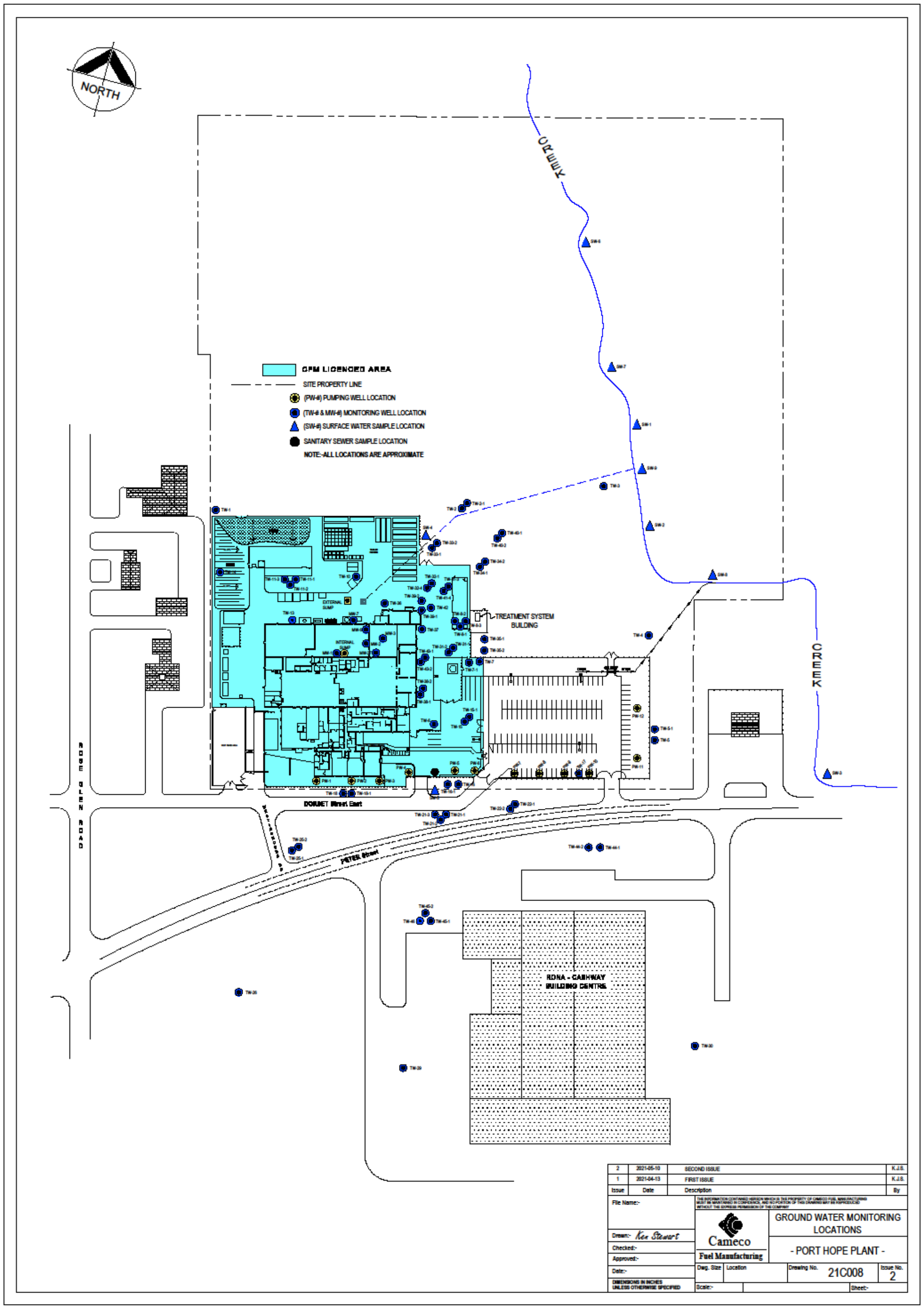


Figure 2 CFM Liquid Sampling Points



Corresponding monitoring for COPCs in the environment was described in section 2.6 of the 2016 ERA.

2.3.3 Meteorological and Climate Data

The meteorological data set used in the 2016 ERA air dispersion model was based on surface and upper air data for the period 1997 to 2001 and processed by Arcadis with AERMET version 14134. In their comments, CNSC staff noted that the data set was over 20 years old and expressed concern that the data was no longer representative of site conditions (CNSC, 2017a). The Derived Release Limits (DRL) report completed in 2021 (Arcadis, 2021) used an updated meteorological data set in the air dispersion model that is based on surface and upper air data for the period 2013 to 2017. The updated data set was processed by the Ontario Ministry of Environment, Conservation, and Parks (MECP) with AERMET version 16216. Figure 3 compares the wind roses from the 2016 ERA and 2021 DRL reports, which show that the wind pattern is similar. In both data sets, the dominant wind direction is west, and the average wind speed is just over 3 m/s (IEC, 2021).

To understand the effect of the updated meteorological data set on the model results, an AERMOD model run was completed using the source data from the 2016 ERA and the updated meteorological data set. For consistency with the 2016 ERA, AERMOD version 14134 was used. A comparison of the model results is provided in Table 1, which shows that the average annual uranium concentrations stayed the same or decreased at R1-R3 but increased by 38% at R4 and the maximum fenceline receptor. Since the air pathway only represents a minor pathway of exposure, this increase is not significant enough to affect the conclusions of the ERA (IEC, 2021).

Figure 3: Comparison of Wind Roses from the 2016 ERA Report and the 2021 DRL Report

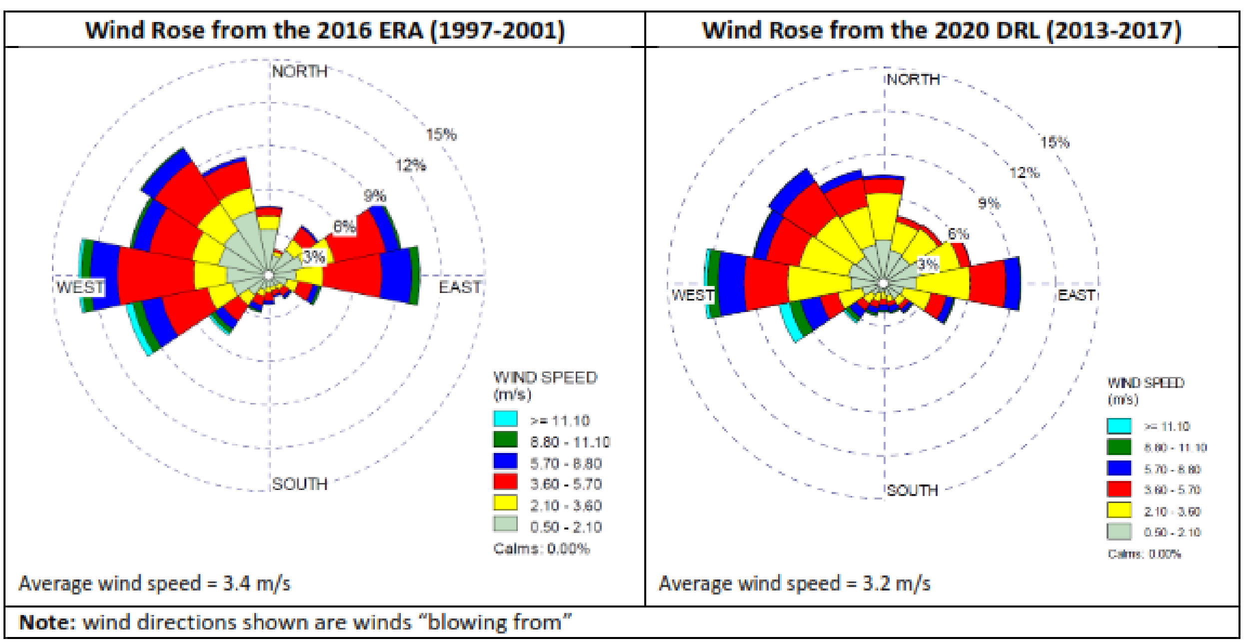


Table 1: Comparison of Uranium Concentrations from 2016 ERA to Uranium Concentrations based on Updated Meteorology

	Original 2016 ERA	2016 ERA w/ Updated Meteorological Data	% Change from 2016 ERA
Meteorological Data Set	AERMET 14134, 1997-2001	AERMET 16216, 2013-2017	
AERMOD Version	14134	14134	
Total U Emission Rate (g/s)	1.65E-05	1.65E-05	
Average Annual Uranium Concentration (µg/m³)			
R1 – Commercial Off-site Worker	2.90E-04	2.90E-04	0%
R2 – Maintenance Off-site Worker	2.50E-04	2.30E-04	-8%
R3 – Sub-surface Off-site Worker	1.22E-03	8.80E-04	-28%
R4 - Resident	4.80E-04	6.60E-04	38%
Maximum Fenceline Receptor	1.20E-03	1.65E-03	38%

The 2016 ERA utilized temperature and precipitation statistics for the Cobourg STP station. CNSC staff noted that there was a significant data gap present in the 2014 calendar year and no explanation was provided for why the data was missing and if there were attempts to fill in the gap with data from another climate station.

To address this comment the climate data for the Cobourg STP station was retrieved from Environment and Climate Change Canada's (ECCC) website. Not only were significant data gaps present in 2014, but all years had data recovery rates of less than 60% for both temperature and precipitation (see Table 2). It is of note that the station operator is designated as CCN - or Co-operative Climate Network, meaning that it is operated by third-party and it is not designated as a climate station by World Meteorological Organization standards. While these stations can provide some useful information, the data recovery rates are often low, and they are not reliable for climate statistics (IEC, 2021).

Table 2: Temperature and Precipitation Statistics for the Cobourg STP Station (2011-2015)

Temperature Statistics[1]	**2011**	**2012**	**2013**	**2014**	**2015**
Mean Daily Temp (°C)	7.0	9.9	5.3	6.9	8.5
Min. Daily Temp (°C)	-26	-19	-22	-11	-23
Max. Daily Temp (°C)	32	33	31.5	25.5	29.5
Count	206	181	172	66	153
Data Availability (%)	56%	49%	47%	18%	42%
Precipitation Statistics[1]	**2011**	**2012**	**2013**	**2014**	**2015**
Total Rain (mm)	585.1	391.9	359.3	103.7	212.4
Total Snow (cm)	48.5	36	77.5	17	20
Total Precipitation (mm)	633.6	427.9	436.8	120.7	232.4
Count	206	181	172	67	153
Data Availability (%)	56%	49%	47%	18%	42%

Notes:
[1] Daily data file retrieved from ClimateData.ca.

An alternate station operated by ECCC was identified approximately 3 km away from the STP station (Cobourg AUT – Climate ID 6151684). While precipitation data is not published on

ECCC's website, it does not mean that this parameter is not collected at the station. Additional station parameters are sometimes available for purchase from ECCC. Total precipitation data for the automatic station was retrieved from ClimateData.ca – a newer website that has an extensive database of historical climate data across Canada. The temperature and precipitation statistics were tabulated for the Cobourg AUT station for the period 2011 to 2015 and compared the statistics presented in the 2016 ERA for the Cobourg STP station. As shown in Table 3, the temperature statistics are similar between the two stations despite the low data recovery at the STP station. However, the precipitation totals are quite different between the two stations. The average annual precipitation amount reported in the 2016 ERA was 370 mm, while the average annual precipitation amount for the AUT station is 979 mm. These amounts were checked against the 1981-2010 Cobourg climate normals (ECCC, 2020), which shows an average annual precipitation amount of 890.4 mm and verifies that the precipitation amounts reported in the 2016 ERA were underestimated. While this has no impact on the air dispersion model, the ERA notes that the Cobourg STP precipitation data was used in the surface water modelling. In future ERAs, it is recommended that data from the Cobourg AUT station be used, and should any data gaps be identified, they should be reported and discussed in the ERA (IEC, 2021).

Table 3: Comparison of Temperature and Total Precipitation Statistics from Cobourg STP and Cobourg AUT (2011-2015)

Station Name	Min. Daily Temp. (°C)	Max. Daily Temp. (°C)	Mean Daily Temp. (°C)	Min. Annual Precip. (mm)	Max. Annual Precip. (mm)	Mean Annual Precip. (mm)
Cobourg STP[1]	-26.0	33.0	7.7	121	634	370
Cobourg AUT[2]	-25.0	33.2	7.6	777	1120	979

Notes:
[1] Values reported in the 2016 ERA (Arcadis, 2016).
[2] Daily data file retrieved from ClimateData.ca.

2.3.4 Noise

The area around CFM is defined as a Class 1 Area (urban), as per MOE Publication NPC-300 (MOE, 2013). This publication describes a Class 1 Area as "an area with an acoustical environment typical of a major population center, where the background noise is dominated by the activities of people, usually road traffic, often referred to as urban hum". The sound level limit is given by the greatest of the applicable exclusion limit value in NPC-300 or the background sound level at the Points of Reception (POR). The background noise environment in the vicinity of the CFM facility is defined by:

- Vehicular traffic on Peter Street (County Road 2, formerly Kings Highway 2) connecting Port Hope to Cobourg (south of facility);
- Vehicular traffic on Highway 401 approximately 2 km to the north;
- Rail traffic on a railroad approximately 360 m north of the facility; and,
- Rail traffic on a railroad approximately 240 m south of the facility.

The facility operates 24 hours a day, seven (7) days a week, up to fifty (50) weeks per year. On average, 8 to 10 trucks per day, including gas and powder deliveries and fuel pick-up, access the facility, mostly between 7:00 to 16:00. Off time and occasional gas deliveries may happen between 15:00 and 24:00. The trucks use the gate located east of the main building on Peter Street except for the hydrogen delivery entering off the east side of the parking lot, east of the main building (SNC, 2013).

An Acoustic Assessment Report (AAR) which modelled noise from CFM based on the worst-case simultaneous operation of all sources identified that existing operations resulted in sound levels that were predicted to be above the exclusionary MOECC sound level limits. Noise modelling results are consistent with sound measurements taken at PORs (SNC, 2013). A Noise Abatement Action Plan (NAAP) was developed for CFM as part of the Environmental Compliance Approval (ECA) application to extend the limited operational flexibility pursuant to its Basic Comprehensive Certificate of Approval (BCCofA) (Air & Noise) in 2014 (CFM, 2015).

The NAAP was completed in two phases. Phase 1, which included installation of silencers on select air intakes, exhausts and stacks was completed in 2015 and 2016 (CFM, 2016; CFM, 2017b). Phase 2, which included installation of silencers on a dust collection system and cooling tower exhaust fans as well as acoustical enclosures on select HEPA exhausts and fan motors was completed in 2018 and 2019 (CFM, 2019b; CFM, 2020a). With the completion of this work, CFM was in full compliance with provincial requirements for noise as shown in Table 4 (Arcadis, 2019b).

2.3.5 Fenceline Gamma

There is a soil berm on the northwest corner of the site near the Fuel (Bundle) Storage Building (FSB). The soil berm is L-shaped and provides shielding along the north and west side of the FSB. In 2017, the north portion of the soil berm was installed behind the between the fenceline and the building as a corrective action to lower the gamma levels in the area of location #12. The soil berm on the west side has a height that is almost the same height as the roofline of the FSB and the soil berm on the north side of the FSB has a height that is approximately two-thirds of the roofline height and slopes downwards from west to east to approximately one-half of the roofline height at the northeast corner of the FSB. The soil berm along the north side of the 60’ (18.288 m) wide and the soil berm along the west side of the FSB is 50’ (15.24 m) wide. The dose rate results in 2018 for location #12 indicate the berm was effective as the results were 70% lower than the dose rate since 2016. It should be noted that this location is on the north side of the site and backs onto property owned by CFM with restricted access and no residential homes (Arcadis, 2021).

Table 4 Cameco Fuel Manufacturing Port Hope Acoustic Assessment Summary Table

Point of Reception ID	Description	Receptor Location	Time of Day	Sound Level at Point of Reception (Leq, dBA)	Performance Limit (Leq, dBA)	Compliance with Performance Limit (Yes/No)
POR1	Retirement Home	1st Floor	Day/Evening	44	50	Yes
			Night	43	45	Yes
		2nd Floor	Day/Evening	46	50	Yes
			Night	45	45	Yes
POR2	Townhouse	1st Floor	Day/Evening	40	50	Yes
			Night	39	45	Yes
		2nd Floor	Day/Evening	41	50	Yes
			Night	41	45	Yes
POR3	House	1st Floor	Day/Evening	38	50	Yes
			Night	38	45	Yes

Table Notes:
[1] Acoustic Assessment Summary Table reference AAR September 2019 (Post NAAP Phase 1 & Phase 2)

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 for CFM (CFM-EP) describes the effluent and environmental monitoring programs. The data from this program is used in the 2021 Review of the ERA.

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

3.1.1 Air Quality Data

The facility is designed with discrete discharge points along the production line. The airborne effluent monitoring program therefore is designed so that each stack is monitored when that area of the plant is operating. Building ventilation discharges are also determined when areas of the plant are operating.

Monitoring data from the process stacks and building ventilation 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 air emissions in the review period 2015 – 2020 were below all action levels and/or regulatory limits.

Table 5 Comparison of 2015 Emissions Quality Data with 2015-2020 Data

Constituent	Unit	2016 ERA	2016-2020			
		2015 Average	5-year Average	Range of Annual Averages		5-year Maximum
				Min	Max	
Annual Stack Emissions	kg/yr	0.01	0.013	0.00	0.03	0.03
Annual Exhaust Emissions	kg/yr	0.45	0.91	0.57	1.25	1.25

CFM maintains an Emission Summary and Dispersion Modelling Report (ESDM) documents the air emissions sources at the facility 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, uranium, suspended particulate matter, volatile organic chlorides (VOCs) was summarized and screened for COPCs in the 2016 ERA. For the 2021 Review of the ERA, the 2019 Consolidated ESDM (Arcadis, 2019a) was used in the same screening process. 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 facility operations and observations in environmental endpoints (IEC, 2021).

3.1.2 Water Quality Data

CFM effluent, including production facility discharges and the groundwater treatment system effluent, is received by the Port Hope Sewage Treatment Plant (STP), where it is diluted by other municipal system inputs. Municipal sewage treatment processes are completed before release to Lake Ontario via the submerged offshore diffuser (Arcadis, 2021).

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). There was one action level excursion in the first quarter of 2018, shortly after the sanitary discharge action level was lowered to 0.1 mg/L. All other emissions in the review period 2016 – 2020 were below all action levels and/or regulatory limits.

In the 2016 ERA, measured liquid effluent concentrations of uranium 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 CFM for the 2015 to 2020 timeframe. The table shows that the average uranium concentrations in the CFM effluent from 2015 to 2020 are lower than the 2014 value used in the 2016 ERA. Additionally, when the volume and concentration of the uranium in CFM effluent are considered within the context of the overall STP effluent volumes, the uranium concentration in STP effluent attributable to the CFM facility is less than half the concentration estimated for the 2016 ERA. Based on this effluent data comparison, the conclusions made in the 2016 ERA regarding the effluent quality remain valid and conservative.

Table 6 Comparison of 2014 effluent quality data with 2015-2020 data – uranium

Year	CFM Effluent		STP Effluent	
	Average Uranium Concentration (µg/L)	Volume (m^3)	Volume (m^3)	Estimated Concentration of CFM Uranium (µg/L)
2014 (2016 ERA)	51.0	30,967	2,171,666	0.73
2015	35.7	34,498	NA	-
2016	24.5	34,767	NA	-
2017	18.1	35,306	2,163,874	0.30
2018	23.5	36,022	1,857,391	0.45
2019	13.5	29,064	1,912,776	0.21
2020	14.0	24,172	1,665,680	0.20

Note: 2014 values used in 2016 ERA from Arcadis (2016, Section 3.4.1). CFM effluent uranium concentrations from 2015-2019 available from "Sewer 2015 to 2019.xlsx". STP effluent volumes from 2017-2019 available from "2017-2019 Flows for Cameco.xlsx". 2020 data provide via email and from file "2017-2020 Flows for Cameco.xlsx". NA – not available.

The STP effluent volume recordings in 2017 and 2019 were impacted by elevated Lake Ontario conditions. While the effluent volumes could potentially underestimate the concentration of CFM uranium in effluent, the values for 2018 were considered in the current evaluation, which were not impacted by elevated Lake Ontario conditions.

The comparison in Table 6 also addresses CNSC Comment 10 concerning variability in discharge and the selection of conservative values for the ERA as it shows that the value used in the 2016 ERA is more conservative than concentrations calculated from 2017 to 2020 period (CanNorth, 2021).

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 CFM 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 CFM may be detected at offsite locations in the vicinity of the facility. 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, hivol data, surface water data, and gamma measurement data. The 2021 Review of the ERA assessed groundwater data, soil data, hivol data, and surface water data available for the period 2015-2020. Gamma measurement data was not included in the 2021 ERA review, as this was recently assessed in the Derived Release Limit report (ARCADIS, 2021).

3.2 Updated Modelling

3.2.1 Air Dispersion Modelling

As part of the 2021 Review of the ERA, updated air dispersion modelling was completed for uranium (IEC, 2021) using source information and model setup files from the 2019 ESDM Report (Arcadis, 2019a). A five-year meteorological data set (2013-2017) was prepared by the MECP using surface data from Cobourg and processed with AERMET version 16126. As such, the updated modelling was completed using AERMOD version 16126r to be consistent with the version of AERMET.

Prior to updating the model, 2021 DRL report was reviewed to better understand recent air emission model performance. This review identified the following items which could contribute to differences in model performance in different assessments (i.e. DRL, 2016 ERA, 2021 ERA review):

- The DRL used the maximum observed concentrations at the hi-vols, not the annual average concentrations.
- Hi-vols are collected on a weekly basis and this data is used to compare to annual uranium concentrations
- Uranium concentrations are determined using alpha counting for stack discharges and ICP-MS for hi-vols
- Different property boundaries were used in different model runs (licensed property vs all CFM property)

Furthermore, the DRL report presented observed uranium concentrations based on alpha counting samples rather than ICP-MS samples (which has a lower detection limit). Comparing the average annual uranium concentrations predicted in the DRL report to observed annual average uranium concentrations in 2017 (based on ICP-MS methodology), the model vs. monitor ratio ranges from 11 to 50, which are outside the acceptable range of +/-2 (see Table 7). It is noted that the site-wide uranium emission rate in the DRL report (1.07 E-04 g/s) is about 6.5 times higher than the emission rate in the 2016 ERA (1.65E-05 g/s), which resulted in predicted concentrations that are about an order of magnitude higher than the ERA. This, combined with the switch to the ICP-MS method, appears to have caused a significant difference in model performance between the ERA and the DRL (IEC, 2021).

Table 7: Updated Validation for the 2021 DRL Air Dispersions Model Results

	2017 Observations[1]	2017 DRL Model	Model vs. Monitor
AERMOD Version		16216r	
Site-Wide Uranium Emission Rate (g/s)		1.07E-04	
Annual Average Uranium Concentrations (µg/m³)			
Southwest Hi-Vol	2.00E-04	9.94E-03	49.7
East Hi-Vol	2.00E-04	2.20E-03	11.0
North Hi-Vol	3.00E-04	3.85E-03	12.8
Northwest Hi-Vol	2.00E-04	2.80E-03	14.0

Notes:
[1] Average annual concentrations based on ICP-MS.

As discussed above, the 2021 DRL model results significantly overestimated annual uranium concentrations compared to observed values. The site-wide uranium emission rate in the 2019 ESDM Report (1.7E-04 g/s) is only slightly higher than the rate used in the DRL report (1.07 E-04 g/s); therefore, one can conclude that the ESDM emission rates would also overpredict annual uranium concentrations. In order to validate the model, uranium emission rates that were based on the highest average annual emission rates from the last three years of stack testing results (i.e., 2017, 2018 and 2019) were used (see Table 8). For model validation purposes, the analysis was restricted to 2017-2019 to eliminate the uncertainty associated with the switch from alpha counting to ICP-MS methodologies in the hi-vol data set. For ventilation sources, the same emission rates from the 2019 ESDM Report were used in the model, which are the same as those used in the 2021 DRL report (IEC, 2021).

Table 8: Average Annual Uranium Emission Rates based on 2017-2019 Stack Testing Data

Stack ID and Description	Average Annual Emission Rate (g/s)			Maximum (2017-2019)
	2017	2018	2019	
ES2 Furnace Burn-off	3.38E-08	3.49E-08	2.18E-08	3.49E-08
ES3 Pangborn South Dust Collector	1.13E-07	2.59E-08	4.38E-08	1.13E-07
ES4 Pangborn North Dust Collector	3.76E-08	4.10E-08	2.81E-08	4.10E-08
ES5 Waste Treatment Pangborn Dust Collector	3.69E-08	1.98E-08	0.00E+00	3.69E-08
ES7 Hoffman Vacuum	1.50E-09	7.64E-10	2.27E-09	2.27E-09
ES26 Mist Collector	9.40E-08	6.00E-08	2.84E-08	9.40E-08
ES36 Waste Treatment Area Absolute Filter	6.02E-08	6.10E-08	3.24E-08	6.10E-08
ES50 PP2 East	4.71E-08	3.24E-08	3.27E-08	4.71E-08
ES51 PP2 West	6.38E-08	3.15E-08	1.81E-08	6.38E-08
ES71 BMS Extraction	8.26E-08	1.82E-08	1.04E-08	8.26E-08

The selected uranium emission rates that were used in the updated model are provided in Table 9, along with the source parameters (e.g., flow rates, temperature, etc.). Note that the site-wide uranium emission rate is 1.34E-04 g/s, which is less than the site-wide rate from the 2019 ESDM Report (1.7E-04 g/s), but higher than the site-wide rate from the 2016 ERA (1.65E-05 g/s). The building setup in the existing model files was used to run the building downwash model, BPIP-Prime, and the default MECP nested receptor grid in model files was also used along with the locations of the four high-volume air samplers (hi-vols) and the four risk receptors (R1-R4) (see Table 10). Note that the fenceline used in the 2016 ERA and 2021 DRL air models is different than what is used in the 2019 ESDM

Report. For the updated model, the fenceline from the 2019 ESDM modelling was used. Finally, the source, building, and receptor elevations in the existing model files were maintained for the updated model runs.

Table 9: Model Source Parameters and Uranium Emission Rates

Stack ID	Flow Rate[1] (m^3/s)	Exit Temperature[1] (°C)	Stack Diameter[1] (m)	Stack height above grade[1] (m)	Release Type[1]	Stack UTM Coordinates [1][2] (X,Y) (m)	Uranium Emission Rate (g/s)	Notes for Emission Rate
ES2	3.38	125	0.61	14.9	Vertical	718677, 4870435	3.49E-08	[3]
ES3	2.27	Ambient	0.51	8.1	Vertical	718687, 4870438	1.13E-07	[3]
ES4	1.89	Ambient	0.51	8.1	Vertical	718686, 4870441	4.10E-08	[3]
ES5	1.89	Ambient	0.46	8.3	Vertical	718685, 4870444	3.69E-08	[3]
ES6	0.07	Ambient	0.10	7.5	Vertical	718680, 4870439	1.32E-10	[1]
ES7	0.15	Ambient	0.15	6.6	Vertical	718676, 4870439	2.27E-09	[3]
ES26	2.36	Ambient	0.51	11.0	Vertical	718647, 4870398	9.40E-08	[3]
ES36	1.51	Ambient	0.43	9.0	Vertical	718679, 4870443	6.10E-08	[3]
ES40	0.71	Ambient	0.25	8.4	Vertical	718689, 4870433	0	[4]
ES50	2.4	Ambient	0.30	12.2	Vertical	718670, 4870419	4.71E-08	[3]
ES51	2.12	Ambient	0.36	12.2	Vertical	718666, 4870420	6.38E-08	[3]
ES59	11.28	Ambient	0.97	11.4	Vertical	718667, 4870440	1.53E-05	[1][5]
ES60	11.28	Ambient	0.97	11.4	Vertical	718668, 4870437	1.53E-05	[1][5]
ES71	1.18	Ambient	0.25	8.5	Vertical	718620, 4870412	8.26E-08	[3]
ES72	2.82	Ambient	0.56	8.5	Vertical	718641, 4870431	0	[4]
ES73	3.76	Ambient	0.61	8.5	Vertical	718644, 4870429	0	[4]
EF1	6.14	Ambient	1.00	9.4	Capped	718674, 4870416	2.35E-05	[1]
EF2	6.14	Ambient	1.00	9.4	Capped	718666, 4870423	2.35E-05	[1][5]
EF3	2.36	Ambient	0.30	9.4	Vertical	718665, 4870418	9.04E-06	[1][5]
EF4	6.14	Ambient	1.00	9.4	Capped	718664, 4870412	2.35E-05	[1][5]
EF6	6.14	Ambient	1.70	9.6	Vertical	718679, 4870405	2.35E-05	[1][5]
EFC16	0.24	Ambient	1.00	6.7	Capped	718655, 4870415	0	[4]
						Site-Wide Uranium Emission Rate (g/s)	**1.34E-04**	

Notes:

[1] From the 2019 ESDM Report, Table 2 – Source Summary Table (Arcadis, 2019).

[2] Universal Transverse Mercator (UTM) coordinates are defined in the North American Datum of 1983 (NAD83)

[3] Process stack. Emissions based on the highest average annual uranium emission rate out of three years (2017-2019) of testing data (see Table 7).

[4] Not in use.

[5] Ventilation source.

Table 10: CFM Hi-Vol Stations and Risk Receptors

Receptor ID	Description	UTM Coordinates[1]	
		Easting (m)	Northing (m)
1	East Hi-Vol	718805	4870478
2	Southwest Hi-Vol	718627	4870344
3	North Hi-Vol	718678	4870486
4	Northwest Hi-Vol	718555	4870464
R1	Commercial Off-site Worker	718850	4870277
R2	Maintenance Off-site Worker	718875	4870466
R3[2]	Sub-surface Off-site Worker	718715	4870448
R4	Resident	718548	4870378

Notes:

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

[2] The UTM coordinates corresponding to Figure A.5 of the 2016 ERA were used.

Model Validation of Uranium Concentrations

The validation exercise compared the uranium model results to hi-vol monitoring data from 2017-2019 using only ICP-MS data. The updated validation results are provided in Table 11 and are compared to the updated ERA/DRL validation results presented previously in Table 7 and Table 8. As can be seen in Table 11, the validation results from the updated modelling are consistent with the findings of the revised DRL report validation results; modelled annual uranium concentrations are well above the annual average concentrations measured at each of the hi-vol stations. The ratios of modelled vs. monitored data range from 10.8 at station 1 (East Hi-Vol) to 38.3 at station 2 (Southwest Hi-Vol). Given that the site-wide emission rates and observed concentrations are similar between the DRL report and those used by IEC, this result is not unexpected.

As noted in the 2021 DRL report, 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 method detection limit). Since the original DRL report showed relatively good agreement (i.e., within a factor of 2) at 3 out of the 4 hi-vol stations, no adjustment was made to modelled uranium concentrations. However, it is now evident that the model results in the 2021 DRL report are very conservative and the uncertainty in the model predictions can be addressed as discussed in the proceeding paragraphs.
Table 12 provides a source contribution analysis at the Southwest Hi-Vol receptor, which shows that the sources likely contributing to the overestimation of uranium concentrations are the ventilation sources (i.e., EF1-EF4, EF6, ES59 and EF60). Therefore, an adjustment was made to these ventilation sources following the same method applied in the Blind River Refinery (BRR) DRL report (Arcadis, 2018) and the recent modelling completed by IEC for BRR (IEC, 2020). This method was able to produce acceptable model results (i.e., modelled concentrations within a factor of 2 of observed values) for both BRR modelling assessments. As a result, the same adjustment method was applied herein, which is outlined in Table 13.

Table 11: Comparison of Modelled vs. Monitored Annual Uranium Concentrations at the Hi-Vol Stations

Hi-Vol Station ID	Description	Updated Annual Uranium Concentration (µg/m³)			Revised 2016 ERA Ratio[3]	Revised 2020 DRL Ratio[3]
		Monitored[1]	Modelled[2]	Model vs. Monitor Ratio		
1	East Hi-Vol	2.17E-04	2.35E-03	10.8	0.5	11.0
2	Southwest Hi-Vol	2.71E-04	1.04E-02	38.3	1.0	49.7
3	North Hi-Vol	2.60E-04	3.72E-03	14.3	1.0	12.8
4	Northwest Hi-Vol	2.21E-04	3.16E-03	14.3	0.5	14.0

Notes:
[1] Based on the three-year annual average of hi-vol data (2017-2019). 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.
[3] Model vs. monitor ratio.

Table 12: Source Contribution Analysis of the Maximum 24-hour Uranium Concentration at the Southwest Hi-Vol

Stack ID	Maximum Predicted 24-hour Uranium Concentration	
	24-hour U Conc (μg/m³)	% of Total Concentration
EF4	2.07E-02	26.21%
EF1	1.89E-02	23.89%
EF2	1.76E-02	22.31%
EF6	1.15E-02	14.51%
EF3	3.56E-03	4.51%
ES60	3.44E-03	4.35%
ES59	3.11E-03	3.94%
ES3	6.00E-05	0.08%
ES26	4.00E-05	0.05%
ES36	3.00E-05	0.04%
ES51	3.00E-05	0.04%
ES4	2.00E-05	0.03%
ES5	2.00E-05	0.03%
ES50	2.00E-05	0.03%
ES2	1.00E-05	0.01%
ES6	0.00E+00	0%
ES71	0.00E+00	0%
ES7	0.00E+00	0%
ES40	0.00E+00	0%
ES72	0.00E+00	0%
ES73	0.00E+00	0%
EFC16	0.00E+00	0%
Total	**7.90E-02**	**100%**

Table 13: Adjustment Factor Calculation for Ventilation Source Emissions

Hi-Vol Station ID	Description	Annual Average U Concentration (μg/m³)				Adj. factor for Ventilation
		Measured [1] (C_{air})	Stack Contribution [2] ($C_{process}$)	(C_{air}-$C_{process}$)	Ventilation Contribution [2] (C_{vent})	(C_{air}-$C_{process}$)/C_{vent}
1	East Hi-Vol	2.17E-04	1.00E-05	2.07E-04	2.41E-03	0.09
2	Southwest Hi-Vol	2.71E-04	4.00E-05	2.31E-04	1.07E-02	0.02
3	North Hi-Vol	2.60E-04	1.00E-05	2.50E-04	3.83E-03	0.07
4	Northwest Hi-Vol	2.21E-04	1.00E-05	2.11E-04	3.24E-03	0.06
					Average Adj. Factor:	**0.06**

Notes:

[1] Based on the three-year annual average of hi-vol data (2017-2019). Concentrations at the detection limit were assumed equal to the detection limit.

[2] Based on the modelled five-year annual average concentration.

The average adjustment factor was calculated to be 0.06, which was applied to the ventilation source uranium emissions listed in Table 9. The adjustment decreased the total ventilation emission rate from 1.34E-04 g/s to 7.94E-06 g/s, which is closer to the total ventilation emission rate used in the 2016 ERA (1.12E-05 g/s from EF1-EF5 and EF22-EF23). The model results suggest that the ventilation emission rates used in the 2021 DRL report and 2019 ESDM Report are conservative (IEC, 2021).

The revised emission rates were evaluated using the same AERMOD setup discussed above. The adjusted annual uranium concentrations predicted at the hi-vol stations are provided in Table 14 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 (IEC, 2021).

As Table 14 shows, the ratio of modelled vs. monitored concentrations are within an acceptable factor of 2 at the East, North, and Northwest Hi-Vol stations; however, modelled concentrations are slightly above a factor of 2 the Southwest station. Although the adjustment to ventilation uranium emissions significantly reduced model uncertainty in the vicinity of the Southwest hi-vol, the results in Table 14 suggest that the model still slightly overpredicts annual uranium concentrations at receptors southwest of the facility (IEC, 2021).

Table 14: Comparison of Modelled vs. Monitored Annual Uranium Concentrations at the Hi-Vol Stations (after ventilation emissions adjustment)

Hi-Vol Station ID	Description	Annual Uranium Concentration (µg/m³)		
		Monitored [1]	Modelled [2]	Ratio Model vs. Monitor
1	East Hi-Vol	2.17E-04	1.70E-04	0.8
2	Southwest Hi-Vol	2.71E-04	7.10E-04	2.6
3	North Hi-Vol	2.60E-04	2.50E-04	1.0
4	Northwest Hi-Vol	2.21E-04	2.20E-04	1.0

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.

Updated Uranium Model Results

Uranium emissions were modelled using the adjusted emission rates described previously. Figure 4 presents the contour plot for maximum annual uranium concentrations predicted by AERMOD, while Table 14 summarizes the maximum fenceline concentration, as well as the concentrations predicted at the risk receptors R1-R4. Figure 4 shows that the highest annual uranium concentration is predicted to occur at a fenceline receptor on the south side of the facility and has a value of 9.7E-04 µg/m³. This concentration is about 20% lower than the 2016 ERA model results, which predicted a maximum annual concentration of 1.22E-03 µg/m³ (Arcadis, 2016). It is of note that the locations of the maximums are different – in the 2016 ERA, the maximum concentration was predicted at a fenceline receptor northeast of the facility, while in the current assessment, the maximum is predicted at a fenceline receptor located south of the facility. This difference is likely attributable to the fact that the fenceline was redefined in the 2019 ESDM Report model setup to reflect all of Cameco's property at this site.

To be conservative, the same uranium deposition velocity as the 2016 ERA (4.4 cm/s) was used to calculate updated uranium deposition rates following Equation 1:

Equation 1

$$U\ deposition\left(\frac{mg}{\frac{m^2}{30}days}\right) = 4.4\frac{cm}{s} \div 100\frac{cm}{m} \times Annual\ U\ Concentration\frac{\mu g}{mg} \div 1000\frac{\mu g}{mg} \times 3600\frac{s}{h} \times 24\frac{h}{day} \times 30\frac{days}{month}$$

Table 15 summarizes the maximum deposition rate along the fenceline, as well as the rates predicted at risk receptors R1-R4. The highest annual deposition rate occurs at the same fenceline receptor as the maximum concentration and has a value of 0.11 g/m²/30 days, which is similar to the maximum predicted in the 2016 ERA (0.14 mg/m²/30 days).

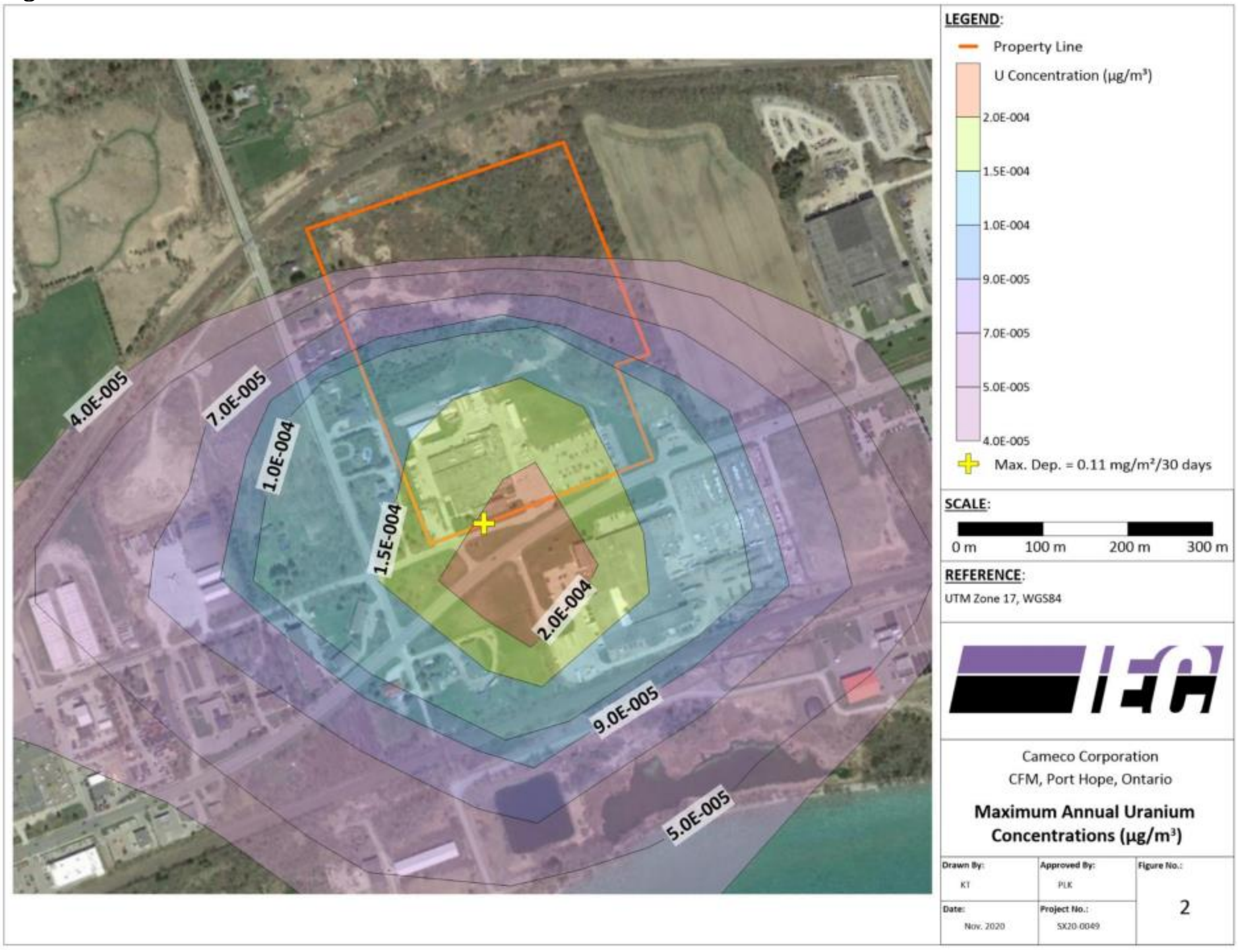
Table 15: Modelled Uranium Concentrations and Deposition Rates at the Fenceline and Risk Receptors (after ventilation emissions adjustment)

Receptor	Description	Max. Annual U Concentration [1] (μg/m³)			U Deposition Rate (mg/m²/30 days)		
		2020 Update	2016 ERA	% change from ERA	2020 Update	2016 ERA	% change from ERA
Fenceline	Maximum fenceline receptor	9.70E-04	1.22E-03	-20%	0.11	0.14	-21%
R1	Commercial Off-site Worker	1.50E-04	2.90E-04	-48%	0.02	0.03	-43%
R2	Maintenance Off-site Worker	1.30E-04	2.50E-04	-48%	0.01	0.03	-51%
R3	Sub-surface Off-Site Worker	5.10E-04	1.22E-03	-58%	0.06	0.11	-47%
R4	Resident	3.70E-04	4.80E-04	-23%	0.04	0.05	-16%

Notes:
[1] Based on the modelled maximum annual concentration out of five years of meteorological data.

Overall, the updated uranium concentrations and deposition rates predicted by the current modelling are less than those predicted in the 2016 ERA. Since the air pathway only represents a minor pathway of exposure, the changes in uranium concentrations and deposition rates are not significant enough to affect the conclusions of the ERA (IEC, 2021).

Figure 4 Maximum Annual Uranium Concentrations



3.2.2 Liquid Effluent Release Modelling – Surface Water near the Municipal Outfall

The CFM has no direct liquid effluent releases to surface water. Liquid effluent releases (routinely monitored for uranium and pH) are directed to the municipal sewer system, which is piped to the Port Hope STP. The STP releases treated effluent to Lake Ontario via an outfall diffuser located offshore.

For the purposes of the EcoRA, the 2016 ERA estimated potential exposure concentrations for ecological receptors exposed to uranium in the CFM effluent. Since the CFM effluent is released to the STP, it is required to consider the additional volume of wastewater treated at the STP. Table 16 summarizes the process for the derivation of the dilution factor (70x) used in the 2016 ERA (ARCADIS 2016, Section 3.4.1). Data from additional years since the 2016 ERA are also provided and indicate that, while the uranium concentration in CFM effluent has decreased since 2014, the volumes from CFM effluent have increased, resulting in an overall decrease in the dilution factors for CFM effluent for the municipal outfall (52x – 69x, Table 16). The STP effluent volume recordings in 2017 and 2019 were impacted by elevated Lake Ontario conditions. During select monthly periods, secondary effluent volumes were biased high. This potentially underestimates the estimated concentration of CFM uranium in effluent and overestimates the dilution factor.

Since 2018 has the highest estimated concentration of CFM uranium in effluent and the lowest dilution factor of the more recent years, these values were used to assess the implications of using the lower dilution factor. Uranium concentrations from 2017 to 2020 are shown in Table 23 and the issues with the STP effluent volume recordings in 2017 and 2019 are unlikely to make a difference to the assessment (CanNorth, 2021).

Based on the Cornell Mixing Zone Expert System (CORMIX) results presented in the 2021 DRL (Table A.6 Appendix A, ARCADIS 2021), an additional dilution factor of 8.8x is expected at the STP diffuser, based on mixing in Lake Ontario. This additional dilution factor was not considered in the evaluation and illustrates the conservative nature of the assessment.

Table 16 CFM dilution with municipal sewage

Year	CFM Effluent		STP Effluent		Dilution Factor
	Average Uranium Concentration (μg/L)	Volume (m^3)	Volume (m^3)	Estimated Concentration of CFM Uranium (μg/L)	
2014 (2016 ERA)	51.0	30,967	2,171,666	0.73	**70**
2015	35.7	34,498	n/a	-	-
2016	24.5	34,767	n/a	-	-
2017	18.1	35,306	2,163,874	0.30	61
2018	23.5	36,022	1,857,391	0.45	52
2019	13.5	29,064	1,912,776	0.21	66
2020	14.0	24,172	1,665,680	0.20	69

Note: 2014 values used in 2016 ERA from ARCADIS (2016, Section 3.4.1). CFM effluent uranium concentrations from 2015-2019 available from “Sewer 2015 to 2019.xlsx”. STP effluent volumes from 2017-2019 available from “2017-2019 Flows for Cameco.xlsx”. 2020 data provide via email and from file “2017-2020 Flows for Cameco.xlsx”. NA – not available.

Surface Water Concentrations at the Harbour

The 2021 DRL (ARCADIS, 2021) used CORMIX to perform dispersion calculations for dispersion between the STP outfall and the harbour, where human receptors may become exposed to COPCs in the receiving environment. The CORMIX modelling used outfall diffuser characteristics, ambient aquatic receiving environment characteristics, and the following effluent characteristics:

- Unit concentration of 1 ppm
- No loss, decay, or degradation (conservative)
- Effluent temperature: 20 degrees C
- Effluent flow rate: 213 m^3/hr, annual average for 2018

A dilution factor of 3058x was determined based on the harbour location approximately 2.1 km from the outfall location (Table C.1 Appendix C, ARCADIS 2021). This is appropriate for use in the ERA (CanNorth, 2021).

3.2.3 Soil Deposition and Build-Up Modelling

The 2016 ERA estimated offsite soil concentrations using predictive model equations from NCRP (1984). The reference document was not available to verify the equations; however, the considerations and principles are similar to those used in CSA N288.1 (2014) and the calculations seem reasonable. Data collected from the Port Hope area (SENES, 2008) was used to provide soil characteristics for the modelling. This information was used in conjunction with fenceline air concentrations for uranium to predict incremental soil concentrations. The deposition rate in the 2016 ERA was based on a deposition velocity of 4.4 cm/s calculated for the nearby Port Hope Conversion Facility (PHCF) in 2014. This is a conservative value based on the most recent five years of data (2015 to 2019) that the 90th percentile value of the deposition velocity is 3.7 cm/s (IEC, 2021). Using the PHCF data represents a conservative assumption, since uranium emissions at PHCF are 1000 times higher than CFM. In addition to the assumptions above, default values were assumed for the velocity of water percolation through soil and the depth of soil zone of interest for surface soils of 2.5 cm. Using a uranium in air concentration of 0.00122 µg/m^3, an incremental soil uranium concentration of 0.05 µg/g in the 2.5 cm surface depth (ARCADIS 2016, Table 3.4) was calculated. This value is well below soil quality guidelines (CanNorth, 2021).

3.2.4 Modelling – Soil & Groundwater Vapours to Trench-Air

Estimated vapour concentrations from volatile COPC in soil and groundwater were considered for air contained within a subsurface trench to assess potential exposures to subsurface workers in the 2016 ERA.

Concentrations in vapour from groundwater were estimated following ASTM (1995, updated 2010) methodology combined with a reduced wind speed to better represent stagnant air conditions within a subsurface trench protected from wind. The 2016 ERA used default values from ASTM (1995) and MOE (2011) and COPC-specific parameters, as well as the following assumptions:

- Wind speed: 100 cm/s to represent calmer conditions in stagnant trench air
- Temperature: 20 degrees C
- Thickness of vadose zone: 5 cm
- Depth to groundwater: 100 cm (assumed trench is 1 m above groundwater level)

The approach is reasonable; however, site specific groundwater depths should be used in these calculations to ensure that the appropriate vapour concentrations in a trench are calculated (CanNorth, 2021). It is further noted that workers in this environment would be nuclear energy workers and would be provided appropriate personal protective equipment, making this a negligible pathway.

Concentrations in vapour from soil were estimated following MOE (2011) methodology combined with a reduced wind speed to better represent stagnant air conditions within a subsurface trench protected from wind. The 2016 ERA used default values from MOE (2011) and COPC-specific parameters, as well as the following assumptions:

- Wind speed: 100 cm/s to represent calmer conditions in stagnant trench air
- Temperature: 20 degrees C
- Timespan: 1 year

The approach is reasonable; however given the fact that the soil concentrations are largely below the detection limit or very low, the evaluation of vapours from soil represent a negligible pathway (CanNorth, 2021).

3.3 Updated COPC Screening

The environmental monitoring data collected since 2014 (the year considered in 2016 ERA) was reviewed to determine whether additional contaminants of potential concern (COPC) need to be considered. The 2016 ERA used the maximum concentrations in groundwater, surface water, soil, and sediments in the screening process. The new data collected since the 2016 ERA were screened and 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 17.

Table 17 Air – COPC Screening (From 2019 ESDM – ARCADIS (2019)

Contaminant	CAS No.	Total Facility 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	0.17	1-hr	277	400	69%	No	Less than screening criterion
Nitrogen Oxides (NOx)	10102-44-0	0.17	24-hr	123	200	61%	No	Less than screening criterion
Trichloroethylene	79-01-6	0.0058	24-hr	5.6	12	47%	No	Less than screening criterion
Vinyl Chloride	75-01-4-	0.0003	24-hr	0.29	1.5	29%	No	Less than screening criterion
Uranium (U)	7440-61-1	0.00017	Annual	0.0176	0.03	59%	Yes	Less than screening criterion. Directly relevant to site operations.

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

3.3.2 Groundwater Screening

Table 18 provides a summary of the updated screening for groundwater based on the new data since the 2016 ERA.

Table 18 Groundwater: updated screening

COPC	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
VOCs							
Chloroethane	mg/L	NA	<5	NA	No	No	No change
1,1-Dichloroethylene	mg/L	0.017	0.0829	0.072	**Yes**	**Yes**	Above screening criteria
cis-1,2-Dichloroethylene	mg/L	0.017	0.804	1.5	**Yes**	**Yes**	Above screening criteria
trans-1,2-Dichloroethylene	mg/L	0.017	0.115	0.066	**Yes**	**Yes**	Above screening criteria
Tetrachloroethylene	mg/L	0.017	0.114	0.11	**Yes**	**Yes**	Above screening criteria
1,1,1-Trichloroethane	mg/L	1.1	0.119	0.067	No	No	Below screening criteria
Trichloroethylene	mg/L	0.017	226	99	**Yes**	**Yes**	Above screening criteria
Vinyl Chloride	mg/L	0.0017	0.147	0.17	**Yes**	**Yes**	Above screening criteria
Metals							
Uranium	mg/L	0.015	0.788	2.3	**Yes**	**Yes**	Above screening criteria

Note: NA – not available. Based on Table 4.1 of the 2016 ERA. Recent data included 2015 to 2019 measurements.

As indicated in Table 18, there are no changes to the COPC selected for consideration based on the updated groundwater data. It is noted that while the maximum concentration of trichloroethylene (TCE) has decreased, the maximum concentrations of breakdown products such as cis-1,2-dichloroethylene (cis-1,2-DCE) have increased in the more recent dataset; uranium levels have also increased.

Tetrachloroethylene (PCE), TCE, and their degradation products 1,1-dichloroethylene (1,1-DCE), cis-1,2-DCE, trans-1,2-dichloroethylene (trans-1,2-DCE), and vinyl chloride (VC) were selected for the 2016 assessment, along with uranium. Although the concentrations of 1,1,1-trichloroethane (1,1,1-TCA) are below the screening criterion, the 2016 ERA included 1,1,1-TCA in the assessment along with chloroethane, since these are also considered to be degradation products of TCE.

3.3.3 Surface Water Screening

Table 19 provides a summary of the updated screening for surface water and demonstrates that there are no changes from the 2016 ERA. The maximum concentration of TCE has decreased in surface water; however, the maximum concentrations of breakdown products cis-1,2-DCE and VC have increased, although still remaining well below the screening criteria. Only TCE and uranium are identified as COPC for surface water. Although concentrations of the other TCE degradation products are below the available screening criteria, they were also included in the assessment for surface water in the 2016 ERA.

It should be noted that the considerations of surface water in Table 19 includes storm water data from three monitoring locations (SW-4, SW-5, and SW-9), which are located within intermittent drainage features that transfer storm water to the natural environment (CNSC Comment 6).

Table 19 Surface water: updated screening

COPC	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
VOCs							
Chloroethane	mg/L	NA	<0.001	NA	No	No	No change
1,1-Dichloroethylene	mg/L	0.04	0.0011	<0.0002	No	No	Below screening criteria
cis-1,2-Dichloroethylene	mg/L	0.2	0.0043	0.0081	No	No	Below screening criteria
trans-1,2-Dichloroethylene	mg/L	0.2	<0.0005	<0.0005	No	No	Below screening criteria
Tetrachloroethylene	mg/L	0.05	<0.0005	<0.0002	No	No	Below screening criteria
1,1,1-Trichloroethane	mg/L	0.07	0.0029	0.0012	No	No	Below screening criteria
Trichloroethylene	mg/L	0.02	0.103	0.038	**Yes**	**Yes**	Above screening criteria
Vinyl Chloride	mg/L	0.6	<0.0005	0.0045	No	No	Below screening criteria
Metals							
Uranium	mg/L	0.005	0.0895	0.093	**Yes**	**Yes**	Above screening criteria

Note: NA – not available. Based on Table 4.2 of 2016 ERA screening. Recent data included 2015 to 2019 measurements.

3.3.4 Soil Screening

Table 20 provides a summary of the updated screening for soil. Data were available for uranium in surface soil collected as part of CFM's regular monitoring every three years from 23 locations surrounding the Port Hope facility (CFM, 2020b). Soil samples are collected from three depths (0-5 cm, 5-10 cm, and bottom 10-15 cm). The maximum uranium concentration in the recent measured data for surface soil 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 of concern at the site, uranium is retained as a COPC in soil.

Additional soil sampling was completed in December 2020 (Golder, 2021) from direct push boreholes on-site. These samples were collected at depth; for the purposes of the screening process for the risk assessment, data with a starting interval to a depth of 0.5 m (50 cm) was considered relevant for potential exposures. This is conservative, since exposures are likely only in the top 15 cm. These data are summarized in Table 20 for metals and volatile organic compounds (VOCs). All constituents are well below the available screening criteria for the noted soil depth interval. PCE and TCE and their degradation products were considered COPC in soil in the 2016 ERA (based on 2009 data) even though the concentrations were below the screening criteria. This is not considered to be appropriate as many of the concentrations were below the detection limit and the TCE concentration was very low. The 2020 data provides verification that PCE and TCE should not be identified as COPC for soil (CanNorth, 2021).

The 2016 ERA did not consider soil samples from studies in 2008 and 2010 and 2015 from the site and thus these data were reviewed to determine whether the selection of COPC would have been different. Older soil data collected from the site were reviewed to determine whether the COPC identified through the screening process would change; however the data were not included in Table 20. The soil concentrations for uranium, radium-226, and arsenic collected in 2008 (Aqua Terre Solutions Inc. 2009a) were all below guidelines indicating that no COPC would have been identified from this sampling program. In 2009, soil samples were collected from 0.13 to 0.47 m below the floor slab in the manufacturing area of the CFM plant and analysed for VOCs. No COPC were identified as all concentrations were below guidelines (Aqua Terre Solutions Inc. 2009b). Uranium concentrations in soil samples collected to a depth of 0.6 m in 2010 (SNC Lavalin 2011) were below the MOE guideline and thus uranium is not identified as a COPC; arsenic and radium-226 concentrations were only reported for samples below 0.6 m which does not represent a depth where human or ecological receptors could be exposed. In 2015, site characterization work was completed on the unlicensed portion of the CFM property (GHD, 2015). The investigation identified two localized areas of soil exceeding MOE criteria; these areas were attributed to contaminated industrial fill (GHD, 2015). Based on the above discussion, the data presented in Table 20 are considered to represent the most complete and relevant data for the CFM site and indicate that no COPC are identified in soil (CanNorth, 2021).

Table 20 Soil: updated screening

COPC	Units	Screening Criteria	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
		MOE					
Surface Soil (to 15 cm)							
Uranium	µg/g	33	17.4	11.2	No	No	Below screening criteria
Borehole Sampling (15 cm to 50 cm)							
Antimony	µg/g	40	--	0.22	No	No	Below screening criteria
Arsenic	µg/g	18	--	4.6	No	No	Below screening criteria
Barium	µg/g	670	--	110	No	No	Below screening criteria
Beryllium	µg/g	8	--	0.39	No	No	Below screening criteria
Boron	µg/g	120	--	13	No	No	Below screening criteria
Cadmium	µg/g	1.9	--	0.2	No	No	Below screening criteria
Chromium	µg/g	160	--	17	No	No	Below screening criteria
Cobalt	µg/g	80	--	5.8	No	No	Below screening criteria
Copper	µg/g	230	--	10	No	No	Below screening criteria
Lead	µg/g	120	--	28	No	No	Below screening criteria
Molybdenum	µg/g	40	--	1.3	No	No	Below screening criteria
Nickel	µg/g	270	--	11	No	No	Below screening criteria
Selenium	µg/g	5.5	--	<0.50	No	No	Below screening criteria
Silver	µg/g	40	--	<0.20	No	No	Below screening criteria
Thallium	µg/g	3.3	--	0.096	No	No	Below screening criteria
Uranium	µg/g	33	17.4	24	No	No	Below screening criteria
Vanadium	µg/g	86	--	27	No	No	Below screening criteria
Zinc	µg/g	340	--	54	No	No	Below screening criteria
Mercury	µg/g	3.9	--	<0.050	No	No	Below screening criteria
1,1,1,2-Tetrachloroethane	µg/g	0.087	<0.002	<0.040	No	No	Below screening criteria
1,1,1-Trichloroethane	µg/g	6.1	<0.002	<0.040	No	No	Below screening criteria
1,1,2,2-Tetrachloroethane	µg/g	0.05	<0.002	<0.040	No	No	Below screening criteria
1,1,2-Trichloroethane	µg/g	0.05	<0.002	<0.040	No	No	Below screening criteria
1,1-Dichloroethane	µg/g	17	<0.002	<0.040	No	No	Below screening criteria
1,1-Dichloroethylene	µg/g	0.064	<0.002	<0.040	No	No	Below screening criteria
1,2-Dichlorobenzene	µg/g	6.8	<0.002	<0.040	No	No	Below screening criteria
1,2-Dichloroethane	µg/g	0.05	<0.002	<0.049	No	No	Below screening criteria
1,2-Dichloropropane	µg/g	0.16	<0.002	<0.040	No	No	Below screening criteria

COPC	Units	Screening Criteria MOE	2016 ERA Max Value	Recent Data Max Value	2016 ERA COPC?	Updated COPC?	Comments
1,3-Dichlorobenzene	µg/g	9.6	<0.002	<0.040	No	No	Below screening criteria
1,4-Dichlorobenzene	µg/g	0.2	<0.002	<0.040	No	No	Below screening criteria
Acetone	µg/g	16	<0.1	<0.49	No	No	Below screening criteria
Benzene	µg/g	0.32	0.004	<0.0060	No	No	Below screening criteria
Bromodichloromethane	µg/g	18	<0.002	<0.040	No	No	Below screening criteria
Bromoform	µg/g	0.61	<0.002	<0.040	No	No	Below screening criteria
Bromomethane	µg/g	0.05	<0.003	<0.040	No	No	Below screening criteria
Carbon Tetrachloride	µg/g	0.21	<0.002	<0.040	No	No	Below screening criteria
Chlorobenzene	µg/g	2.4	<0.002	<0.040	No	No	Below screening criteria
Chloroform	µg/g	0.47	<0.002	<0.040	No	No	Below screening criteria
cis-1,2-Dichloroethylene	µg/g	55	<0.002	<0.040	No	No	Below screening criteria
cis-1,3-Dichloropropene	µg/g	NV	<0.002	<0.030	No	No	Below screening criteria
Dibromochloromethane	µg/g	13	<0.002	<0.040	No	No	Below screening criteria
Dichlorodifluoromethane	µg/g	16		<0.040	No	No	Below screening criteria
Ethylbenzene	µg/g	9.5	<0.002	<0.010	No	No	Below screening criteria
Ethylene Dibromide	µg/g	0.05	<0.002	<0.040	No	No	Below screening criteria
Hexane	µg/g	46		<0.040	No	No	Below screening criteria
Methyl Ethyl Ketone	µg/g	70	<0.03	<0.40	No	No	Below screening criteria
Methyl Isobutyl Ketone	µg/g	31	<0.03	<0.40	No	No	Below screening criteria
Methyl t-butyl ether	µg/g	11	<0.002	<0.040	No	No	Below screening criteria
Methylene Chloride	µg/g	1.6	<0.003	<0.049	No	No	Below screening criteria
Styrene	µg/g	34	<0.002	<0.040	No	No	Below screening criteria
Tetrachloroethylene	µg/g	4.5	<0.002	<0.040	No	No	Below screening criteria
Toluene	µg/g	68	0.015	<0.020	No	No	Below screening criteria
trans-1,2-Dichloroethylene	µg/g	1.3	<0.002	<0.040	No	No	Below screening criteria
trans-1,3-Dichloropropene	µg/g	NV	<0.002	<0.040	No	No	Below screening criteria
Trichloroethylene	µg/g	0.91	0.003	0.014	No	No	Below screening criteria
Trichlorofluoromethane	µg/g	4		<0.040	No	No	Below screening criteria
Vinyl Chloride	µg/g	0.032	<0.002	<0.019	No	No	Below screening criteria
o-Xylene	µg/g	NV	0.004	<0.020	No	No	Below screening criteria
p+m-Xylene	µg/g	NV	0.017	<0.020	No	No	Below screening criteria
Xylene (Total)	µg/g	26	0.021	<0.020	No	No	Below screening criteria

Note: Based on Table 4.4 of the 2016 ERA. The 2016 ERA also considered screening criteria from CCME; this is not considered to be appropriate for the application at CFM. Recent data for surface soil included 2015 to 2019 measurements, but only uranium concentrations were available. Additional data from borehole sampling in December 2020 is summarized for samples with a starting depth interval above 0.5 m (50 cm). Data for radium-226 and thorium-230 was reported as less than the detection limit in the 2020 sampling.

3.3.5 Sediment Screening

There were no additional data collected for sediment since the 2016 ERA. Sediment sampling ceased as of 2015 and is not part of the on-going facility environmental monitoring program as the work was completed to determine a baseline sediment characterization from stormwater discharge receivers. However, several CNSC comments were related to sediment and these are addressed here. CNSC Comment 13 requested additional information on the sediment sampling completed in 2014 and this information was provided in follow-up response (CFM, 2017a). The CNSC also requested the justification for the lack of sampling of uranium in sediments downstream of the municipal wastewater treatment facility.

The CFM contribution of uranium in the sanitary sewer and thus to the municipal wastewater treatment facility is very low and as a result, the sedimentation rates associated are expected to be negligible. This is confirmed with a simple calculation considering the uranium in STP effluent attributable to CFM (0.73 µg/L, Table 6**Error! Reference source not found.** which is the most conservative concentration) and a generic distribution coefficient for the uranium transfer from water to sediments (330 L/kg dw, CSA 2008). The estimated uranium concentration in sediment is 0.00024 µg/g dw[1], which is well below the lowest effects level for uranium in sediments of 104.4 µg/g dw (Thompson et al. 2005) and can be considered negligible.

CNSC Comment 14 and CNSC Comment 18 related to the limited sediment dataset. Since uranium was the only COPC measured in the baseline sediment characterization work completed in 2008, 2011, 2013, and 2014, it is the only COPC identified in sediment available for the assessment. Potential radiological effects from uranium were considered for fish, benthic invertebrates, and aquatic birds and were all found to be low (ARCADIS 2016, Table 6.17 and 6.19).

Based on the review of surface water data (Table 19), TCE is the only COPC selected other than uranium that may merit inclusion. However, TCE generally does not partition to aquatic sediments to an appreciable degree, except in sediments with high organic content (EC/HC 1993). TCE also has a low n-octanol/water partition coefficient (log K_{ow} 2.29 to 2.42), which suggests that TCE is unlikely to bioaccumulate significantly in aquatic biota and piscivorous birds (EC/HC 1993). Therefore it is considered that the existing sediment database for uranium is appropriate and no other COPC need to be considered (CanNorth, 2021).

[1] 0.00024 µg/g dw = 0.72 µg/L x 330 L/kg dw x 0.001 kg/mg x 0.001 mg/g

3.4 Comparison of EMP with 2016 ERA Data

Comparing the data in the 2016 ERA with the more recent monitoring data at CFM, the following observations can be made:

- Surface water: maximum uranium concentration in surface water is consistent with data used in the 2016 ERA. Maximum concentration of TCE has decreased in surface water while the maximum concentrations of cis-1,2-DCE and VC have increased;
- Groundwater: maximum uranium concentration in groundwater has increased from the uranium concentrations used in the 2016 ERA. The maximum concentration of TCE has decreased in groundwater, however, the maximum concentrations of cis-1,2-DCE and VC have increased;
- Soil: uranium concentrations appear to be declining in 2016 and 2019 from the measurements used in the 2016 ERA for surface soil. Based on recent soil data collected on-site from direct push boreholes, metal and VOC constituents remain below guidelines to a depth of 0.5 m;
- Vegetation: uranium concentrations appear to be declining in 2016 and 2019 from the data considered in the 2016 ERA;
- Sediment: no additional data available;
- Indoor air: uranium concentrations in indoor air appear consistent between the 2016 ERA and data collected from 2016-2019. The TCE indoor air concentrations are based on data from 2012 and no additional data are available;
- Fenceline gamma: corrective action completed in 2017 to lower the gamma levels in the area of fenceline location 12 resulted in lower gamma levels in recent years compared with the data used in the 2016 ERA; and,
- Plant gamma: consistent levels in 2016-2019 with data used in the 2016 ERA.

From this review it appears that the most 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 review did not identify a significant effect on the conclusion of the 2016 ERA (CanNorth, 2021).

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 one recommendation:

1. CFM should require all on-site non-Cameco workers or contractor (i.e. non-Nuclear Energy Workers (NEWs)) to follow the same health and safety procedures with regard to the use of respirators while working inside the facility. Cameco may also consider a requirement for all on-site workers to be NEWs. This policy would ensure that workers are trained, protected and monitored effectively and on a harmonized basis.

4.1.1 Use of Respiratory Protection

CFM maintains HSI 020 Respiratory Protection which defines the site requirements for the use of air purifying respirators. This procedure encompasses the requirements of CSA Z94.4-18 Selection, Use and Care of Respirators as required by the facility Licence Conditions Handbook. The Radiation Protection Program (CFM-RP) defines the site requirements with respect to the designation of NEWs. This recommendation is considered implemented.

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. These included modelling information, opportunities for improvement to the site characterization and other assumptions made in the 2016 ERA.

4.2.1 Description of Modelling Activities

CNSC staff recommended that additional information regarding modelling activities be undertaken in comments 1, 7, 8 and 10. This information has been included in Section 3.2.

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 CFM, meteorological data, and noise as set out in comments 2, 3, 4, 5 and 6. This information has been included in Section 2.3.

4.2.3 Meteorological Statistics and Climate Setting

Comments 3 and 4 from CNSC staff related to the quality of the meteorological and climate data used in the 2016 ERA. A discussion regarding this data is included in Section 2.3.3. It is noted that the provision of this information does not impact the conclusions of the ERA.

4.2.4 Environmental Data

Comments 5 and 6 from CNSC staff related to inclusion of environmental data. Noise information is included in Section 2.3.4 and storm water data is included in the surface water discussion in Section 3.3.3. It is noted that the provision of this information does not impact the conclusions of the ERA.

4.2.5 Validation of the Air Dispersion Model

CNSC staff requested information regarding validation of the air dispersion modelling in comment 7. A discussion of the air dispersion model validation activities is included in Section 3.2.1. It is noted that the provision of this information does not impact the conclusions of the ERA.

4.2.6 Uranium deposition

Uranium deposition in the 2016 ERA was estimated by applying a deposition velocity of 4.4 cm/s, which was based on ambient uranium concentrations and dustfall amounts collected at the nearby Port Hope Conversion Facility (PHCF) in 2014 and was the best available information for the ERA. Table A.4 of the 2016 ERA reported a maximum deposition rate of 0.14 mg/m²/30 days at a fenceline receptor, while the deposition rates predicted at the risk receptors ranged from 0.02 to 0.11 mg/m²/30 days.

CNSC staff in comment 9 noted that there was statistical uncertainty in the PHCF data set and requested an explanation as to why the deposition velocity is considered conservative. Using the ambient uranium concentration and dustfall data from PHCF for the period 2014-2019, the uranium deposition velocities for 2015-2019 - the statistics for each year are presented in Table 21.

Table 21 shows that the mean deposition velocity is lower in every year since 2014 due a reduction in uranium emissions at PHCF; however, the data remains variable (i.e., the standard deviations are almost the same as the means). One way to address the uncertainty in the data set is to use the 90th percentile. For the most recent five years of data (2015-2019), the 90th percentile is approximately 3.7 cm/s, which is less than the deposition velocity of 4.4 cm/s used in the 2016 ERA. Further, as noted by CFM in its previous response to the CNSC (CFM, 2017), using PHCF data is conservative since uranium emissions at PHCF are 1000 times higher than CFM. Based on this information and the recent deposition data, it can be concluded that using a deposition velocity of 4.4 cm/s is conservative for CFM (IEC, 2021). Given that PHCF dustfall data is typically at detection levels with emissions 1000 times higher than CFM emissions, it follows that conducting dustfall monitoring at CFM is unlikely to generate measurable concentrations of uranium for use in determining deposition velocity.

Table 21 PHCF Uranium Deposition Velocity Statistics, 2014-2019

Statistics	Uranium Deposition Velocity (cm/s)						
	2014	2015	2016	2017	2018	2019	2015-2019
Maximum	17.86	24.19	9.15	5.84	4.63	6.39	24.19
Minimum	0	0	0	0	0	0	0
Mean	4.42	3.25	1.31	1.08	1.69	1.76	1.82
Standard Deviation	4.10	3.73	1.78	1.47	1.41	1.58	2.29
Number of Samples	47	48	48	48	46	48	238
90^{th} percentile	9.4	6.0	3.2	3.1	3.4	3.7	3.7

4.2.7 Preliminary Screening – Progeny of Uranium Decay

Progeny of uranium decay (U-238 chain) were also included in the ERA assessment due to the selection of uranium as a COPC. Based on the values provided in the 2016 ERA (Table 6.4 and Appendix I, Arcadis, 2016), it appears that the daughter products were correctly calculated using established isotopic activities for natural uranium, summarised in Table 22. This addresses CNSC comment 11 and confirms that the conclusions of the 2016 ERA remain valid and radiological dose to non-human biota remain below the applicable dose limits.

Table 22 Isotopic activities for natural uranium

Isotope	Activity (Bq/g U-nat)	Example for Soil (Table 6.4) Uranium = 17.4 mg/kg
U-234	12,356	215
U-235	568	9.9
U-238	12,356	215

4.2.8 Preliminary Screening – Air Emissions

CNSC comment 12 requested additional information regarding the selection of COPCs for air emissions. This information is provided in Section 3.3.1.

4.2.9 Preliminary Screening – Sediment Screening

CNSC comments 13, 14 and 18 requested additional justification regarding the assessment of sediments in the 2016 ERA. This information is provided in Section 3.3.1.

4.2.10 Exposure Assessment

CNSC Comment 15 related to the rationale for choosing worker occupancy times. From the follow-up response (CFM, 2017a), worker occupancy times are based upon operational experience for the tasks and are the upper bounds of time that a worker would spend dedicated to a task in a year and are inherently conservative. It is also noted that for on-site workers, maximum occupancy factors were assumed for non-NEWs; worker present at site for more than 80 hours a year are classified as NEW and are out of the scope for the assessment (CanNorth, 2021).

4.2.11 Discussion on HHRA

The CNSC requested a discussion of interactions (synergistic/potentiation) between the COPCs assessed in the HHRA (CNSC Comment 16). The current method for evaluating synergism and potentiation is to consider the toxic endpoints of the COPC and consider the cumulative HQs for these COPC. Without conducting a thorough review of the toxic endpoints for the COPC considered in the assessment, a conservative approach using the sum of all HQs was considered. A review of the HHRA results presented in the 2016 ERA (ARCADIS 2016, Table 5.23 - 5.33) indicates that results of the assessment would not change with the consideration of potential interactions between COPCs. HQs are either well enough below 0.2 that the total does not exceed this benchmark, or individual COPC HQs are already above 0.2 and identified in the assessment (CanNorth, 2021).

The CNSC requested CFM consider making all onsite workers NEWs in Comment 19. Since the 2016 ERA, the Radiation and Environmental Protection Manual was replaced by CFM-EP Environmental Protection Program and CFM-RP Radiation Protection Program. CFM-RP defines the criteria for making workers NEWs.

4.2.12 Discussion on EcoRA

The CNSC requested a discussion of the potential exposure pathway associated with the municipal sewage treatment plant and exposure pathways related to sediment in Comments 17 and 18. This information is provided in section 6.1 and 3.3.5.

4.2.13 Sources Cited

CNSC Comment 20 requested a complete reference list for the ERA. The reference list for the 2021 ERA review is provided in section 9.0.

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

As part of the 2021 Review of the ERA, an independent accounting of the 2016 ERA compliance with N288.6-12 was completed (CanNorth, 2021). 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 (2007). 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. 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. Similarly, the TRV for the evaluation of indoor air exposures from uranium to workers is not appropriate as it is for members of the public, instead, occupational exposure limits should have been used. The importance of reasonable exposure scenarios is discussed in the Problem Formulation Update for Exposure Assumptions (Section 6.2).

4.3.3 Receptor and Exposure Pathway Selection

The 2016 assessment was overly conservative in some areas. Based upon the COPC screening for soil, no COPCs were identified in soil and therefore the pathway should not have been assessed, at minimum some receptors could have been dropped from the HHRA due to the lack of COPC for soil.

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 2021 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, CFM 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 CFM operations since the 2016 ERA. The only change to site-specific environmental regulatory requirements is that based on the current North America Industrial Classification System (NAICS) code 332410 most appropriate for CFM Port Hope facility, an Environmental Compliance Approval (ECA) is not required and the MECP Environmental Activity and Sector Registry (EASR) will be used for future facility modifications.

6.0 Problem Formulation Updates

6.1 Conceptual Site Model

From a human health perspective, the 2016 ERA provided two human health conceptual site models (CSMs) one for on-site workers (maintenance and sub-surface) and the other for off-site members of the public. The off-site members of the public included residents, as well as off-site commercial, maintenance, and sub-surface workers. A combined resident and on-site sub-surface worker was also considered. Various exposure pathways were discussed including, direct soil exposure, consumption of local food (backyard produce and fish), inhalation, and gamma exposure. These are typical receptors and exposure pathways considered within an ERA. However, given that no COPC were identified in soil, the off-site maintenance worker may not be needed. In addition, given that the influence of the CFM on the water in the harbour is negligible, the consideration of fish consumption should be revisited (CanNorth, 2021).

The ecological CSM considered a wide range of receptors including fish, benthic invertebrates, 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 Comment 17 related to the potential exposure pathway of sewage sludge waste disposal and whether this was a potential exposure pathway for humans and ecological receptors. This pathway was assessed in the 2021 DRL (ARCADIS, 2021), even though the sludge circuit is automated and only negligible exposure to workers is expected. MPH currently does not dispose of biosolids to a land use application. Solids removed at the headworks (travelling screen debris and vortex grit removal) are disposed of to a county landfill and dewatered biosolids are routed to an alternate external facility for renewable product reuse.

At Cameco's request, the MPH initiated a short-term sampling program and collected four weekly samples of uranium in influent/effluent and dewatered biosolids from the STP in February 2019 (ARCADIS, 2021). It was estimated that the contribution of uranium from CFM was around 9.8% (ARCADIS, 2021). Gamma exposures to workers at the STP and in the biosolids storage room were also evaluated and indicated that under the conservative exposure assumptions (worker spending 100% of time next to the biosolids bin at the maximum level), the incremental gamma dose was 0.05 µSv/hr, with 0.0049 µSv/hr attributable to CFM releases. These doses are well below the exposures evaluated for on-site CFM workers (see Table 25 below). This analysis confirmed that there is negligible exposure to STP workers from CFM releases to the MPH sanitary sewer (CanNorth 2021).

6.2 Receptor Selection and Characterization

6.2.1 Aquatic Receptors

The 2016 ERA identified fish, benthic invertebrates, and aquatic vegetation as the major biota groups (ARCADIS 2016, Table 6.1). Potential indicator species were also specified. No amphibians were identified for the assessment and amphibians do not appear to have been considered. Since there is a lack of toxicity data for amphibians, they are typically assessed as fish. Therefore, consideration of amphibians in the assessment is not expected to change the conclusions of the 2016 ERA (CanNorth, 2021).

6.2.2 Terrestrial Receptors

The 2016 ERA selected ecological receptors based on SENES (2007). According to ARCADIS (2016), indicator species were selected based on knowledge of the site and surrounding environment, relevant environmental studies and field observations, 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. 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 TRV Section below (CanNorth, 2021).

6.2.3 Human Receptors

As mentioned above, the 2016 ERA selected off-site members of the public (residents, off-site commercial, maintenance, and sub-surface workers) as well as on-site workers (maintenance and sub-surface). A combined resident and on-site sub-surface worker was also considered. The consideration of Nuclear Energy Workers (NEWs) is beyond the scope of the assessment, consistent with CSA N288.6 (Table 5.6 of 2016 ERA). Cameco defines all employees and contractors working more than 80 hours per year at CFM as NEWs and they are treated accordingly following health and safety protocols (CFM, 2015).

CNSC Comment 15 related to the rationale for choosing worker occupancy times. From the follow-up response (CFM, 2017a), worker occupancy times are based upon operational experience for the tasks and are the upper bounds of time that a worker would spend dedicated to a task in a year and are inherently conservative. It is also noted that for on-site workers, maximum occupancy factors were assumed for non-NEWs; worker present at site for more than 80 hours a year are classified as NEW and are out of the scope for the assessment (CanNorth, 2021).

The 2016 ERA considered the presence of First Nations groups in the development of the receptor characteristics for the assessment and determined that no groups were present in the study area (ARCADIS 2016, Table 5.3). The 2016 ERA established exposure factors for the HHRA based on the values from Health Canada[2] (2012, as recommended by CSA 2012).

6.3 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 2016 ERA states that in the Tier 1 assessment, the maximum concentration in any particular environmental medium is used, regardless of its particular location. This is an unreasonable level of conservatism for this stage of risk assessment given that a previous risk assessment was conducted in 2006. 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. Further discussion on the specific exposure point concentration (EPC) assumptions are provided below by environmental media (CanNorth, 2021).

The air quality modelling completed as part of this review (IEC, 2021) predicts air concentrations of uranium at various receptor locations that are 20% to 60% lower than the concentrations used in the 2016 ERA. The lower uranium in air concentrations do not change the conclusion of the 2016 ERA as the air pathway only represents a minor pathway of exposure and the values used in the report represent a conservative estimation of the air pathway.

6.3.1 Surface Water

The 2016 ERA assessed four surface water scenarios for the human and ecological assessments, as summarized in Table 23. Uranium concentrations are summarized for the human and ecological assessments and the TCE concentration is provided for the ecological assessment. These were the only COPC identified in the surface water screening. Table 23 also shows the updated concentrations based on data collected since the 2016 ERA. From Table 23 it can be seen that the uranium EPCs for the ecological assessment increased for Case 1 and decreased for Case 2 Tier 2. For Case 1, the EPCs consider storm water data from three monitoring locations (SW-4, SW-5, and SW-9), which are located within intermittent drainage features that transfer water to the natural environment. This is a conservative assumption but addresses CNSC Comment 6. The updated uranium concentration for Case 2 Tier 2 is based on a dilution factor of 52 with the municipal effluent, which is lower than the dilution factor of 70 that was used in the 2016 ERA. These changes in uranium concentrations do not affect the conclusions of the ERA. The Case 2, Tier 1 uranium concentration was used to evaluate aquatic organisms and represents chronic exposure to

[2] ARCADIS (2016) referenced the 2010 version of the Health Canada PQRA guidance and CSA (2012) specifies the 2004 Part I guidance; this was updated in 2012.

aquatic organisms exposed to the CFM effluent. As the CFM effluent is not released to surface water this is an unrealistic scenario. The Tier 1 uranium surface water concentration for the human assessment was related to the predicted concentration in the harbour based on the dilution factor obtained from the CORMIX modelling. The uranium concentration based on more recent data is lower than the concentration used in the 2016 ERA and the conclusions remain unchanged (CanNorth, 2021).

TCE in surface water was considered for the ecological assessment; Table 23 shows that the EPC for TCE has increased using the 2015-2019 data and additional storm water data from SW-4, SW-5, and SW-9. The new EPC remains well below the TRV for aquatic receptors and there is no change to the conclusion of the 2016 ERA.

7.0 Table 23 EPCs – surface water

COPC	Assessment	Value (mg/L)	Rationale	Comments related to more recent data
Uranium	Ecological	0.0062	Case 1: Maximum measured surface water concentration (excluding SW-4 and SW-9)	0.006 mg/L: 95% UCLM of 2015-2019 data (including intermittent storm water at SW-4, SW-5, and SW-9); no change to conclusions
		0.051	Case 2 Tier 1: CFM effluent concentration (no dilution factor)	Ecological receptors are not directly exposed to CFM effluent; this is an unrealistic assumption
		0.00073	Case 2 Tier 2: CFM effluent concentration with 70x dilution for municipal effluent	0.00045 mg/L: 2017-2020 data maximum (Table 6), minimum 52x dilution for municipal effluent; conservative assumption as assumes that all biota are at the end of the pipe; no change to conclusions
	Human	0.0000244	Tier 1: CFM annual average effluent (0.051 mg/L) with 2090x dilution factor for harbour	0.000012 mg/L: 2015-2020 data maximum (based on annual average effluent of 0.0357 mg/L in 2015 and 3058x dilution factor for harbour); no change to conclusions
TCE	Ecological	0.0005	Case 1: Maximum measured surface water concentration (excluding SW-4 and SW-9)	0.0019 mg/L: 95% UCLM of 2015-2019 data (including intermittent storm water at SW-4, SW-5, and SW-9); no change to conclusions

6.3.2 Groundwater

The 2016 ERA assessed groundwater for potential onsite exposures as well as offsite exposures. For the human assessment, potential issues were indicated for subsurface workers due to dermal and oral exposures to maximum concentrations of TCE and VC in groundwater. Therefore, these COPC were further evaluated with Tier 2 concentrations for human exposure.

The risks associated with TCE and VC were minimized with further discussion of existing health and safety procedures and standard personal protection equipment (PPE), which essentially eliminate oral and dermal exposures to groundwater. For many reasons other than potential chemical exposures, sub-surface work is governed by protocols to minimize worker exposure to groundwater. For example, the Ontario Occupational Health and Safety Act (O. Reg. 213/91, s. 230) specifies as part of general requirements for construction projects that every excavation that a worker may be required to enter be kept reasonably free of water (Government of Ontario, 1990). Thus, oral and dermal exposure to groundwater in a trench is an unrealistic exposure scenario.

In addition to the concern regarding the use of maximum concentrations for this level of a risk assessment, there is concern with the EPCs selected for the assessment. Maximum values (as well as statistical representations) considered groundwater concentrations from monitoring wells screened at depths that would not be accessible to subsurface workers. In order to accurately represent the potential risks to subsurface workers, concentrations from shallow wells should be considered. For the purposes of the analysis presented in Table 24, shallow wells were considered to be screened to a depth of 4 m, which continues to be conservative.

Table 24 shows the previous groundwater EPCs used in the assessment in comparison to groundwater EPCs based on the depth to groundwater that a sub-surface worker may encounter. These updated EPCs were derived as the 95% Upper Confidence Limit of the Mean (UCLM) in place of the Tier 1/Tier 2 approach. This is a common statistic used in many risk assessments. Although the EPCs for onsite exposure to TCE and VC are reduced (~3x and 2x, respectively) from the Tier 2 values used in the 2016 ERA, the HQ and risk results presented for onsite exposure to groundwater (2016 ERA, Tables 5.31 and 5.33) are sufficiently high that conclusions of the risk assessment would not change. However, as previously noted the consideration of oral and dermal exposures to groundwater for the subsurface worker are unrealistic. For offsite exposures to groundwater, the proposed EPCs for TCE and VC are reduced (~1000x and 10x, respectively) such that the identified risks for VC exposure for offsite workers would no longer exist.

Table 24 EPCs – groundwater

COPC	Location	Value (mg/L)	Rationale	Updated Groundwater Concentrations Based on Shallow Wells[a]
TCE	Onsite, Tier 1	226	Maximum measured value from TW-36 (screen interval 1.3-4.4 m)	10.5 mg/L: 2015-2019 95% UCLM of shallow onsite wells and interior sump
	Onsite, Tier 2	30.62	95% UCLM of onsite wells	
	Offsite, Tier 1	1.19	Maximum measured value from TW-30 (screen interval 5.4-6.9 m)	0.0004 mg/L: 2015-2019 95% UCLM of shallow offsite wells (TW-21-3, TW-44-2, TW-45-2)
	Offsite, Tier 2	0.309	95% UCLM of offsite wells	
VC	Onsite, Tier 1	22.8274	Maximum measured value from off-site well TW-22-1 (screened interval 7-8.5 m) plus degradation of TCE and DCE	1.05 mg/L: 2015-2019 95% UCLM of shallow onsite wells and interior sump + 10% of TCE for degradation
	Onsite, Tier 2	3.072	95% UCLM of onsite wells plus degradation of TCE and DCE	
	Offsite, Tier 1	0.2729	Maximum measured value from off-site well TW-22-1 (screened interval 7-8.5 m) plus degradation of TCE and DCE	0.0085 mg/L: 2015-2019 95% UCLM of shallow offsite wells (TW-21-3, TW-44-2, TW-45-2) + 10% of TCE for degradation
	Offsite, Tier 2	0.0859	95th percentile of offsite wells plus degradation of TCE and DCE	

Note: Groundwater at depths less than 4 m are considered to represent a reasonable depth for subsurface exposure

6.3.3 Gamma

Although the assessment for radiological exposures to human receptors did not identify any doses exceeding the dose limit, relatively high doses were calculated for some receptors, notably the resident receptors and on-site workers (2016 ERA, Table 5.22). These results precipitated CNSC Comment 19 regarding Cameco's treatment of on-site workers considered non-Nuclear Energy Workers (non-NEWs). The calculated doses were almost entirely due to gamma exposures. Therefore, the selected EPCs for gamma (off-site and on-site) were examined further in Table 25.

For the resident receptors, off-site gamma was considered based on the maximum measured gamma rate at fenceline location 12 (0.97 µSv/hr, quarterly maximum from 2014), even though residences are located closer to fenceline locations 1 and 2, which have much lower measurements (0.01 µSv/hr and 0.03 µSv/hr). The exclusive use of the fenceline location 12 data resulted in excessively conservative calculations and an unreasonable representation of potential radiological risks to resident receptors (CanNorth, 2021). This is due to the concept of a critical receptor, who is a person located at this location, given their proximity to the facility and theoretical length of time spent at the location, would be expected to receive the highest possible radiation dose that any member of the public could receive (ARCADIS, 2021). This location is on the north side of the site and backs onto a property owned by CFM with restricted access and no residential homes (CFM, 2019a).

The 2021 DRL (ARCADIS, 2021) further evaluated gamma exposures at the CFM facility. In 2017, a soil berm was installed behind the Fuel (Bundle) Storage Building (FSB) between the fenceline and the building as a corrective action to lower the gamma levels in the area of fenceline location 12. The 2021 DRL (ARCADIS, 2021) considered data from 2018 to be representative of current conditions (post-berm installation).

An updated EPC (0.25 µSv/hr) based on the 95% UCLM of the 2018-2019 data from fenceline locations 1, 2, and 12 is shown in Table 25. With consideration of the updated EPC, the estimated annual gamma dose for adult residents is 0.13 mSv/yr, compared to the 0.51 mSv/yr presented in the 2016 ERA (ARCADIS 2016, Table 5.22). This is still considered to be a conservative dose estimate as fenceline location 12 is not near permanent residences (CanNorth, 2021).

For the on-site worker receptors, in-plant gamma monitoring data was considered. The 95th percentile of the maximum quarterly gamma rate of 5.56 µSv/hr was selected for the exposure calculations, although the average of the maximum quarterly gamma rates was 1.7 µSv/hr. Only three locations had quarterly gamma rates above 5.56 µSv/hr (Ceramics Lab, Powder Receipt, and S. Waste Treatment). An updated EPC (2.9 µSv/hr) is provided in Table 25 based on the 95% UCLM of the 2014 maximum quarterly gamma data. With consideration of the updated EPC, the estimated annual gamma dose for the onsite workers is 0.16 mSv/yr, compared to the 0.31 mSv/yr presented in the 2016 ERA (ARCADIS 2016, Table 5.22).

Using the recommended gamma EPCs in Table 25 results in an estimated annual gamma dose for the resident and onsite subsurface worker receptor of 0.29 mSv/yr[3], compared with 0.82 mSv/yr

[3] 0.29 mSv/yr = 0.13 mSv/yr (resident) + 0.16 mSv/yr (onsite worker)

presented in Table 5.22 of the 2016 ERA. This is still a conservative estimate of the dose and does not represent a concern for non-NEW workers (CanNorth, 2021).

Table 25 EPCs – gamma

Location	Value (µSv/hr)	Rationale	Comment
Offsite	0.97	Maximum measured rate in 2014 at location 12	0.25 µSv/hr: 95% UCLM of 2018-2019 (post-berm installation) data from fenceline locations 1,2, and 12
Onsite	5.56	95th percentile of maximum quarterly gamma rates	2.9 µSv/hr: 95% UCLM of 2014 maximums, represents a much more reasonable exposure level for gamma and remains conservative

6.4 TRVs

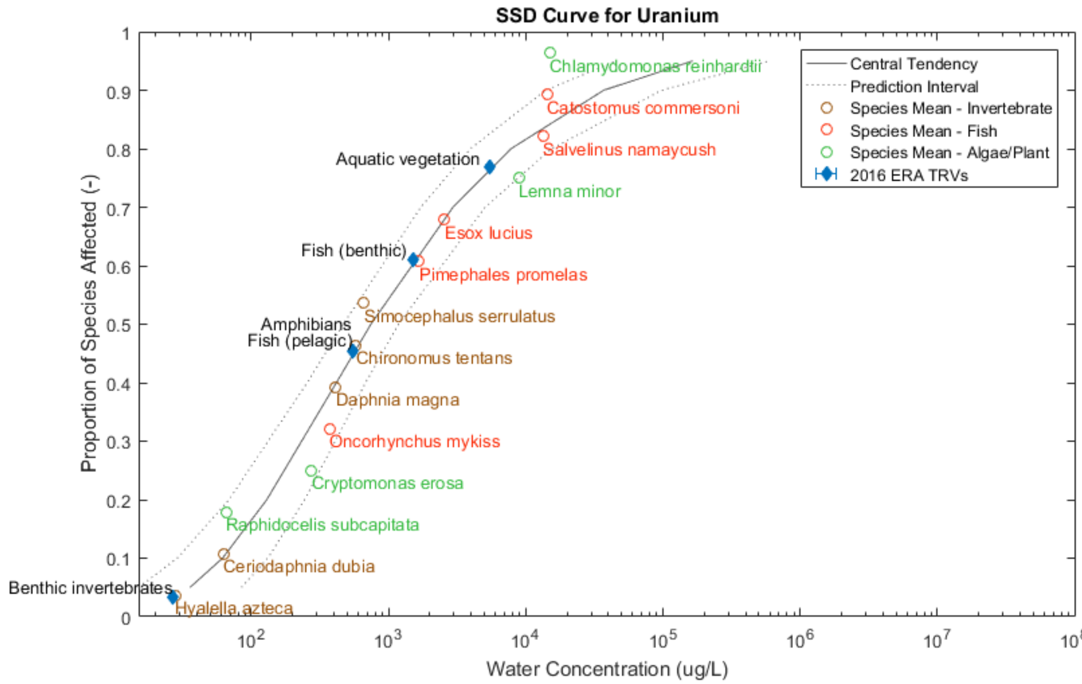
The 2016 ERA used the methodologies of the time as well as the toxicity reference values (TRVs). This review examines the TRVs and determines whether any values have been changed since the 2016 ERA and indicates the impact of these changes. For the radiological assessment, the selected dose coefficients 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 uranium for benthic invertebrates, aquatic plants, and fish were used. In more recent ERAs 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 5 provides the uranium SSD with the 2016 ERA TRVs (ARCADIS 2016, Table 6.12) 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 SSD curve (Figure 5) is based on CCME (2011 Table 11), with additional data from U.S. EPA ECOTOX and a literature review including Goulet et al. (2015).

There are more sensitive species of aquatic vegetation and fish considered in the SSD curve (Figure 5) 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 6.2 µg/L (ARCADIS 2016, Table 6.5 Case 1) 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 (CanNorth, 2021).

Figure 5 Uranium species sensitivity distribution



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 non-radiological effects. As noted above, the maximum concentration of uranium at 6.2 µg/L (ARCADIS 2016, Table 6.5 Case 1) is at the lower end of the curve and 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 (CanNorth, 2021).

The 2016 ERA considered aquatic receptor TRVs for chlorinated organics obtained from the CCME. The value for TCE of 0.021 mg/L (ARCADIS 2016, Table 6.14) is a water quality guideline from CCME, derived using an uncertainty factor of 10 on the lowest toxicity data of 0.21 mg/L for brook trout. For PCE, the value specified appears to be for a different chemical and could not be located in the CCME database. However, toxicity data for American flagfish were found in WHO (2006) and the lowest toxicity values are a 28-d NOEC for fry survival of 2.34 mg/L and a 10-d NOEC for larval survival of 1.99 mg/L (WHO 2006). Applying an uncertainty factor of 10 results in a TRV for PCE of 0.199 mg/L; this is higher than the TRV used in the 2016 ERA (0.110 mg/L, Table 6.14) and therefore no changes to the conclusions are expected (CanNorth, 2021).

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 6.17 and 6.19), the SI values calculated using a dose limit of 9.6 mGy/d are very low (<0.2), 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, 2021).

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 26 provides a comparison of the TRVs selected for the 2016 ERA and updated TRVs in more recent ERAs for Cameco in Northern Saskatchewan.

Table 26 Comparison of TRVs – terrestrial receptors - uranium

Receptor		2016 ERA TRV (mg/kg-d)	Updated TRV (mg/kg-d)	Effect on Conclusion
Mammals	Cotton-Tailed Rabbit	5.6	14	No change
	Red Fox	5.6	8.8	No change
	Meadow Vole	5.6	8.8	No change
Birds	American Robin	16	16	No change
	Yellow Warbler	16	16	No change
	Great Horned Owl	16	16	No change
	Horned Grebe	16	16	No change
	Lesser Scaup	16	16	No change

Note: Cotton-tailed rabbit, American robin, and great horned owl were not selected as terrestrial receptors in the most recent ERAs for Cameco in Northern Saskatchewan; therefore, LOAEL TRVs for these receptors 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 robin and owl do not have a match at the order and family level and were therefore assigned the default LOAEL TRV. However, specific uranium toxicity data was available for the order and family of rabbit and this is reflected in a different LOAEL TRV.

For mammals, the updated TRVs are 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 6.20 and 6.22). 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) (CanNorth, 2021).

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. Table 26 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 NOAEL TRV for uranium is 4 mg/kg-d, based on 5 studies. A single study is available for rabbit, with a NOAEL for uranium of 2.8 mg/kg-d. The highest SI calculated for a mammalian receptors in the 2016 ERA (ARCADIS 2016, Table 6.22) was 0.016 for the cotton-tail rabbit and red fox. Scaling this SI for consideration of the NOAEL value results in an SI value of 0.032 and 0.022[4] for the rabbit and fox, respectively; these values are 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 (CanNorth, 2021).

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 6.16 to 6.19) appear to use an incorrect dose limit of 9.6 mGy/d for grebe and scaup (dose limit of 2.4 mGy/d as presented in Table 6.15 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. Assuming that the indicator species selected for the 2016 ERA are reasonable surrogates for the SAR receptors, consideration of the dose threshold value of 1 mGy/d for no observable effects results in doses that remain well below one (CanNorth, 2021).

6.4.3 Human Receptors

The TRVs specified for the HHRA in the 2016 ERA (ARCADIS 2016, Table 5.20) for uranium are consistent with TRVs used in more recent ERAs for Cameco in Northern Saskatchewan. However, the use of the inhalation TRV for uranium used in the 2016 ERA for the evaluation of on-site workers was not appropriate since it is based on the protection of the general public. For on-site workers, occupational exposure limits are the appropriate values to be used. Ontario has a time-weighted average limit (TWA) for uranium of 200 µg/m^3 (Ontario Ministry of Labour 2020). The comparison of this TWA with the Tier 1 (7 µg/m^3) and Tier 2 (3 µg/m^3) indoor air concentrations (CFM 2015, Table 20) used in the 2016 ERA show that they are well below the occupational exposure level. Review of the indoor air data from 2016 to 2019 indicates that average room samples were comparable to the 2014 concentrations and also well below the TWA. Therefore, there is no concern for non-NEW on-site workers (maintenance and sub-surface) at the CFM from exposure to uranium in indoor air.

For chlorinated organic COPC, the 1,1-DCE toxicity data presented is for 1,1-DCA and the inhalation value for PCE presented in the 2016 ERA is a typographical error; both the 1,1-DCE and PCE values have been updated by the Ministry of Environment, Conservation, and Parks (MECP) since the ERA was completed and the values are currently less restrictive than those considered in the 2016 ERA (ARCADIS 2016, Table 6.14). The TCE inhalation slope factor appears to also have a minor error; the correct value ($4.1x10^{-3}$ $(mg/m^3)^{-1}$) would not affect the conclusions of the assessment (CanNorth, 2021).

[4] Rabbit: 0.032 = 0.016 x 5.6 mg/(kg-d) / 2.8 mg/(kg-d)
Red fox: 0.022 = 0.016 x 5.6 mg/(kg-d) / 4 mg/(kg-d)

7 Conclusion

The 2016 ERA for CFM was generally conducted using the framework outlined in N288.6-12 and using the available toxicity information at that time (CanNorth, 2021). There are a few issues that have been noted:

- 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.
- Groundwater EPCs for the evaluation of workers in a trench were not from depths where workers would encounter groundwater.
- Depth to groundwater assumption for vapour from groundwater calculation should be based on site-specific considerations.
- The evaluation of oral and dermal exposure pathways from groundwater for subsurface workers in unrealistic as workers would not be permitted into a trench with water.
- The evaluation or uranium in indoor air exposures to on-site workers incorrectly used benchmarks protective of members of the public rather than occupational exposure benchmarks.
- Daughter products should be considered separately in the radiological calculations.
- The human health calculations for the radiological dose are not correct as they do not represent incremental doses. Background needs to be subtracted from the calculations.
- Case 2 Tier 1 assessed aquatic receptors in the CFM effluent. This is an unreasonable assumption given that the CMF effluent does not discharge to surface water.
- Lack of evaluation of Species at Risk.
- Incorrect application of radiation benchmarks in the ecological assessment.

Addressing the above issues is likely to result in a reduction of the risks identified in the 2016 ERA such that very few if any risks would be identified.

The approach to the evaluation of aquatic receptors has evolved since the completion of the 2016 ERA; additionally, some toxicity values have changed. These changes in toxicity values and approaches to evaluation of aquatic receptors do not result in changes to the 2016 ERA conclusions, with the exception of the evaluation for uranium in indoor air for onsite workers.

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 2021 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. There were no areas identified for follow-up prior to the next review of the ERA.

8 References

Aqua Terre Solutions Inc. 2009a. 2008 Summary for Soil and Groundwater Monitoring for Uranium, Cameco Fuel Manufacturing Inc., Port Hope, Ontario. File no. 07-105C, July 6.

Aqua Terre Solutions Inc. 2009b. Pelleting Area Subsurface Soil Assessment. Letter to David Werry, CNSC, March 19.

Arcadis Canada Inc. (Arcadis). 2016. Environmental Risk Assessment for the Cameco Fuel Manufacturing Facility. Proj. 351175. Prepared for Cameco Fuel Manufacturing. November 2016.

Arcadis Canada Inc. 2018. Derived Release Limits for the Cameco Blind River Refinery. Report No. 351390. August 2018.

Arcadis Canada Inc. 2019a. Emission Summary and Dispersion Modelling Report. Report No. 351354. December 2019

Arcadis Canada Inc. 2019b. Acoustic Assessment Report (Confidential). Report No. 351488. September 2019

Arcadis Canada Inc. 2021. Derived Release Limits for the Cameco Fuel Manufacturing Facility. February 2021.

ASTM. 2010. Standard guide for risk-based corrective action applied at petroleum release sites. E1739.

Cameco Corporation letter. D. Clark to M. Leblanc. Application for Renewal of the Cameco Fuel Manufacturing Inc. Operating Licence, FFOL-3641.0/2022. December 2, 2020.

Cameco Fuel Manufacturing. 2015. 2014 Annual Compliance Monitoring & Operational Performance Report, Cameco Fuel Manufacturing.

Cameco Fuel Manufacturing. 2016. Written Summary for Reporting Year 2015, Certificate of Approval 7385-5QCSL5 Cameco Fuel Manufacturing Inc., 200 Dorset Street East Port Hope, Ontario. May.

Cameco Fuel Manufacturing. 2017b. Letter to Graham Smith (CNSC). Response to CNSC Staff Comments on the Cameco Fuel Manufacturing Environmental Risk Assessment. May 1.

Cameco Fuel Manufacturing. 2017a. Written Summary for Reporting Year 2016, Certificate of Approval 7385-5QCSL5 Cameco Fuel Manufacturing Inc., 200 Dorset Street East Port Hope, Ontario. July.

Cameco Fuel Manufacturing. 2019a. 2018 Annual Compliance Monitoring & Operational Performance Report. Reporting Period January 1 – December 31, 2018, Cameco Fuel Manufacturing Inc., March.

Cameco Fuel Manufacturing. 2019b. Written Summary for Reporting Year 2018, Environmental Compliance Approval 6603-ADBQEC Cameco Fuel Manufacturing Inc., 200 Dorset Street East Port Hope, Ontario. June.

Cameco Fuel Manufacturing. 2020a. Written Summary for Reporting Year 2019, Environmental Compliance Approval 6603-ADBQEC Cameco Fuel Manufacturing Inc., 200 Dorset Street East Port Hope, Ontario. August.

Cameco Fuel Manufacturing. 2020b. 2019 Annual Compliance Monitoring & Operational Performance Report. Reporting Period January 1 – December 31, 2019, Cameco Fuel Manufacturing Inc., March 31.

Canadian Council of Ministers of the Environment (CCME). 2011. Canadian Water Quality Guidelines: Uranium. Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for the Protection of Aquatic Life.

Canadian Nuclear Safety Commission (CNSC) letter. 2017a. G. Smith to M. Longinov. CNSC comments – 2016 Environmental Risk Assessment for Cameco Fuel Manufacturing Facility. March 1, 2017.

Canada North Environmental Services Limited Partnership (CanNorth). 2021. Review of Cameco Fuel Manufacturing Facility 2016 ERA. February 2021.

Canadian Standards Association (CSA) 2014. *Guidance on calculating derived release limits for radioactive material in airborne and liquid effluent for normal operation of nuclear facilities*. CSA N288.1-14.

Canadian Standards Association (CSA) 2012 (R2017). *Environmental risk assessment at class I nuclear facilities and uranium mines and mills*. CSA N288.6-12

Canadian Standards Association (CSA). 2014. *Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities*. CSA N288.1-14.

Environment and Climate Change Canada (ECCC). 2020. Canadian Climate Normals 1981-2010 Station Data. Available at: https://climate.weather.gc.ca/climate_normals/index_e.html. Accessed on 5 November 2020.

EC/HC. 1993. Priority substances list assessment report: Trichloroethylene. Canadian Environmental Protection Act. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contaminants/psl1-lsp1/trichloroethylene/trichloroethylene-eng.pdf.

GHD. 2015. Environmental Investigation Report: Existing Unlicensed Property. Prepared for Cameco Fuel Manufacturing Inc., December.

Golder Associates Ltd. 2021. Targeted Soil Investigation and Monitoring Well Replacement. Project 20350259. March 2021.

Goulet, R.R., P.A. Thompson, K.C. Serben, and C. V Eickhoff. 2015. Impact of environmentally based chemical hardness on uranium speciation and toxicity in six aquatic species. Environmental Toxicology and Chemistry 34(3):562–574.

Government of Ontario. 1990. O.Reg 213/91: Construction Projects, Occupational Health and Safety Act. https://www.ontario.ca/laws/regulation/910213.

Health Canada. 2012. Federal contaminated site risk assessment in Canada, Part I: Guidance on human health preliminary quantitative risk assessment (PQRA). Version 2.0.

International Atomic Energy Agency. 1992. Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards. Technical Reports Series No. 332.

Independent Environmental Consultants (IEC). 2020. Blind River Refinery (BRR) Review of Environmental Risk Assessment. Project No. SX20-0035. September.

Independent Environmental Consultants (IEC). 2021. Subject: Cameco Fuel Manufacturing (CFM) Review of Environmental Risk Assessment. Project No. SX20-0049. March 2021.

Ministry of the Environmnet (MOE). 2011. Rationale for the development of soil and ground water standards for use at contaminated sites in Ontario. Prepared by the Standards Development Branch, September.

Ministry of the Environment (MOE). 2013. Environmental Noise Guideline – Stationary and Transporttion Sources – Approval and Planning (NPC-300). August 2013.

National Council on Radiation Protection and Measurements (NCRP). 1984. Radiological Assessment: Predicting the Transport , Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment, Report No. 076.

Ontario Ministry of Labour, T. and S.D. 2020. Current Occupational Exposure Limits for Ontario Workplaces Required Under Regulation 833. https://www.labour.gov.on.ca/english/hs/pubs/oel_table.php#uv (accessed November 4, 2020).

Sample, B.E., D.M. Opresko, and G.W. Sutter II. 1996. Toxicological benchmarks for wildlife : 1996 revision. Prepared by the Risk Assessment Program Health Sciences Research Division for the U.S. Department of Energy, Office of Environmental Management.

SENES. 2007. Environmental Review of the Zircatec Port Hope Fuel Fabrication Facility. Project No. 34406-5, April.

SENES. 2008. Soil Characterization and Evaluation Study at Port Hope, Final. Project No. 34406-5, April.

SNC Lavalin. 2011. 2010 Groundwater Monitoring for Uranium, Cameco Fuel Manufacturing Inc. Port Hope, Ontario. REF: 98-230V, March 31.

SNC Lavalin. 2013. Cameco Fuel Manufacturing Inc. Port Hope Facility. Acoustic Assessment Report. {roject 612883. September 2013.

Thompson, P.A., J. Kurias, and S. Mihok. 2005. Derivation and use of Sediment Quality Guidelines for Ecological Risk Assessment of metals and radionuclides released to the environment from uranium mining and milling activities in Canada. Environmental Monitoring and Assessment 110:71–85.

United States Environmental Protection Agency (U.S. EPA). 2003. Title 40 – Protection of Environment. Code of Federal Regulations, Appendix W to Part 51 – Guideline on Air Quality Models; 40 CFR Ch. I (7-1-03 Edition). Available at: http://www.epa.gov/scram001/guidance/guide/appw_03.pdf. Accessed on 23 August 2020.

U.S. EPA. 2005. Guidance for developing ecological soil screening levels. February Revision.

WHO. 2006. Concise International Chemical Assessment Document 68: Tetrachloroethene. https://www.who.int/ipcs/publications/cicad/cicad68.pdf.