BWXT Nuclear Energy Canada Inc.

Environmental Risk Assessment Report

Peterborough Consolidated Operations

November 2018

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ENVIRONMENTAL RISK ASSESSMENT REPORT

Peterborough Consolidated Operations

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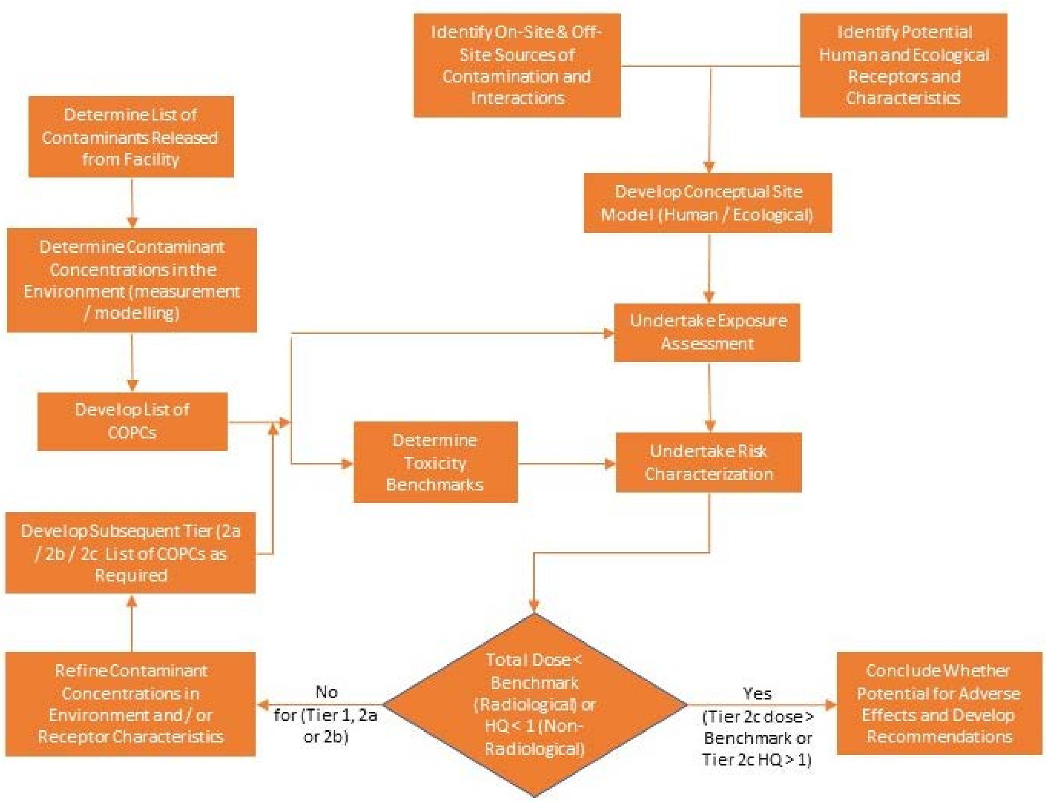
EXECUTIVE SUMMARY

The BWXT NEC Nuclear Fuel Pellet Operation (NFPO) in Toronto may be consolidated with existing BWXT Nuclear Fuel Assembly Operations (NFAO) in Peterborough. As per Canadian Nuclear Safety Commission's (CNSC) environmental protection series of regulatory documents, every applicant or licensee must have an Environmental Risk Assessment (ERA), which must be updated whenever significant change occurs in the facility or activity. As this possible consolidation would be a significant change in the Peterborough operation, an ERA was undertaken to determine whether there is a potential for significant environmental (i.e. ecological and human health) effects from current or planned emissions or physical stressors associated with the consolidated operations of the facility.

Effectively, the assessment evaluates the contaminants that are released to the air and water from the facility to determine whether there is any potential for health effects to humans through a Human Health Risk Assessment (HHRA) or non-human biota through an Ecological Risk Assessment (EcoRA). The general methodology followed for both the human health and ecological risk assessments are defined by Canada Standards Association (CSA) and Health Canada (Health Canada (2012a), CSA N288.1 (2008) and CSA N288.6 (2012)). This iterative methodology allows for the calculations to be refined in each iteration (or Tier) by removing conservatism. This methodology is illustrated in the following figure:

Figure 1 ERA Methodology



Integral to this assessment is to understand how the contaminants from the facilities operations enter the natural environment and interact with the Human and Ecological Receptors. Figures 2 and 3 illustrate the pathways of contaminant exposure to humans and ecological receptors, respectively.

Figure 2 Sample Human Pathway Model (CSA 2012)

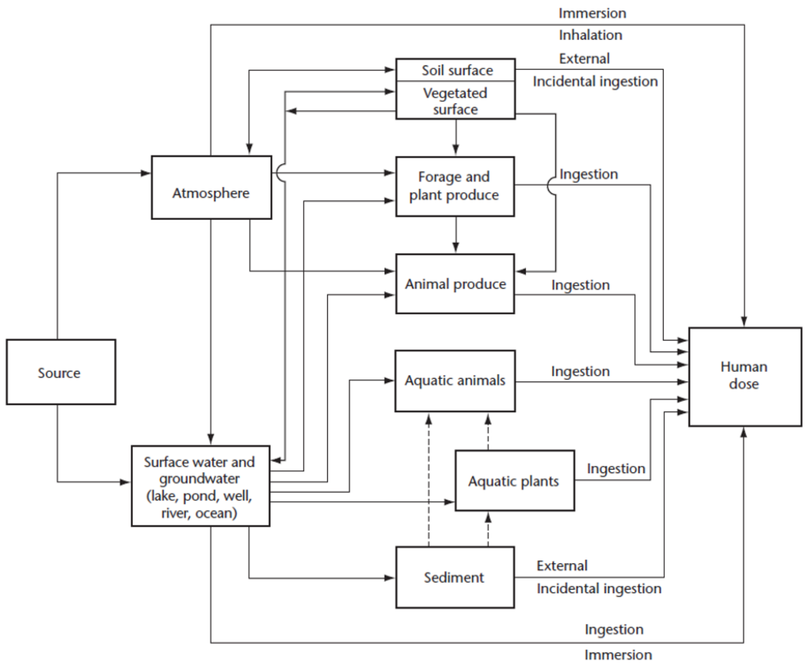
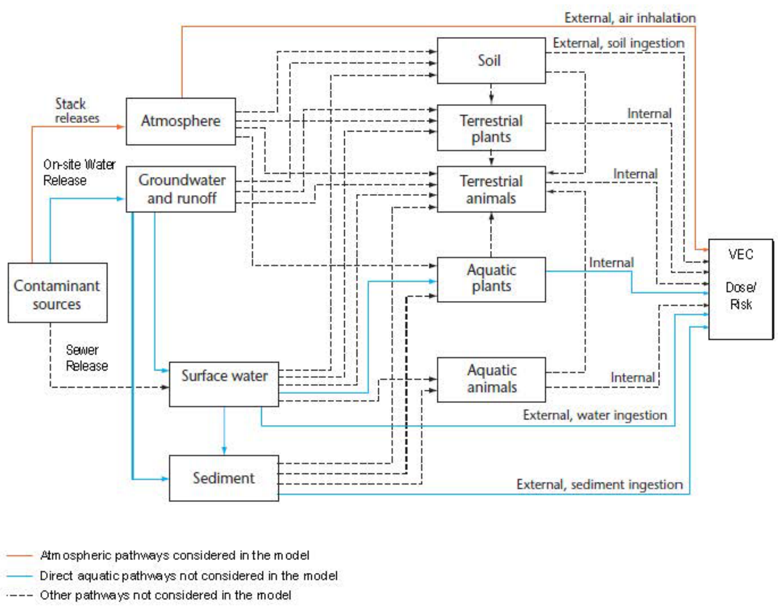


Figure 3 Sample Ecological Exposure Pathway Model (CSA 2012)



Once this is understood, the Contaminants of Potential Concern (COPCs) need to be determined. This is a list of all radiological and non-radiological contaminants released to air and water from facility operations. When contaminants are released in very small quantities, they are removed from further consideration. Also, if it is determined that the contaminants are not a concern from a human or ecological health perspective, they are removed from further consideration.

EMISSIONS TO AIR

The principle radiological contaminant emissions of BWXT NEC consolidated operations are uranium and beryllium. The number of stacks servicing the consolidated operations have not been finalized, thus, uranium emissions may differ from historical conditions, but are likely to be within or lower than the range of emissions observed at the existing nuclear fuel pelleting operation.

Beryllium is only handled during the fuel bundle assembly process, therefore the expected air emissions from the consolidated operations will be similar to the current emissions measured at the Peterborough facility.

Airborne non-radiological contaminant emissions for the consolidated operations have modelled air concentrations less than 70% of the screening criteria in all cases. Furthermore, all non-radiological substances are currently and will continue to be below CNSC licence limits, BWXT NEC *Action Levels,* BWXT NEC *Internal Control Levels* and Ontario Ministry of the Environment, Conservation and Parks (MECP) Benchmarks limits, and are therefore expected to be negligible.

EMISSIONS TO WATER

There are no surface waters present in the vicinity of consolidated operations and limited liquid effluent from the facility, therefore no measurable effects on surface water and sediment components are expected. For discharges to sewer, after passing through the municipal wastewater treatment plant, concentrations of uranium and beryllium are currently, and will continue to be, well below WHO drinking water quality guidelines.

HUMAN HEALTH RISK ASSESSMENT

Because airborne contaminant emissions are expected to be well below applicable guidelines and limits, no non-radiological airborne substances have been identified as COPCs for further assessment in the HHRA. Similarly, because contaminant emissions are well below applicable guidelines and criteria, no non-radiological waterborne substances have been identified as COPCs for further assessment.

The estimated annual effective dose as a result of air releases and direct gamma exposure radiation from the combined operation is expected to be on the order of 10 µSv/year. This dose represents 1% of the 1 mSv (1,000 µSv) per year effective dose limit to a member of the public and 5% of the 0.2 mSv (200 µSv) per year screening criterion for radiological releases to air and water. Therefore, it can be concluded that there will be no radiological effects to the public due to the proposed consolidated operations of

BWXT NEC, and there is no radiological risk posed to off-site human receptors, thus, no further assessment is required.

Noise was identified as a potential physical stressor for human health. The consolidated operations will be required to demonstrate conformance to MECP NPC-300 noise criteria during the environmental compliance approvals process. Therefore, it is expected that noise levels from the proposed facility will pose no adverse effects to human health.

ECOLOGICAL RISK ASSESSMENT

As for human health, because airborne and waterborne contaminant emissions are currently and will continue to be well below applicable guidelines and limits, no non-radiological substances have been identified as COPCs for further assessment in the EcoRA.

Radiation (external and internal) exposure due to uranium emissions to air will be negligible as only between 10.4 and 17.2 g of uranium per year are estimated to be released, resulting in very low uranium in air concentrations and very low soil concentrations, such that inhalation and soil ingestion are not expected to be of concern. Direct external exposure to gamma radiation is estimated to be well below levels that are known to cause adverse effects. Therefore, it can be concluded that no radiological effects to VECs (Valued Ecosystem Components) are expected due to the consolidated operations and no further assessment is required.

The BWXT NEC Peterborough facility is located in a highly urbanized area which limits the site-specific potential for physical stressors to impact on biota. The consolidation of the operations is not expected to measurably increase the existing stressors to biota (road kill, heat and intake cooling water, artificial night lighting or noise) and no further assessment is required.

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1 INTRODUCTION

1.1 Background

In June 2012, Canadian Standard Association (CSA) issued N288.6-12, *Environmental risk assessments at class I nuclear facilities and uranium mines and mills, 2012*. This standard addresses the design, implementation, and management of an environmental risk assessment program that incorporates best practices used in Canada and internationally. The Canadian Nuclear Safety Commission (CNSC) RegDoc-2.9-1, version 1.1 states for Class I facilities, “the licensee shall conduct an ERA in accordance with CSA 288.6”.

On July 7, 2014, the Directorate of Nuclear Cycle and Facilities Regulation issued a letter noting that “*while GE Hitachi Nuclear Energy Canada Inc (GEH-C)* [now operating as BWXT Nuclear Energy Canada Inc.] *currently has acceptable environmental protection programs and plans in place, CNSC staff expects GEH-C to make any required adjustments to these programs and plans in order to align with the standardized requirements found in N288.6-12.*”

An ecological risk assessment for the Peterborough facility was completed in 2009 in support of the Environmental Impact Statement Report for the Low Enriched Uranium (LEU) Fuel Bundle Production Project (GEH-C, 2009). This risk assessment was generally consistent with requirements N288.6-12, however, the proposed LEU production line was never implemented.

This current ecological risk assessment is being completed to update previous work to fully conform with N288.6-12 requirements, reflect current and future plant operations and to incorporate recent monitoring data into the risk assessment process.

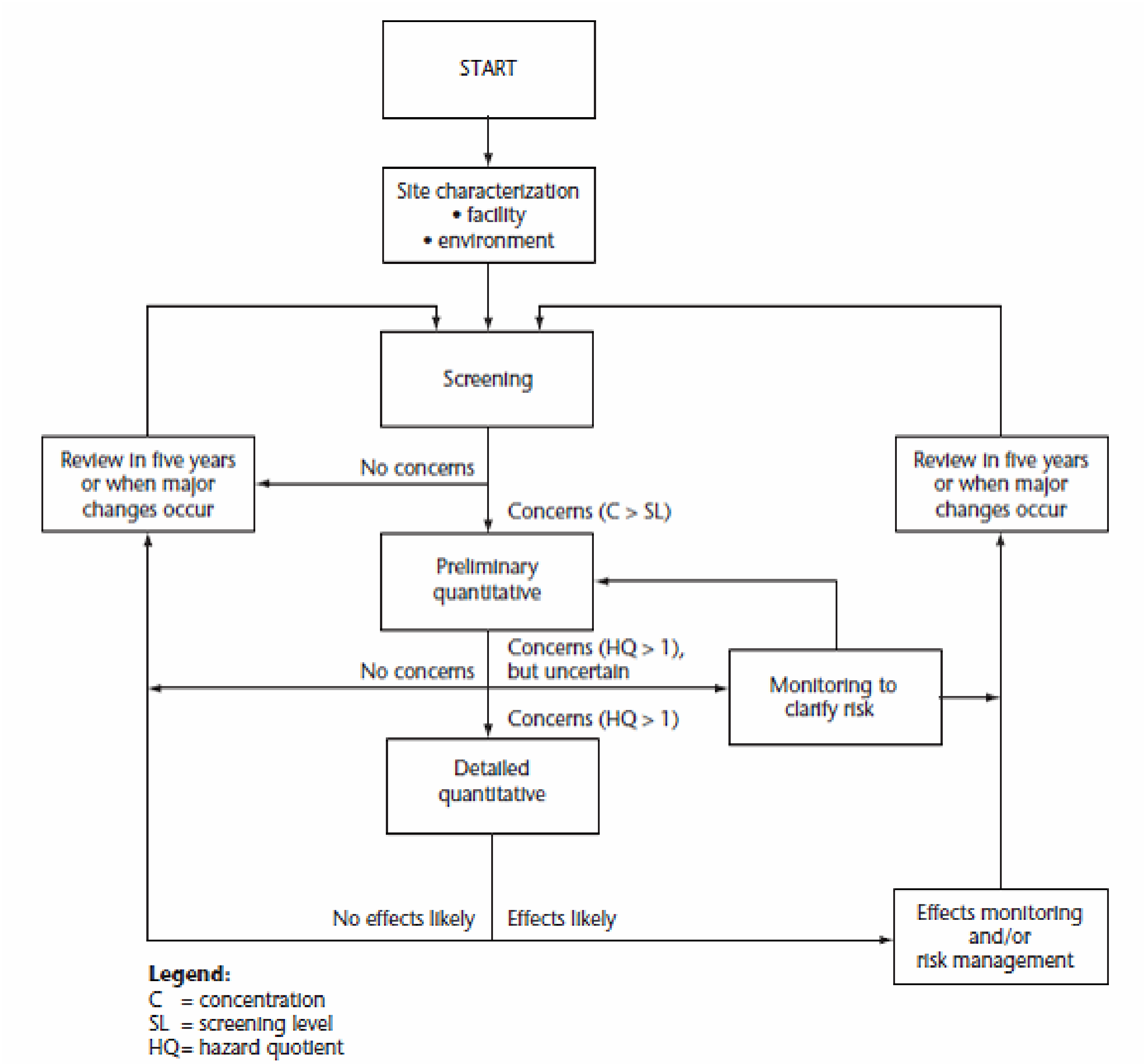
N288.6-12 defines an Environmental Risk Assessment (ERA) as a systematic process to assess the risk posed by contaminants and physical stressors in the environment on biological receptors, including the magnitude and extent of the potential effects associated with a facility. Human receptors are addressed through a human health risk assessment (HHRA) and non-human biota are addressed through an ecological risk assessment (EcoRA) (CSA, 2012).

In accordance with CSA N288.6-12, the ERA should follow a tiered approach where risks that require more detailed consideration are identified and assessed in greater detail. CSA N288.6-12 recommends that the following tiers of assessment be conducted for the nuclear facilities, as appropriate:

- Tier 1 - Screening level risk assessment (SLRA): This first tier of assessment is broad in scope and serves to identify potential issues (receptors and stressors) that require further quantitative evaluation at a higher tier. If no such issues are identified, no further assessment is needed;
- Tier 2 - Preliminary quantitative risk assessment (PQRA): This second tier addresses the identified potential issues quantitatively, generally using available site data. If an issue is resolved as being of no concern, it requires no further assessment.
- Tier 3 - Detailed quantitative risk assessment (DQRA): This third tier addresses any issues that are still of concern after the PQRA.

This progression is illustrated at a high level in Figure 1.1. Specifically, the tasks identified in Table 1.1, as appropriate, should be performed in each tier.

Figure 1.1 – ERA Progression through Tiers of Assessment



Source (CSA, 2012)

Table 1.1 – ERA Tasks by Tier

Screening level risk assessment (SLRA) — Tier 1	Preliminary quantitative risk assessment (PQRA) — Tier 2	Detailed quantitative risk assessment (DQRA) — Tier 3
Problem formulation • characterize the site • compare screening levels to screening criteria • select contaminants and physical stressors • select receptors and exposure pathways • define assessment and measurement endpoints (EcoRA) • develop conceptual model • problem formulation checklist (HHRA)		
	Exposure assessment • estimate exposure/dose for receptors at relevant locations for each contaminant of potential concern (COPC) or physical stressor Toxicity/effects assessment • select TRVs/benchmarks for each receptor and COPC or physical stressor (if possible) Risk characterization • calculate HQs for each COPC or physical stressor (if possible) at relevant locations • calculate cancer risk for non-radiological carcinogens for human receptors (HHRA)	
		• Refine exposure assessment and risk characterization as needed to reduce uncertainty (additional site data might be necessary) • Consider any other lines of evidence (e.g., epidemiology and field studies of toxicity or of population/community effects) • Provide recommendations for further uncertainty reduction, effects monitoring, or risk management if applicable

Note: *Only issues (receptors or stressors) that remain of concern at the end of each assessment tier need to be considered further in the next assessment tier.*

Source (CSA, 2012)

1.2 Goals, Objectives, and Scope

As per CNSC's environmental protection series of regulatory documents, every applicant or licensee must have an ERA, commensurate with the scale and complexity of the environmental risks associated with the facility or activity and should update the ERA at least every five years and whenever significant change occurs in either the facility or activity. This ERA was prepared to identify potential health and ecological risks associated with the consolidation of the BWXT NEC Nuclear Fuel Pellet Operation (NFPO) in Toronto with the existing BWXT Nuclear Fuel Assembly Operations (NFAO) in Peterborough.

The objectives of this ERA are to:

- understand the potential risks to human and non-human biota receptors resulting from the consolidated operations;
- establish baseline conditions for the consolidated operations;
- confirm the focus of the environmental monitoring program; and,
- recommend further action or assessment, as appropriate.

The scope of the ERA covers both human health risk assessment and ecological risk assessment.

Baseline conditions for the consolidated operations are reflected in the operations, emissions and environmental impacts associated with the nuclear fuel assembly operation and current environmental conditions in the Peterborough area, up to and including 2016 data.

CSA N288.6-12, clause 0.4 notes that the nature and complexity of ERAs will vary according to the nature and complexity of the subject (site, scenario, magnitude, facility, etc.) and provides for a tiered approach to ERA. Where concerns are below screening criteria, a Screening Level Risk Assessment (SLRA) is deemed adequate. Where concerns are noted, a Preliminary Quantitative Risk Assessment (PQRA) is required, with any a Detailed Quantitative Risk Assessment (DQRA) required where the PQRA identifies a hazard quotient, as defined in the Standard, greater than 1. Within the context of this tiered approach, compared to other nuclear fuel cycles facilities, the Peterborough Operation presents a relatively low environmental risk profile.

1.3 Organization of Report

The ERA has been structured for consistency with Appendix A of CSA N288.6-12. The report is structured as follows:

- Section 2: Site Description;
- Section 3: Human Health Risk Assessment;
- Section 4: Ecological Risk Assessment;
- Section 5: Conclusions and Recommendations;
- Section 6: Quality Assurance / Quality Control; and,
- Section 7: References.

2 SITE DESCRIPTION

2.1 Engineered Site Facilities

The Peterborough Nuclear Facility is operated by BWXT NEC and is located within the General Electric (GE) main plant complex between Monaghan Road and Park Street North in Peterborough (See Figures 2.1 and 2.2). The business address for BWXT NEC NFAO is 1160 Monaghan Road, Peterborough, Ontario K9J 0A8. The total plant complex is registered as Lots 14 to 17 and Lots 6 to 30 inclusive, of plan 30 North side of Albert Street, registered September 3, 1892.

2.1.1 BWXT NEC Buildings

Within the larger GE complex, BWXT NEC NFAO occupies Buildings 21, 24, 26 and 28 (see Figure 2.2). Other buildings in the GE complex are used for offices and conventional manufacturing.

Building 21 is a two-story brick and steel frame building located within the Main Plant Complex at 107 Park St. North in Peterborough. Building 21 currently accommodates fuel bundle assembly which consists of uranium pellet storage, pellet load, end cap weld, bundle assembly, test, inspection and pack. BWXT NEC proposes to consolidate the production of uranium fuel pellets from its Toronto, Ontario facility into Building 21 operations.

Building 24 was built in three stages (A, B and C) between 1961 and 1981. Building 24 will continue to be used primarily for storage of finished product in shipping containers prior to shipment, pellets and powder.

Building 26 will continue to be used for the manufacture, refurbishment and assembly of fuel handling equipment.

Building 28 will continue to be used for conventional shipping and receiving and contains the shipping dock.

2.1.2 Process Description

BWXT NEC is licensed to produce natural uranium fuel bundles under Nuclear Fuel Facility Operating Licence FFOL-3620.01/2020. BWXT NEC is proposing to consolidate its fuel pellet production located at 1025 Lansdowne, Toronto, Ontario with its existing fuel bundle assembly operations located at 1160 Monaghan Road, Peterborough.

The proposed consolidated operations will process natural uranium dioxide powder (UO_2) into fuel pellets. Specifically, ceramic grade UO_2 powder will be received in standard steel drums from the Cameco Port Hope Facility or alternate supplier. The powder will be compressed into “slugs” and granulated to a free-flowing powder. This powder is pressed into pellet shape and sintered in hydrogen atmosphere furnaces at high temperature. The sintered pellets are hard and ceramic, ground to the required diameter. In the fuel bundle assembly operation, fuel pellets will be loaded into tubes that are sealed and welded to produce fuel elements which are then assembled into fuel bundles (See Figure 2.3). Details of fuel bundle design vary by reactor. However, fuel bundles currently manufactured at BWXT NEC in Peterborough generally consist of 28 or 37 fuel elements.

The Facility will operate 24 hours per day, 7 days per week.

2.1.3 Uncertainties in Site Engineered Facilities

Based on BWXT NEC's conceptual design, the fuel pellet production will be integrated with the fuel bundle assembly process in Building 21. No major infrastructure changes are expected as a result of process consolidation. While specific fuel pelletizing equipment and associated, environmental controls have not yet been selected, it is expected that environmental performance of the equipment will be as good as or better than that currently in use at the current fuel pelleting operation.

Figure 2.1 – BWXT NEC Peterborough Facility

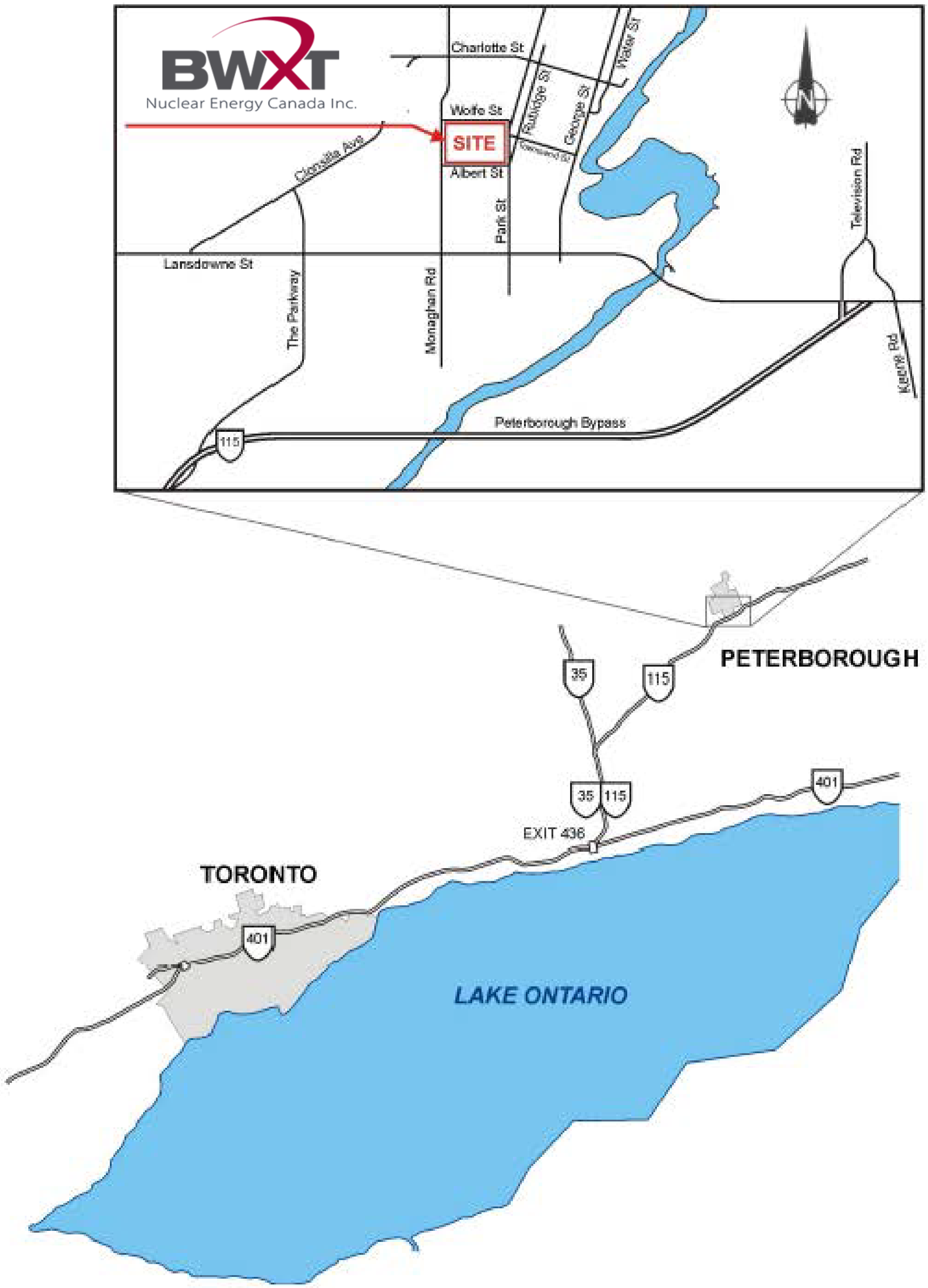


Figure 2.2 – Site Plan of the BWXT NEC Peterborough Facility

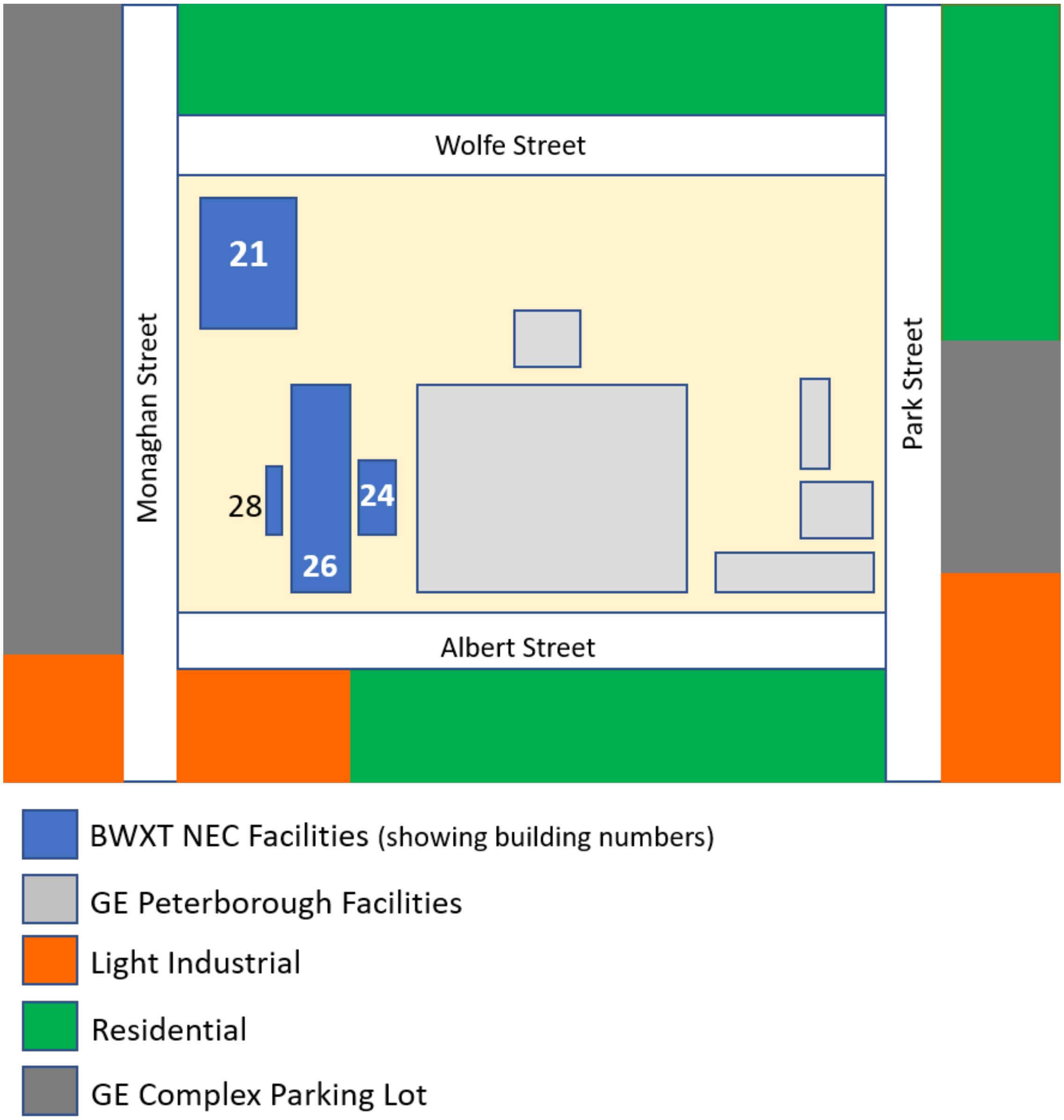
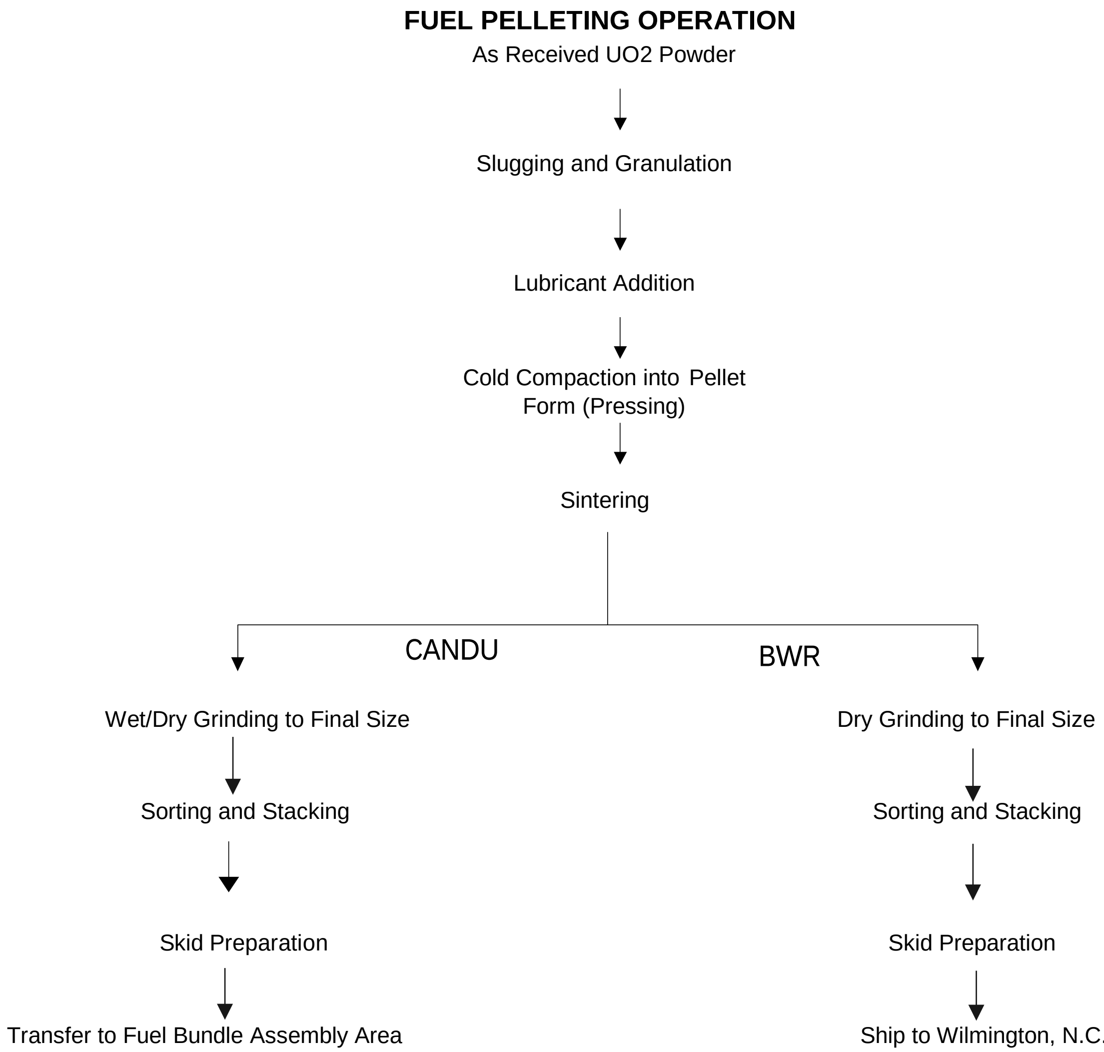
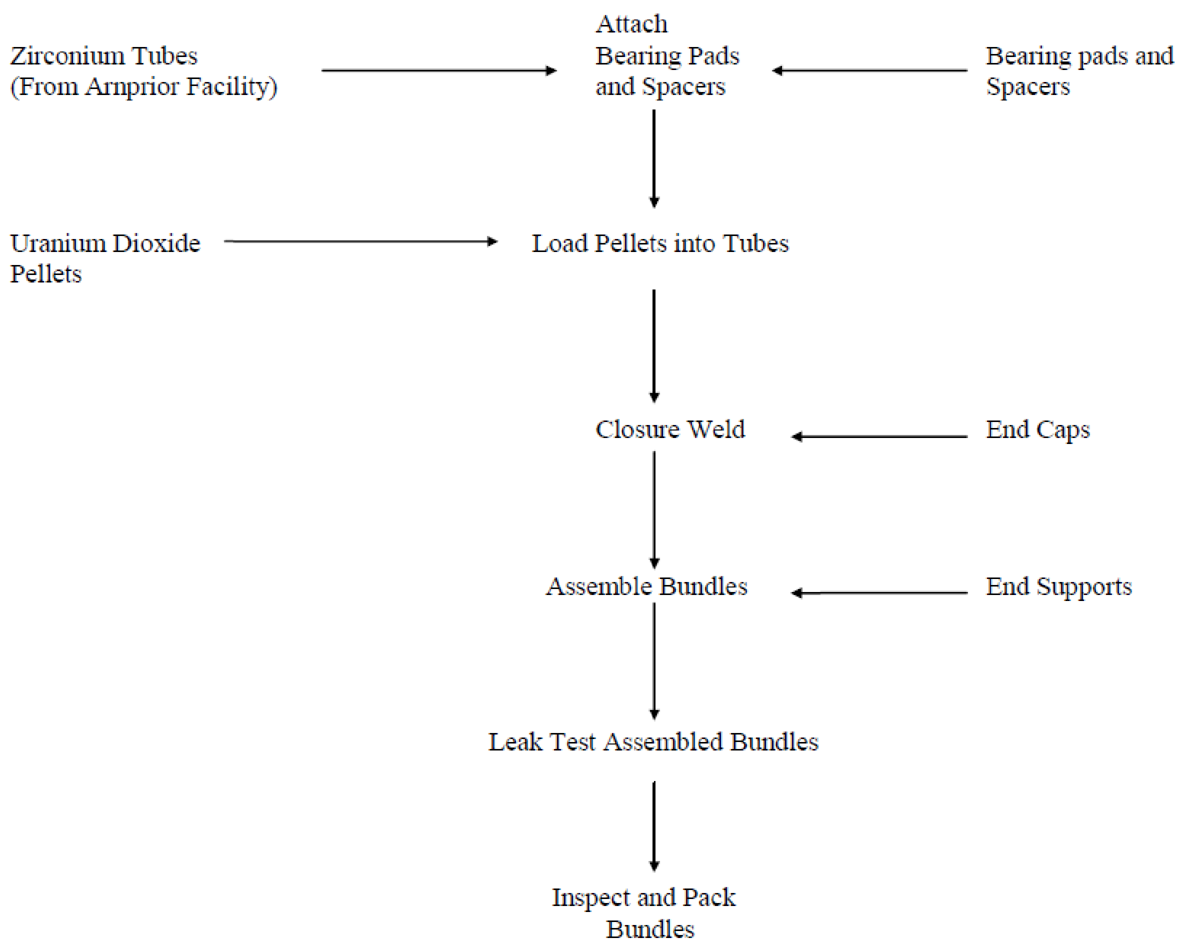


Figure 2.3 – Natural Uranium Fuel Pelleting and Fuel Bundle Manufacturing Process



Nuclear Fuel Bundle Fabrication



2.2 Description of the Natural and Physical Environment

The natural and physical environment of the BWXT NEC consolidated operations and the surrounding area is described in this section. Since the principle contaminant emissions associated with the operation of the BWXT NEC consolidated operations are uranium and beryllium, the discussion focuses on these constituents.

2.2.1 General Description of Surrounding Area

The BWXT NEC consolidated operations will be located within the GE Peterborough main plant complex. The surrounding area is a mix of residential, light industrial and heavy industrial zones. The nearest sensitive land uses are residences located on Residential (R) zoned land immediately north, south, and east of the Facility (see Figure 2.2) and the Prince of Wales Public School located approximately 50 m to the northwest.

2.2.2 Climate and Meteorology

Peterborough has a humid continental climate (according to the Köppen classification, OMAFRA, 2011) with large seasonal temperature differences, with warm to hot (and often humid) summers and cold (sometimes severely cold) winters. Further details are provided in section 2.2.2.2 below. Precipitation is usually well distributed through the year as discussed further in section 2.2.2.3 below. This climate is characterized by four different seasons and is greatly affected by the Great Lakes. Summers in Ontario are warm with several stretches of hot, humid and hazy weather. Fall brings mainly warm sun-filled days and cool temperatures at night. Winters can last anywhere from three to five months whereas spring is the shortest season of the year.

Ontario is located across one of North America's major storm tracks. As a result, when high and low-pressure systems move over the area they bring great variation in the day-to-day weather. The majority of weather systems travel through the province every two to five days during the year. Periods of active weather rarely last long (Environment Canada, 2005).

The long-term climate conditions in the region are described by the Environment and Climate Change Canada (ECCC) 30-years climate data normals from the Peterborough Airport climate station for the period from 1981 to 2010. The local meteorology near the BWXT NEC consolidate operations, as described below, is characterized by the surface meteorological data collected from the ECCC Peterborough climate station, for the period from 2012 to 2016.

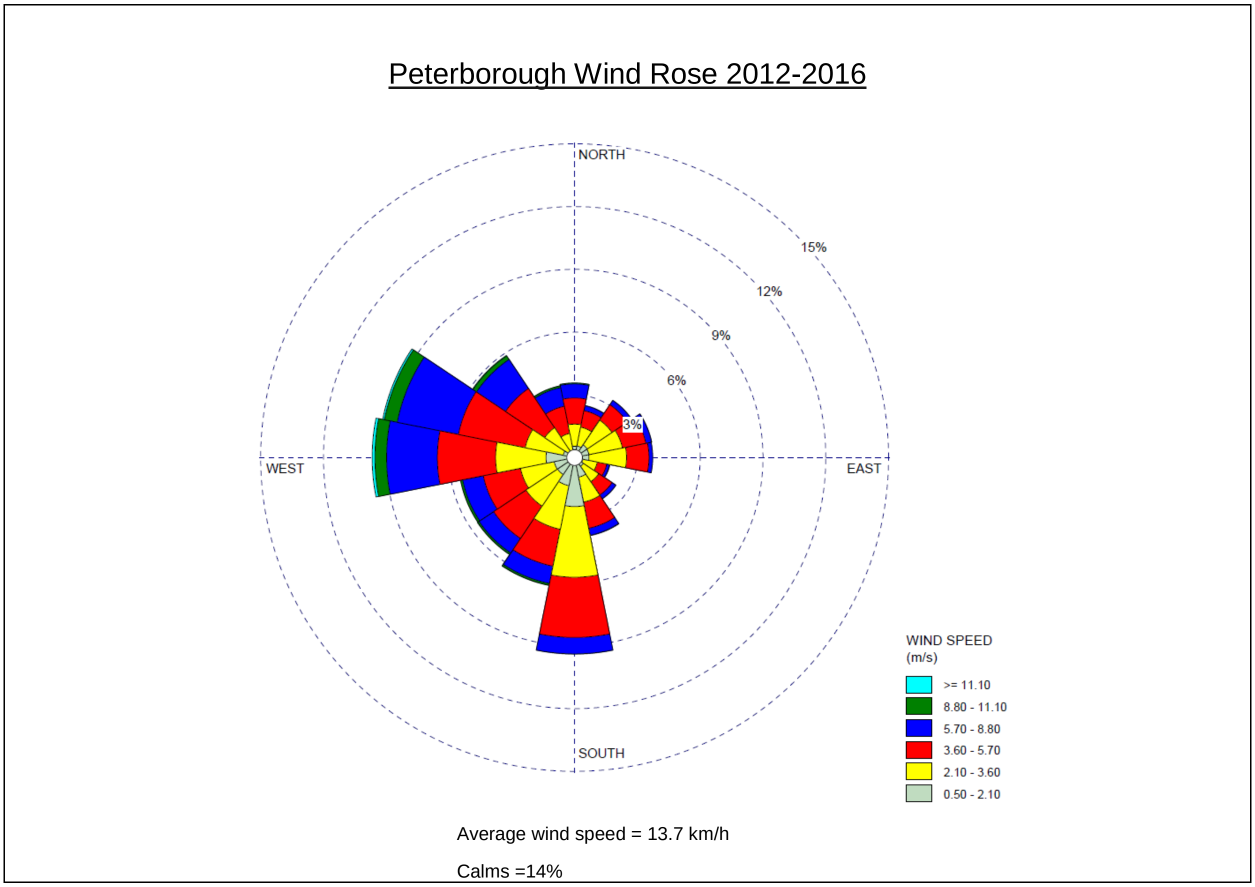
2.2.2.1 Wind

Table 2.1 summarizes the wind speed and wind direction for the 30-year period from 1981 to 2010 at the Peterborough A station. Wind direction is reported as the direction from which the wind blows and is based on surface (i.e. 10 m) observations. The most frequent wind recorded at Peterborough A in the period 1981 to 2010 was from the west, with average annual wind speed of 10.6 km/h. The maximum hourly wind speed was in the range from 42 km/h (from the SE recorded in July) to 70 km/h (from the W recorded in April).

Figure 2.4 presents the frequency distribution of hourly surface wind speed and direction at the Peterborough station in the period from 2012 to 2016 in the form of a wind rose. The prevailing annual wind direction was from the west (occurring 9.6% of the time), consistent with the dominant westerly wind in the climate normals. The average wind speed was 13.7 km/h. Calm wind conditions were observed 13% of the time.

Direction and speed of the wind dictates the location and distance from the source that a pollutant may travel.

Figure 2.4 – Wind Rose



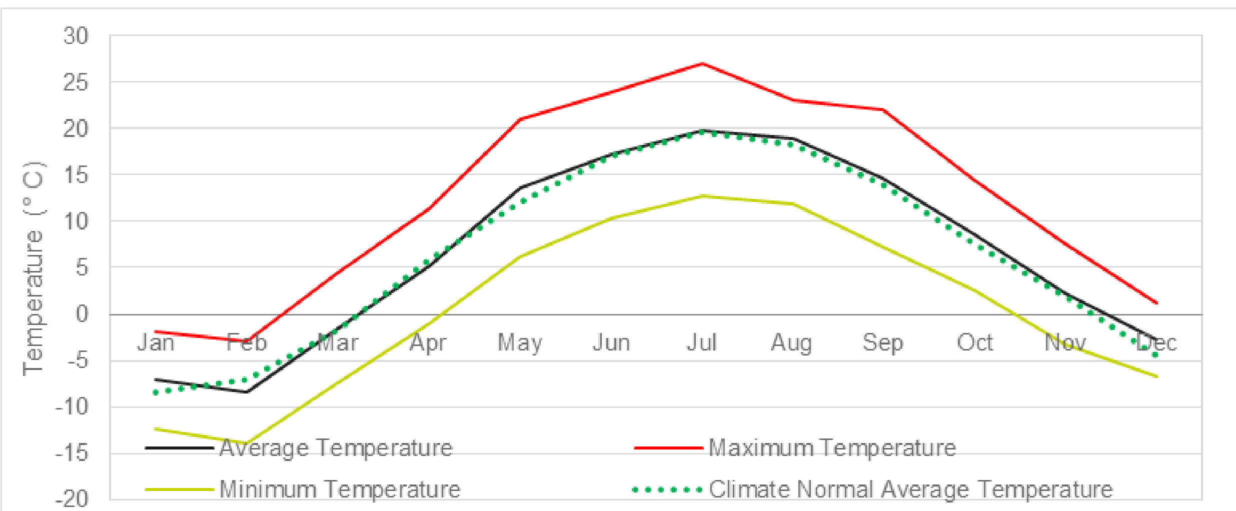
Note: Wind directions shown are winds "blowing from".

2.2.2.2 Temperature

Thirty-year temperature normals, which are updated by ECCC every ten years, are provided in Table 2.2 for the period 1981 to 2010, for the Peterborough Airport station (http://climate.weather.gc.ca/climate_normals/). Mean daily temperatures were below 0°C from December through March and ranged from 19.6°C in July to -8.5°C in January. The average daily temperature is 6.2°C. The mean daily maximum temperature was in the range from a high of 26.4°C in July to a low of -3.2°C in January for the 1981 to 2010 period. The mean daily minimum temperature ranged from 12.8°C in July to -13.7°C in January between 1981 and 2010. For this 30-year period, the extreme temperature ranged from a maximum of 36.2°C in August to a low of –37.9°C in January.

Local temperature data for the most recent period of 2012 to 2016 were collected from the EC meteorological station at Peterborough (http://climate.weather.gc.ca/climate_data) and are summarized in Table 2.4. Mean daily temperatures were below 0°C from December through March and ranged from 19.9°C in July to -8.5°C in February. The average daily temperature was 6.7°C. The mean daily maximum temperature was in the range from a high of 27°C in July to a low of -3°C in February for the 5-year period 2012 to 2016. The mean daily minimum temperature ranged from 12.8°C in July to -14°C in February between 2012 and 2016. For this 5-year period, the extreme temperature ranged from a maximum of 35.4°C in August to a low of –32°C in January. Figure 2.5 presents mean, maximum and minimum monthly temperatures for the period 2012 to 2016. For comparison, the average daily temperature climate normal is presented in the same figure. The temperature data from the recent 5-year period are generally consistent with the temperature climate normals.

Figure 2.5– Average Monthly Temperatures at the Peterborough Meteorological Station (2012 - 2016)



The combination of low temperature and wind can produce a chilling effect experienced by the human body that is much greater than the actual measured temperature. Based on the Climate Normals (1981 to 2010) the lowest wind chill in Peterborough was calculated to be –44.5°C in February (see Table 2.3).

2.2.2.3 Precipitation

Table 2.4 summarizes the thirty-year precipitation normals for the Peterborough Airport station for the 1981 to 2010 period provided by ECCC. The average annual precipitation measured within 30-year period was 855 mm, with approximately 83% of the total annual precipitation falling as rain. The highest mean monthly rainfall was in September (84.5 mm), while the greatest rainfall in a 24-hour period occurred in July (83.8 mm). The highest mean monthly snowfall was in January (40 cm), while the greatest snowfall in a 24-hour period occurred in February (33.2 cm). An extreme snow depth of 71 cm for the period from 1981 to 2010 was recorded in March.

Local precipitation data are available from daily data collected from the Peterborough meteorological station in the form of total precipitation (i.e., individual rain and snowfall data were not available). Total precipitation data for the 5-year period 2012 to 2016 are summarized in Table 2.6 and presented in Figure 2.6. The annual total precipitation over the 5-year period 2012 to 2016 was 684 mm, or 80% of the total precipitation climate normal. Monthly precipitation averages ranged from 29 mm in March to 98 mm in June. Total monthly precipitation data for the year 2016 were incomplete and data for the period 2012-2015 were added for comparison to the climate normals. The average annual total precipitation for the 2012 to 2015 was 750 mm or 88% of the total precipitation climate normal.

Figure 2.6– Total Monthly Precipitation at the Peterborough Meteorological Station (2012 - 2016 and 2012 - 2015)

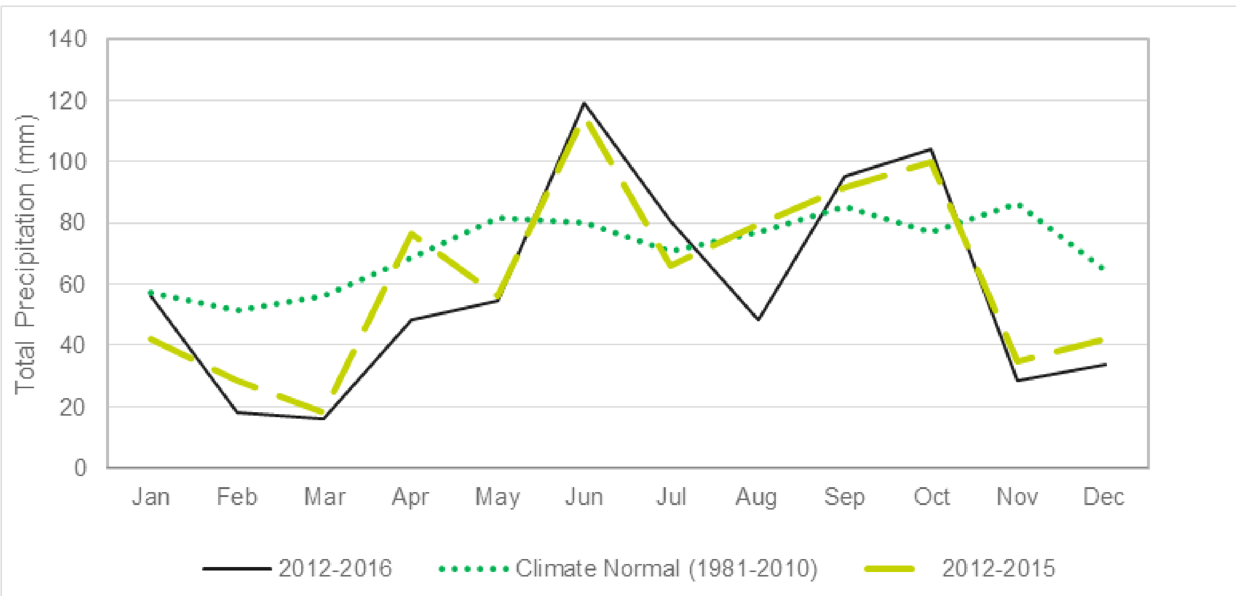


Table 2.1 – Wind Climate Normals, Peterborough A, Ontario, 1981 to 2010

Wind	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Speed (km/h)	12.3	11.7	12.2	12.6	11	9.7	8.8	7.7	8.4	9.8	11.6	11.7	10.6
Most Frequent Direction	W	W	W	W	W	W	W	W	W	W	W	W	W
Maximum Hourly Speed (km/h)	64	69	58	70	52	52	42	46	52	56	63	63	70
Direction of Maximum Hourly Speed	W	SW	SW	W	SW	SW	SE	S	W	SW	W	W	W
Maximum Gust Speed (km/h)	100	87	117	101	109	104	98	133	89	89	100	104	133
Direction of Maximum Gust	N	W	W	W	SW	W	NW	SW	W	W	SW	SW	SW

Source (Environment Canada, 2016)

Table 2.2 – Temperature Climate Normals, Peterborough A, Ontario, 1981 to 2010

Temperature	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily Average (°C)	-8.5	-7	-1.8	5.9	12.1	17	19.6	18.3	13.9	7.5	1.9	-4.4	6.2
Standard Deviation	3.6	2.6	2.1	1.5	1.7	1.4	**1.3**	1.3	1.3	1.2	1.5	3.2	1
Daily Maximum (°C)	-3.2	-1.4	3.7	11.7	18.6	23.6	26.4	25.2	20.6	13.4	6.4	0.2	12.1
Daily Minimum (°C)	-13.7	-12.5	-7.3	0.1	5.6	10.4	12.8	11.4	7.2	1.5	-2.6	-8.9	0.3
Extreme Maximum (°C)	12.2	12.5	24.3	29.7	32.5	34.4	36.1	**36.2**	33.9	28.9	22.8	19.2	36.2
Extreme Minimum (°C)	**-37.9**	-37.8	-31.4	-15	-7.7	-0.7	3.5	0	-6.3	-9.4	-19.2	-33.9	-37.9

Note: Bolded values represent the extreme temperature conditions

Source (Environment Canada, 2016)

Table 2.3 – Wind Chill Climate Normals, Peterborough A, Ontario, 1981 to 2010

Wind Chill	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Extreme Wind Chill	-44.2	-44.5	-35.4	-22.3	-7.2	0	0	0	-3.9	-13.3	-23.3	-37.8	-44.5

Source (Environment Canada, 2016)

Table 2.4 – Temperature Normals, Peterborough, Ontario, 2012 to 2016

Temperature	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily Average (°C)	-7.1	-8.5	-1.5	5.2	13.7	17.2	19.9	18.9	14.6	8.6	2.2	-2.8	6.7
Daily Maximum (°C)	-1.8	-3.0	4.4	11.3	21.1	23.9	27.0	23.1	22.0	14.6	7.6	1.2	12.6
Daily Minimum (°C)	-12.4	-14.0	-7.4	-1.0	6.2	10.4	12.8	12.0	7.3	2.6	-3.2	-6.8	0.5
Extreme Maximum (°C)	12.4	12.4	25.7	25.1	30.8	31.8	33.9	**35.4**	31.2	25.4	22.6	15.4	35.4
Extreme Minimum (°C)	**-32.0**	-29.5	-28.8	-9.4	-3.0	2.1	7.1	4.7	-1.0	-7.3	-18.4	-28.0	-32.0

Table 2.5 – Precipitation Climate Normals, Peterborough A, Ontario, 1981 to 2010

Precipitation	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Rainfall (mm)	24.5	24.7	30.8	60.5	81.4	79.9	70.6	77	**84.5**	75.2	71.7	31.8	712.5
Snowfall (cm)	**40.0**	29.2	24.6	6.7	0	0	0	0	0	1.4	15.2	34	151.2
Precipitation (mm)	57.4	51.5	56.1	68.6	81.5	79.9	70.6	77	85.3	76.9	86.4	64.2	855.3
Average Snow Depth (cm)	14	16	8	0	0	0	0	0	0	0	1	6	4
Median Snow Depth (cm)	13	16	8	0	0	0	0	0	0	0	0	5	4
Snow Depth at Month-end (cm)	17	13	1	0	0	0	0	0	0	0	1	9	3
Extreme Daily Rainfall (mm)	43.2	35.4	59.8	46.7	50.6	56.6	**83.8**	70	52.8	42.6	55.6	37.2	83.8
Extreme Daily Snowfall (cm)	20.7	**33.2**	22.4	16.8	1.5	0	0	0	0	10.4	17	33.2	33.2
Extreme Daily Precipitation (mm)	43.2	35.4	61.3	46.7	50.6	56.6	**83.8**	70	52.8	42.6	55.6	41	83.8
Extreme Snow Depth (cm)	61	70	**71**	38	0	0	0	0	0	7	25	64	71

Note: Bolded values represent the extreme precipitation conditions.

Source (Environment Canada, 2016)

Table 2.6 – Total Precipitation Normals, Peterborough, Ontario, 2012 to 2016 and 2012-2015

Precipitation	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2012-2016 Total Precipitation (mm)	36.3	30.8	29.1	66.2	48.0	98.2	57.1	74.4	82.6	86.7	33.5	41.5	684.4
2012-2015 Total Precipitation (mm)	42.2	28.7	17.9	76.4	56.3	114.9	65.9	79.5	91.7	99.7	34.8	41.9	749.6

2.2.3 Geology

Peterborough County is noted for its many drumlins, with the city of Peterborough occupying the geographic center of the drumlin field. The Peterborough drumlin filed is composed of streamlined landforms of 1.5 kilometre in length, 400 meters or less in width and 25 meters in height. The dominant drumlin orientation is north-northeast. The drumlins are predominately spindle shaped in the Peterborough area and towards the east; whereas, south of Rice Lake they are more oval. The drumlins are composed of highly calcareous glacial till containing great quantities of angular limestone and Precambrian materials.

The bedrock in the area is originally composed of the Middle Ordovician-aged Verulam Formation. The Verulam Formation consists of relatively soft, fossiliferous to argillaceous limestone with layers of calcareous shale. The overburden in the area is part of an extensive till plain that has been drumlinized. The till consists of unsorted sand, silt and gravel, and typically contains a high portion of fines.

Peterborough was originally built over seven drumlins but has since continued to develop over several more. The general orientation of the drumlin axes in this field is from northeast to southwest. The rock underlying this region is limestone of the Lindsay and Verulam Formations. While drumlins are the most striking features of the plain, in respect to soils they are not as important as the deposits of clay, which lie between the drumlins. The site of the BWXT NEC facility lies on such a deposit of clay. Due to the presence of multiple drumlins in the area, land use is influenced by stoniness, steep slopes, and wet swampy hollows, all characteristics of drumlins.

The overburden consists of glacial, glaciofluvial, and glaciolacustrine deposits of Pleistocene age and fluvial and organic deposits of Recent age. In general, the soils of the area belong to the Grey Brown Luvisolic group (Chapman and Putnam, 1984). Soil profiles are often shallow and the content of the till is high in limestone since it is underlain by carbonate-rich, Palaeozoic bedrock (Chapman and Putnam, 1984). Associated with the Otonabee River is the Otonabee loam, which lacks the distinct brownish grey, leached layer of the Luvisolic soils of the general area. It is a dark brown, clayey, nut- structured horizon under the surface (Chapman and Putnam, 1984).

Based on Ontario groundwater well records (wells 7104323 and 7048133) the site is characterized by fill/sand from 0 to 3.0 m, followed by silt from 3 to 4.7 m (MOECC, 2017). Further characterization of the soil setting was not included in this assessment as there is not a credible groundwater pathway for contaminants release from the site (see Section 3.1.4).

2.2.4 Groundwater

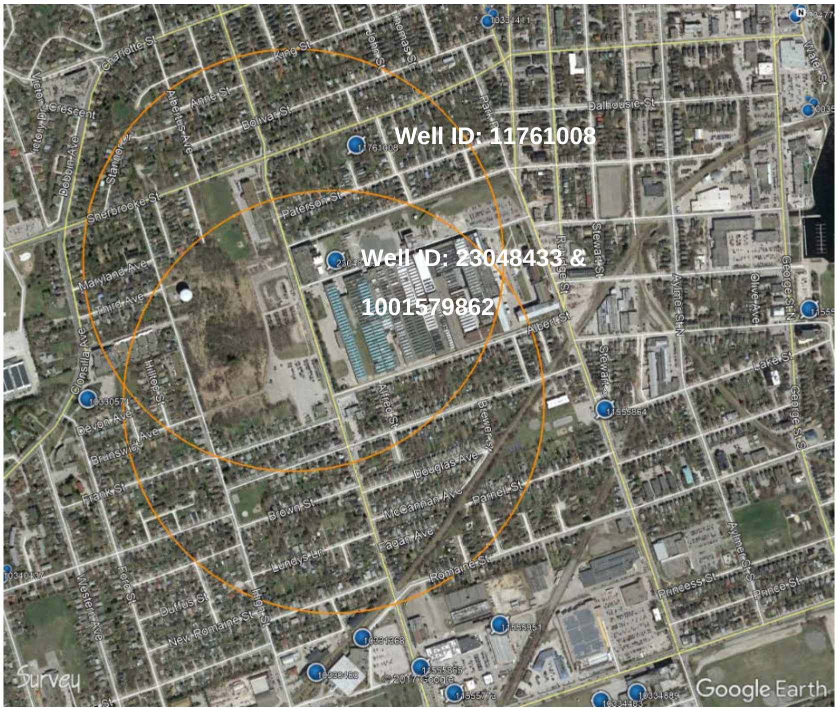
The BWXT NEC consolidated operations will not use any groundwater, with water needs met by the City of Peterborough municipal water system. There are no active groundwater extraction wells on site or within 0.5 km of the site. There are no known or suspected groundwater contamination plumes or subsurface contamination attributable to the operations, either on- or off-site. Groundwater concentrations are considered in the range of natural background and low compared to water quality guidelines.

The entire drainage system in Peterborough County is part of the Trent River system, connected by a chain of lakes and rivers including, Pigeon, Buckhorn, Stony and Rice lakes and the Otonabee River. These basins retain large quantities of water which aids in maintaining groundwater levels in the area.

Regionally, groundwater flow is to the southeast towards the Otonabee River. Groundwater elevation varies from high 250 masl to around 210 masl at the Otonabee River. Based on the closest available well with groundwater information (well 7036280), the depth to groundwater was 2.4 m (MOECC, 2017).

Figure 2.7 identifies groundwater wells located within a 0.5 km radius of the BWXT NEC facility. Within this radius, there are three observation wells (Borehole IDs 23048433, 1001579862 and 11761008) neither of which are currently in use. The BWXT NEC consolidated operations will not use any groundwater, with water needs met by the City of Peterborough municipal water system. There are no active groundwater extraction wells on site or within 0.5 km of the site (MOECC, 2017a).

Figure 2.7 – Groundwater Wells Around the BWXT NEC Peterborough Facility



Source: MOECC, 2017a

The Provincial Groundwater Monitoring Network (PGMN) assesses current groundwater conditions and provides a warning system for changes in water levels and water quality. PGMN Well ID: W0000225-1, shown in Figure 2.8 and located in concession 4, lot 5 of South Monaghan Township is the closest representative PGMN monitoring location with on-going monitoring. Table 2.7 presents uranium and beryllium sample data from 2003-2015 which shows a maximum level of 0.155 ppb and 0.01 ppb respectively. Groundwater concentrations are considered in the range of natural background and low compared to water quality guidelines.

There are no known or suspected groundwater contamination plumes or subsurface contamination attributable to the operations, either on- or off-site. As such, detailed information on subsurface utilities and infrastructure is not required for the purpose of risk assessment.

Figure 2.8 – Provincial Groundwater Monitoring Network Wells (PGMN) Near Peterborough

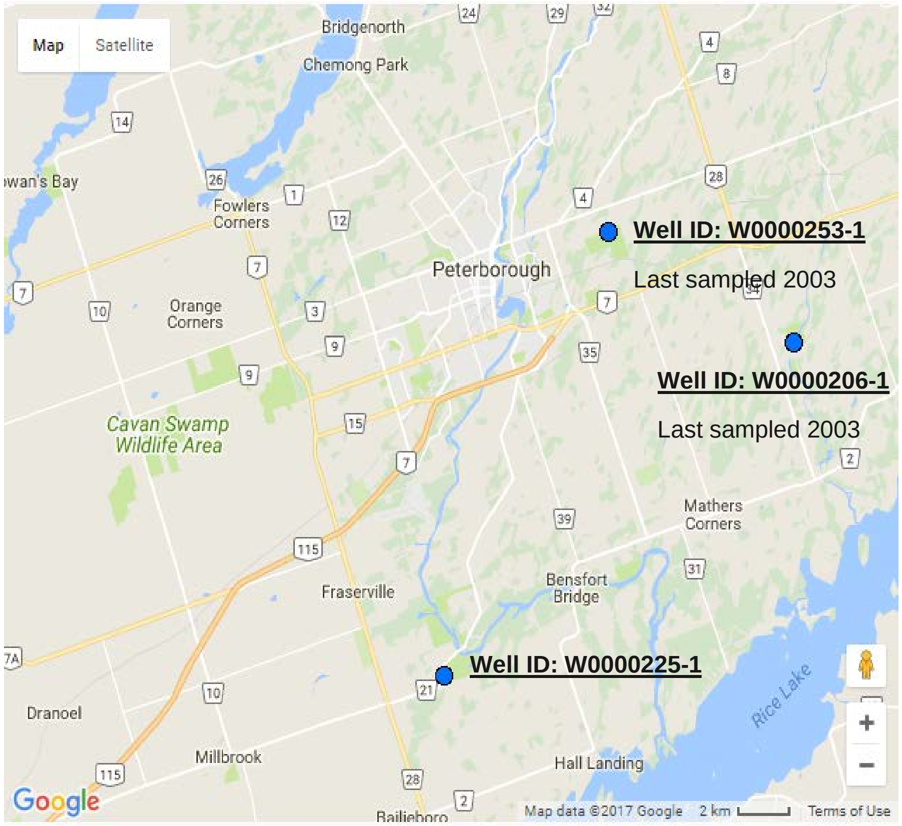


Table 2.7 - Groundwater Quality Data - PGMN Well IDs W0000225-1

Parameter Name	Sample Date	Value	Units	Qualifiers
PGMN_WELL W0000225-1				
Beryllium	2003-08-13	0.01	ug/L	+/-0.05
	2006-10-11		ug/L	<
	2007-10-11		ug/L	<
	2008-09-12	0.01	ug/L	+/-0.05
	2009-10-16	0	ug/L	+/-0.25
	2010-10-15	0	ug/L	+/-0.25
	2011-10-18	0	ug/L	+/-0.25
	2012-10-16	0	ug/L	+/-0.20
	2013-10-22	0	ug/L	+/-0.20
	2014-10-28	0		+/-0.20
	2015-10-26	0	ug/L	+/-0.20
Uranium	2003-08-13	0.01	ug/L	+/-0.05
	2006-10-11		ug/L	<0.02
	2007-10-11	0.155	ug/L	N/A
	2008-09-12	0.01	ug/L	+/-0.05
	2009-10-16	0	ug/L	+/-0.18
	2010-10-15	0	ug/L	+/-0.18
	2011-10-18	0	ug/L	+/-0.18
	2012-10-16	0	ug/L	+/-0.20
	2013-10-22	0	ug/L	+/-0.20
	2014-10-28	0		+/-0.20
	2015-10-26	0	ug/L	+/-0.20

2.2.5 Surface Water

Surface water concentrations are considered in the range of natural background and low compared to water quality guidelines. Uranium and beryllium concentrations are well below the drinking water guideline.

The GE complex is entirely industrial with no surface water features. The immediately adjacent land to the GE complex is mostly a developed urban area with no surface water features. The BWXT NEC consolidate operations will not directly use surface water, with water needs met by the City of Peterborough municipal water system which extracts and treats water from the Otonabee River. The nearest surface water body to the facility is the Otonabee River, located approximately 1 km to the east of the facility.

The BWXT NEC facility is located within a drainage system that is part of the Trent River system, connected by a chain of lakes and rivers including, Pigeon, Buckhorn, Stony, Rice and Little lakes and the Otonabee River. The BWXT NEC facility is located at the southern portion of a subcatchment lying south of Jackson Creek which flows into the Otonabee River. Stormwater runoff from the subcatchment is generally directed towards the south-east corner of the subcatchment.

Within approximately two kilometres from the BWXT NEC facility, the valley areas, all associated ravines, valleys and stream corridors of their primary tributaries include the following:

- Jackson Creek;
- Otonabee River;
- Trent Canal;
- Little Lake.

These surface water features are all part of the same watershed. This watershed is that of the Otonabee River, which covers an area of 1951 km^2 and extends over eight municipalities. The Otonabee Watershed contains several physiographic regions and features including the Oak Ridges Moraine, Peterborough Drumlin Field, Canadian Shield and Kawartha Lakes making it a very diverse watershed. This river is part of the Trent-Severn Waterway (Trent Canal).

In the vicinity of the site, there are three surface water monitoring stations. These stations are part of the Provincial Water Quality Monitoring Network coordinated by Ministry of the Environment, Conservation and Parks (MECP). The Otonabee Region Conservation Authority is responsible for the collection and analysis of water samples. Each year, samples are collected every month from April to October. Water quality indicators used to screen overall water quality include temperature, pH, conductivity, turbidity, suspended solids, major ions, nutrients, metals and pesticides.

A drainage system analysis (UMA, 2005) of the City of Peterborough's storm sewer system capacity notes that during heavy rainfall, all stormwater runoff in subcatchment area around the facility may not flow into the storm sewer system. Overland flow paths for the 100-year storm event were modeled to occur along Park Street North.

Due to the high impervious coverage of the BWXT NEC facility (i.e., parking lots, buildings and roads), stormwater runoff currently flows from north to south and from west to east via overland sheet flow and through an internal network of stormwater collection sewers. Stormwater is then conveyed from the corner of Albert Street and Park Street North to the City of Peterborough's trunk sewers, which flows approximately 500 m eastwards to Little Lake. Drainage from Little Lake flows southwards via the Otonabee River, eventually discharging to Rice Lake.

2.2.5.1 Surface Water Quality

Surface water monitoring (SWM) data is available from the Provincial (Stream) Water Quality Monitoring Network. Data for the most recent five years (2012-2016) at three stations (Station IDs: 17002103802 - Jackson Creek at Dalhousie St; 17002107002 - Otonabee River at Lock 19; and 17002114402 – Otonabee River at Marchett Ln) located in the Peterborough area (see Figure 2.9) are presented in Table 2.8. Jackson

Creek (ID 17002103802) is the only station in the vicinity with available data for Uranium and Beryllium. The maximum concentrations measured for uranium and beryllium during this time period were 3.63 ppb and 0.104 ppb, respectively. Uranium concentrations are well below the drinking water guideline of 20 ppb. Similarly, the beryllium concentrations are well below the drinking water guideline of 11 ppb (hardness ,75 ppm).

Surface water concentrations are considered in the range of natural background and low compared to water quality guidelines. Hence exposures associated with the BWXT NEC consolidated operations are not expected.

Figure 2.9 – Provincial Surface Water Monitoring Stations in Peterborough

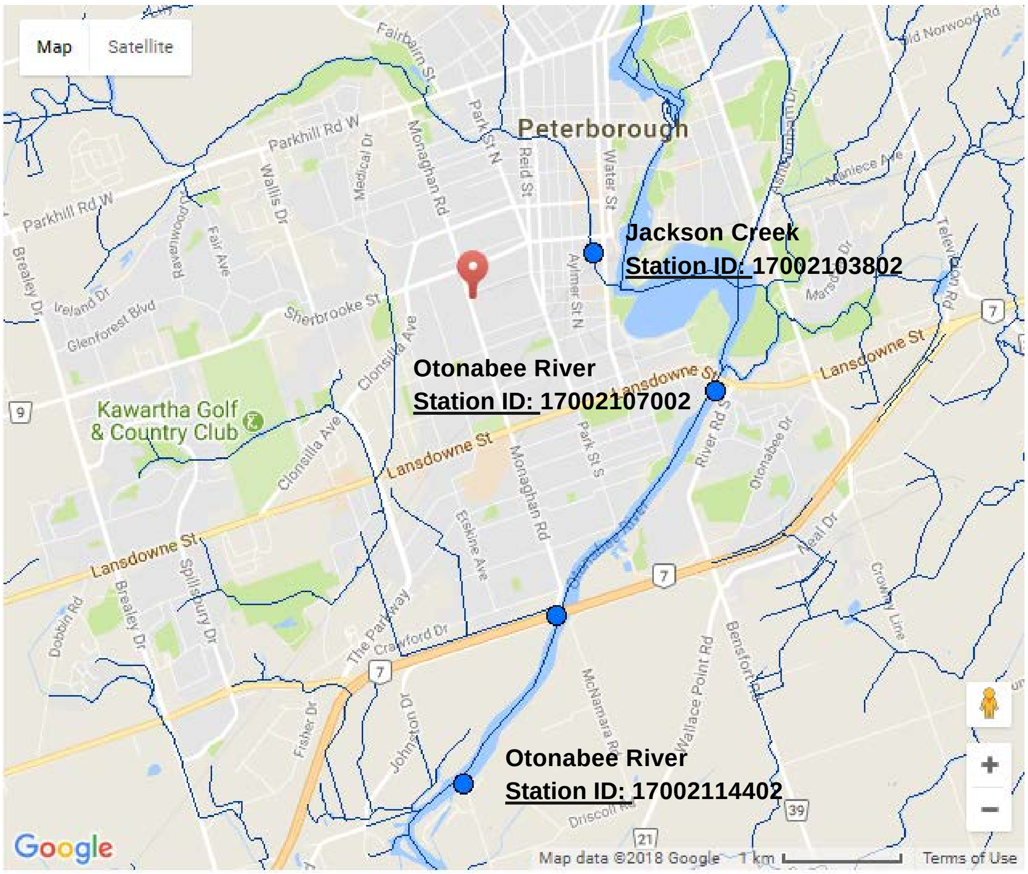


Table 2.8 – Surface Water Monitoring Station

Station ID	Parameter	2016	2015	2014	2013	2012
Otonabee River Station No 17002107002	TSS (mg/L)	8.4	3	2.2	1.1	1.7
		1.8	2.1	1.5	3	1.8
		2.2	1.7	1.8	1	1.6
		1.7	1.8	2.1	0.8	1.9
		1.3	1.4	0.9	2.8	4.4
		3.5	1.8	1.8	N/A	1.1
		2.5	0.7	1	N/A	0.9
	Max	8.4	3	**2.2**	**3**	**4.4**
	Min	1.3	0.7	**0.9**	**0.8**	**0.9**
	Average	3.1	1.8	**1.6**	**1.7**	**1.9**
	Chloride (mg/L)	12.8	18.2	12.6	9.3	12.2
		10.1	11.6	10.8	10.3	13
		11.3	11	11	10	13.4
		10.6	15.1	11.9	9.8	14.2
		11.5	14.6	10.1	9.8	13.4
		11	14.2	9.5	N/A	14.1
		23.5	15.1	10.4	N/A	12.2
	Max	23.5	18.2	**12.6**	**10.3**	**14.2**
	Min	10.1	11	**9.5**	**9.3**	**12.2**
	Average	13.0	14.3	**10.9**	**9.8**	**13.2**
Jackson Creek Station No 17002103802	TSS (mg/L)	16.2	6.1	5.1	8.1	13.8
		5.6	12.5	4.2	14.9	7.2
		3.7	16.2	8.6	2.3	7
		5.2	8.3	7.5	3.6	9.3
		2.4	5	3.9	13.3	8.1
		1.5	4.3	5.6	N/A	27.4
		1.9	2.3	3	N/A	4.1
	Max	4.8	N/A	**8.6**	**14.9**	**27.4**
	Min	16.2	16.2	**3**	**2.3**	**4.1**
	Average	1.5	2.3	**5.4**	**8.4**	**11.0**
	Chloride (mg/L)	48.4	25.9	30.4	21.8	29.8
		44.3	77.3	35.3	29.6	32.3
		67	25.3	32.2	33	18
		65.9	35.7	22.5	27.4	28
		83.9	39.2	24.5	21	19.9
		68.7	29.7	24.8	N/A	17.1
		9.9	28.9	27.2	N/A	26.3
	Max	294	N/A	35.3	33	32.3
	Min	294	77.3	22.5	21	17.1
	Average	9.9	25.3	28.1	26.6	24.5

Table 2.8 – Surface Water Monitoring Station (cont'd)

Station ID	Parameter	2016	2015	2014	2013	2012
Jackson Creek Station No 17002103802	**Uranium (ug/L)**	-1.56*	0.492	-1.71	0.208	-3.32
		-1.02	0.296	-2.73	3.63	-0.463
		8.63	-2.44	-1.99	0.337	1.02
		8.1	-2.6	-2.53	0.52	2.22
		9.39	0.533	-2.53	-1.09	N/A
		6.52	-0.825	-2.91	N/A	N/A
		N/A	N/A	-2.67	N/A	N/A
	Max	9.39	0.533	**-1.71**	**3.63**	**2.22**
	Min	-1.56	-2.6	**-2.91**	**-1.09**	**-3.32**
	Average	5.0	-0.8	**-2.4**	**0.7**	**-0.1**
	Beryllium (ug/L)	0.00131	0.015	-0.0107	0.0125	0.027
		-0.0436	0.0179	0.017	-0.00213	0.03
		0.181	0.0314	0.0923	-0.014	-0.012
		0.0719	-0.00134	-0.000622	-0.0474	0.00969
		0.0336	-0.00983	0.0366	0.00338	0.0176
		0.0824	0.0925	-0.00968	N/A	0.104
		N/A	N/A	0.0651	N/A	0.0451
	Max	0.181	0.0925	**0.0923**	**0.0125**	**0.104**
	Min	-0.0436	-0.00983	**-0.0107**	**-0.0474**	**-0.012**
	Average	0.1	0.0	**0.0**	**0.0**	**0.0**
Otonabee River Station No 17002114402	**TSS (mg/L)**	4	13.8	1	1.6	2.8
		2.5	2.3	5.5	4.1	1.3
		2.7	3.7	3.2	1.9	2.8
		1.3	3.1	3.5	2.3	2.4
		1.6	2.7	1.5	N/A	4.9
		2.3	2.6	2.7	N/A	1.5
		1.9	0.9	1.5	N/A	2.7
	Max	4	13.8	**5.5**	**4.1**	**4.9**
	Min	1.3	0.9	**1**	**1.6**	**1.3**
	Average	2.3	4.2	**2.7**	**2.5**	**2.6**
	Chloride (mg/L)	12.5	27.8	14.1	10.8	16.5
		10.5	16.4	12.9	13.3	5.4
		15.1	14.3	11.7	12.4	14.7
		13.9	17.5	14.3	10.2	16.6
		13.5	16.4	11.6	N/A	16.5
		11.8	15.3	10.9	N/A	16.9
		11	16	12.4	N/A	13.7
	Max	15.1	27.8	**14.3**	**13.3**	**16.9**
	Min	10.5	14.3	**10.9**	**10.2**	**5.4**
	Average	12.6	17.7	**12.6**	**11.7**	**14.3**

* Note: A negative concentration value indicates that the sample was analyzed but that the concentration was below the determination limits of the analytical method

2.2.6 Air Quality

The measured airborne uranium and beryllium concentrations in air were well below the ambient air quality objectives and in the range of natural background.

According to the latest ESDM report prepared by Conestoga Rovers & Associates, in 2007 the most significant contaminant in the air emissions from this Facility is Particulate Matter (PM), at 75% of the limit established by Ontario's Local Air Quality Regulation.

The Facility's steam plant generates about 62% of the total PM emissions. Table 2.9 presents the readily available background air quality data for Particulate Matter in Peterborough. Based on precedent, the 90% percentile concentrations in this instance, of $PM_{2.5}$, are often taken to (conservatively) represent background concentrations.

Table 2.9 – $PM_{2.5}$ Concentrations (µg/m3) at Peterborough Monitoring Station

Year	Data Points (hrs)	Percentiles						Mean	1 hr Max	24 hr Max
		10%	30%	50%	70%	90%	99%			
2003	8606	1	3	5	8	15	35	6.7	60	42
2004	8695	0	2	3	6	15	40	5.9	55	39
2005	8680	0	2	4	8	19	45	7.5	70	50
2006	8677	1	2	4	7	15	32	6.3	53	36

The Ministry of Environment Ontario Air Standards for Uranium document (MOE, 2011), identified an annual average uranium in air concentration of 0.0001 ug/m^3 for urban environments.

As described in Appendix A, limited air quality sampling undertaken by the CNSC (CNSC 2016) in 2014 in the vicinity of the Peterborough facility. The measured airborne uranium concentration was 0.0013 µg/m^3, well below the MECP ambient air quality objective of 0.03 µg (U in PM10)/m^3 over a 24-hour averaging period (ACB list) corresponding to the sample collection period, and in the range of natural background. The measured airborne beryllium concentration was 0.000077 µg/m^3 and was well below the MECP 24-hour ambient air quality objective of 0.01 µg/m^3 based on health considerations (ACB list).

2.2.7 Terrestrial and Aquatic Environments

The major components of terrestrial and aquatic environments within the area surrounding BWXT NEC facility are shown in Figure 2.10. All natural features within the City of Peterborough are identified in the Official Plan of the City of Peterborough (City of Peterborough, 2003; Schedule C – Natural Areas & Flood Plains). There is one sensitive area within approximately two kilometres of the BWXT NEC facility, this being the Harper Creek Wetland. Harper Creek Wetland is located 2.3 km southwest from BWXT NEC facility and is 17.8 ha in surface area (NHIC ID 9645). It is an Ontario Ministry of Natural Resources and

Forestry (MNRF) non-provincially significant wetland, composed of two wetlands types (90% swamp and 10% marsh).

The physiographic character of the Peterborough area is the Peterborough Drumlin Field Region (Chapman and Putnam, 1984), which region is named after the City for occupying its geographical centre.

Peterborough is located within the Manitoulin-Lake Simcoe Ecoregion of the Mixedwood Plains Ecozone (Environment Canada, 2005). The Mixedwood Plains Ecozone is bounded by the three Great Lakes in southern Ontario and extends along the St. Lawrence valley. The Manitoulin Lake Simcoe Ecoregion extends from Manitoulin Island to Kingston in southern Ontario. The dominant land cover is agricultural land (56%) with significant areas of mixed forest.

Forested upland areas are characterized by Sugar Maple, American Beech, Eastern Hemlock, Red Oak, and American Basswood. Younger growth may include Eastern White Pine, Paper Birch, and Trembling Aspen. Moist sites are characterized by Yellow Birch, White Elm, and Red Maple, including Slippery Elm, Black Ash, and Eastern White Cedar (Environment Canada, 2005).

The dominant vegetation is 34.3% deciduous trees, 48.1 coniferous trees, 7.8% tall shrubs, 8.6% narrow-leaved emergent. Soils are 100% organic.

Wildlife is characterized by White-tailed Deer, Snowshoe Hare, Coyote, Red and Grey Squirrel, and Eastern Chipmunk. Bird species includes the Northern Cardinal, Wood Thrush, Screech Owl, Mourning Dove, Green Heron, Pileated and Red-bellied Woodpeckers, and Wood and American Black Ducks (Environment Canada, 2005).

Based on the Species at Risk Act (SARA), when reviewing local biota, it is important to consider the potential for Species at Risk. In the vicinity of the facility, though it has not been observed since 1934, one species of concern was identified. The five-lined skink (a lizard) with a provincial status of vulnerable (S3) -- as recorded by the Natural Heritage Information Centre (NHIC, 2009), within approximately two kilometers of the site. There are no recent records of species of concern on site or the immediately surrounding area, consequently, it was not considered further in the assessment.

Land immediately adjacent to BWXT NEC facility and the GE complex is mostly developed urban area with a mix of residential, commercial and industrial uses. Interspersed within the urban area are small recreational green spaces. The BWXT NEC facility is a fenced-off area with very limited vegetative growth. There are no natural features within the BWXT NEC site.

The urban wildlife that may be found in the area around the BWXT NEC site include birds such as Red-breasted Nuthatch, Downy Woodpecker, American Robin, Black-capped Chickadee, Blue Jay, and House Sparrow. Among mammals, urban species may include House Mouse, Eastern Gray Squirrel, Eastern Cottontail, Striped Skunk, Raccoon and Red Fox.

2.2.8 Land Use

BWXT NEC is located within the GE main plant complex within the City of Peterborough. The GE complex is located in a mixed industrial, commercial and residential area. General land use within the City of Peterborough is shown in Figure 2.11.

2.2.9 Population

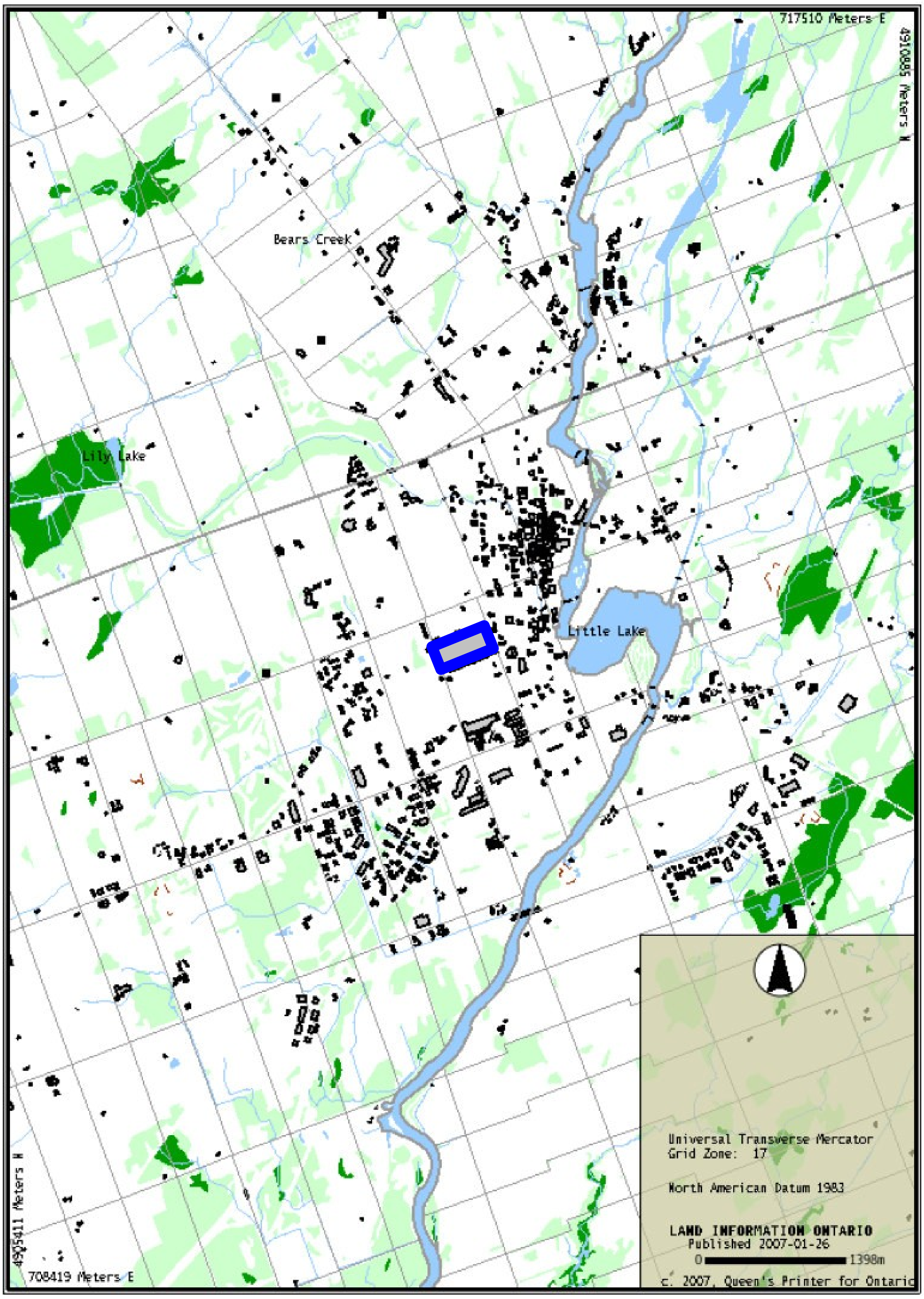
In 2016, 82,094 people resided within the City of Peterborough and 121,721 within the Peterborough census metropolitan area (CMA), representing a percentage change of 2.9% and 2.3%, respectively from 2011 (Statistics Canada, 2017). The City of Peterborough comprises a land area of 53.81 km^2 with a population density of 1,525.7 persons/km^2. The Peterborough CMA comprises a land area 1,507.12 km^2 with a population density of 80.8 persons/km^2. Demographic trends are summarized in Table 2.10.

Table 2.10 – City of Peterborough Demographic Trends (1986 – 2016)

Age	1986	%	1991	%	1996	%	2001	%	2006	%	2011	%	2016	%
0 - 14	11830	19.4%	13605	19.9%	13520	19.4%	12710	17.8%	11485	15.3%	11355	14.4%	11940	14.4%
15 - 24	9705	15.9%	9360	13.7%	9210	13.2%	9985	14.0%	11615	15.5%	11600	14.7%	10765	13.1%
25 - 44	17370	28.5%	20735	30.3%	19905	28.6%	18530	25.9%	17855	23.8%	18465	23.4%	19485	23.7%
45 - 64	12315	20.2%	12700	18.6%	13915	20.0%	16380	22.9%	19390	25.9%	21545	27.4%	21565	26.3%
65+	9825	16.1%	11995	17.5%	12995	18.7%	13835	19.4%	14540	19.4%	15730	20.0%	18335	22.3%
Total	61045	100.0%	68395	100.0%	69545	100.0%	71440	100.0%	74885	100.0%	78695	100%	82095	100%

Source (Statistics Canada; 2012, 2017)

Figure 2.10 – Terrestrial and Aquatic Environment



Source (Adapted from MNR, 2007)

BWXT NEC Peterborough

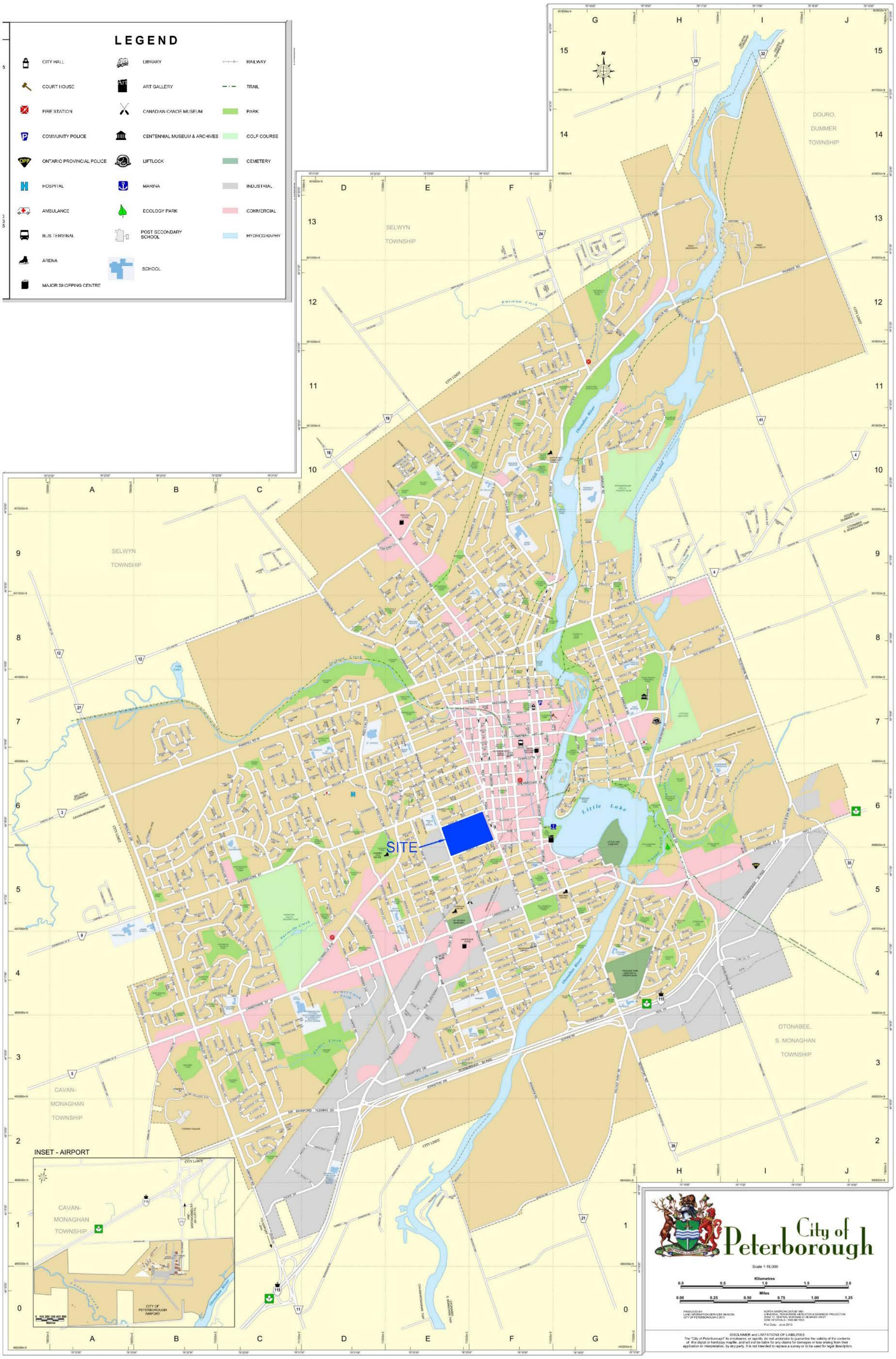
Buildings to scale, i.e., smallest are excluded

Water bodies showing dams and locks

Areas of marsh

Vegetation

Figure 2.11 – Land Use in City of Peterborough



Source (City of Peterborough, 2016)

2.2.10 Effluent and Environmental Monitoring Programs

As activities associated with beryllium emissions to air and water are unaffected, the average and maximum concentrations are not expected to change. Beryllium levels are currently well below regulatory release limits and Action Levels.

Estimated uranium emissions to air and water currently are and will continue to be well below regulatory release limits and Action Levels once the operations are consolidated.

Radiological and non-radiological substances will be released to the environment as the result of the consolidated operations.

The second edition of CSA N288.4, *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* was published in May 2010 (CSA, 2010). The scope of this revised edition includes significant changes and addresses the monitoring of both radiological and hazardous substances and their potential impacts to human and non-human biota.

CSA N288.5, *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* was published in April 2011 (CSA, 2011). This standard addresses the design, implementation, and management of an effluent monitoring program that meets legal and business requirements and incorporates current best practices and technologies used internationally.

As of the end of 2016 the BWXT NEC NFAO and BWXT NEC NFPO effluent monitoring programs and environmental monitoring programs were updated to fully reflect requirements of the CSA N288.4-10 and N288.5-11 Standards. For the consolidated operations, the effluent monitoring program and environmental monitoring program in Peterborough will be revised with enhanced effluent and ambient air and soil monitoring programs to reflect monitoring programs currently in place for the BWXT NEC NFPO.

Data collected through the long-standing effluent monitoring programs and environmental monitoring programs established for BWXT NEC NFAO and BWXT NEC NFPO are considered to be of an acceptable quality for use in the HHRA and EcoRA. Programs and associated monitoring data are described in Sections 2.2.9.1 to 2.2.9.2.

In support of monitoring programs, BWXT NEC has established facility specific CNSC approved *Action Levels* for various radiological and environmental parameters. An *Action Level* is defined in the *Radiation Protection Regulations* "a specific dose of radiation or other parameter that, if reached, may indicate a loss of control of part of a licensee's radiation protection program, and triggers a requirement for specific action to be taken." *Action Levels* are set below regulatory limits; however, they are CNSC reportable events. Accordingly, BWXT NEC has established *Internal Control Levels* for various radiological and environmental parameters that are set even lower than *Action Levels* to act as an early warning system. An *Internal Control Level* exceedance results in internal investigation and corrective action.

To complement existing and ongoing compliance activities and site monitoring programs, the CNSC implemented an Independent Environmental Monitoring Program (IEMP) (See Appendix A) to verify that the public and environment around CNSC-regulated nuclear facilities are not adversely affected by releases to the environment. This verification is achieved through independent sampling and analysis by the CNSC. An IEMP sampling program was conducted in 2014 at the Peterborough facility. The results of this program are presented in Appendix A and compared to federal and provincial guidelines.

2.2.10.1 Effluent Monitoring at BWXT NEC

The estimated airborne and waterborne radiological and non-radiological emissions to the environment from the consolidated operation, are based on the most recent available data, collected as part of the BWXT NEC NFAO and BWXT NEC NFPO effluent monitoring programs.

Air

For airborne emissions, beryllium and uranium will be routinely monitored.

Uranium

The consolidated operations will have a number of uranium air emission sources from pellet and fuel bundle assembly operations, the exact number of which has not yet been determined. The facility will continue to perform in-stack sampling for uranium. Filter papers will be analyzed in-house daily and verified externally. An external independent laboratory will test the filter papers by delayed neutron activation analysis. The minimum detection limit is 0.01 µg uranium. Following internal procedures, the results will be compared to the previous results and to the relevant Action Level for a process exhaust sample measurement of 1 µg uranium/m^3. This level is set based on past facility performance. A result above the Action Level would be considered outside the concentration range expected for routine operation.

Based on BWXT NEC annual compliance reports, total uranium air emissions for the consolidated operations were estimated by summing the total mass discharge from existing fuel bundle assembly and fuel pelleting operations. Baseline uranium emissions at Peterborough represent 0.04% of the total emissions released from the existing nuclear fuel pelleting operation which have ranged from 10.4 to 17.2 g uranium/year over the 2012 to 2016 period (Arcadis, 2018). Emissions from the consolidated operations are expected to be comparable to, or lower than emissions from the existing fuel pelleting operation. The uranium emissions from the consolidated operations are estimated to be between 10.4 to 17.2 grams of uranium/year. As shown in the Table 2.11, emissions for the consolidated operations will be well below the licenced release limit of 550 g/yr for the Peterborough facility (established for fuel bundle assembly operations only).

Table 2.11 – Summary of uranium emissions

Parameter	Baseline Operations					Consolidated Operations
	2012	2013	2014	2015	2016	
Uranium to Air (g/year)	0.005	0.013	0.003	0.003	0.004	10.4 – 17.2

Source (BWXT annual compliance reports)

There are currently six (6) distinct air discharge points for uranium at the existing nuclear fuel pelleting operation and one at the existing Peterborough fuel bundle assembly operation. The concentration of uranium in air emission sources from the consolidated operations will depend on how individual sources are emitted (e.g., individual stacks or one or more common stacks) and the flow rate from each stack. Table 2.11 summarize baseline conditions and expected performance of the consolidated operations. As the number of stacks servicing the consolidated operations have not been finalized, uranium concentrations may differ from historical conditions, but are likely to be within or lower than the range of emissions observed at the existing nuclear fuel pelleting operation.

Beryllium

Beryllium is only handled during the fuel bundle assembly process, therefore the expected air emissions from the consolidated operations will be similar to the current emissions measured at the Peterborough facility.

Three beryllium exhaust vents are measured by inserting a probe into the duct centerline and withdrawing a sample of air. The air is passed through a filter capable of trapping beryllium. The filter is analyzed for beryllium using the Atomic Absorption method or the Inductively Coupled Plasma - Atomic Emission Spectrometer method at an external independent laboratory. The result is related to the air volume passed through the filter. The minimum detection level is 0.002 µg beryllium. As of April 2016, BWXT NEC Peterborough implemented continuous monitoring at each of the three stacks - North, South and Acid - on a weekly basis. Prior to this, one 24-hour sample per week was collected from each stack.

A summary of air effluent sampling results reported over the 2012-2016 period, at the exhaust points is provided in Table 2.12. The table shows that emissions at the consolidated operations are expected to be well below regulatory and *Action Levels*.

Table 2.12 – Summary of Air Effluent Sampling at Exhaust Stack (2012 to 2016)

Parameter	Baseline Conditions					Consolidated Operations
	2012	2013	2014	2015	2016	
Highest Uranium Concentration Value Recorded (µg/m^3)	0.0054	0.0046	0.0023	0.016	0.039	0.809(1)
Average Uranium Concentration (µg/m^3)	0.0009	0.0012	0.0006	0.002	0.001	0.0017 - 0.019
Number of Uranium Samples > Action Level (1 µg/m^3)	0	0	0	0	0	0
Highest Beryllium Concentration Value Recorded (µg/m^3)	0.002	0.0069	0.0045	0.009	0.002	0.002
Average Beryllium Concentration Recorded (µg/m^3)	0.000	0.0001	0.0005	0.001	0.001	0.001
Number of Beryllium > MECP POI (0.03 Be µg/m^3)	0	0	0	0	0	0

(1) For the 2012 to 2016 period, the highest annual maximum uranium concentration in air emissions for either facility from normal operations ranged from 0.375 to 0.809 µg/m^3, excluding a known excursion of 3.6 µg/m^3 at the NFPO (Arcadis, 2018).

Source (GEC-H, 2012-2015 and BWXT NEC, 2016 annual compliance reports)

Water

In the consolidated operations, as part of the fuel pellet production process, bulk quantities of uranium dioxide (UO_2) powder will be handled, requiring frequent cleaning and washing. Contaminated water generated from wet grinders, laundry services, routine maintenance activities, such as washing floors, walls, equipment and in various other janitorial functions will be held in batches and treated to remove UO_2. The concentration of UO_2 in waste water leaving the treatment system will be measured in-house. Each batch will only be released when in-house sample results confirm the concentration is below the Internal Control Level of 3 ppm and the Action Level of 6 ppm (per batch).

The consolidated operations will continue to use alpha counting for uranium determination of water effluent samples. Sample analyses will be audited by laser fluorimetry or delayed neutron activation analysis. A weekly composite sample will be prepared and sent for independent analysis at an external laboratory. The minimum detectable quantity will be no more than 0.000002 mg U/L

As the majority of process related liquid effluent is expected to be generated by the fuel pelleting operation, the process water effluent volume at Peterborough represents less than 0.1% of the total volume handled at the existing fuel pelleting operation. The maximum and average concentrations reported for the existing fuel pelleting operation, will therefore be a good indication of the expected maximum uranium concentrations generated at the consolidated operations (See Table 2.12).

The site sewer system also receives other wastewater from the non-nuclear fuel operations resulting in some dilution prior to discharge to city sewers. Wastewater from the consolidate operations will further mix with wastewater from other, non-nuclear operations within the Peterborough Plant Complex prior to discharge to the municipal sewer.

A second hazardous liquid effluent from the Peterborough facility is beryllium in water that is be generated from cleaning activities as well as from the appendage de-burring operation. BWXT NEC has established an *Internal Control Level* of 4 µg/L, which is conservative and consistent with international drinking water guidelines for beryllium. Currently, the beryllium contaminated water passes through a weir settling system prior to release to the sanitary sewer. Regular sampling of the beryllium wastewater is conducted. The water sample consists of a 24-hour composite sample taken from the outflow lines. It is sent for analysis at an external independent laboratory. The minimum detectable level is 0.007 µg Be/L (0.000007 mg Be/L or parts per million (ppm)).

Beryllium is only handled during the production of uranium fuel bundles and the consolidated operations will not require to add any additional source of this contaminant, therefore it can be assumed that concentrations will not be higher than existing effluent concentration at the Peterborough site. As beryllium operations are unaffected, the average and maximum concentrations are not expected to change (see Table 2.13).

As shown in the table, the estimated uranium discharge is expected to be low and below the Action Levels of 6 ppm (per batch) and 3 ppm (annual average).

Table 2.13 – Estimated Liquid Effluent Monitoring Results

Parameter	Baseline Operations					Consolidated Operations
	2012	2013	2014	2015	2016	
Total Amount of Liquid Discharged (L) from Uranium Processing Areas	1230	820	820	820	820	1,240,000 – 1,650,000
Maximum Uranium Concentration in Water (ppm)	0.16	0.46	0.29	0.09	0.48	2.74
Average Uranium Concentration in Water (ppm)	0.06	0.29	0.17	0.07	0.15	0.47 – 1.02
Number of Samples Exceeding *Action Level* (6 ppm per batch)	0	0	0	0	0	0
Total Uranium Discharge to Sewer (g)	0.06	0.24	0.14	0.06	0.13	390 – 900
Maximum Beryllium Concentration in Water µg/L		1.6	5.3	65.5	2.5	Unchanged
Average Beryllium Concentration in Water µg/L		0.4	≤1.3	4.5	0.4	Unchanged
Number of Samples Exceeding Internal Control Level (4 µg/L)		0	2	3	0	Unchanged

Source (GEC-H, 2012-2015 and BWXT NEC, 2016 annual compliance reports)

2.2.10.2 Environmental Monitoring at BWXT NEC

Radiological and Non-Radiological Emissions

Air and water emissions are routinely measured at the existing fuel bundle assembly operation to demonstrate compliance with the Canadian Nuclear Safety Commission's environmental protection requirements and the ALARA principle. All measurements were below BWXT NEC Action Levels and annual releases were a small fraction of regulatory limits. The effluent monitoring results from the existing fuel bundle assembly operation also show a consistent trend of very low air and water releases of uranium and beryllium for which routine environmental monitoring is not warranted.

With the consolidated operations, an environmental monitoring program will be implemented, similar to that currently in place at the existing fuel pelleting operation. As the main source of uranium dioxide emissions from the proposed consolidated operations will be from uranium fuel pelleting production, BWXT NEC will implement an environmental soil and air monitoring program similar to that in place at the existing nuclear fuel pelleting operation to verify that the public and environment around the facility will not be adversely affected by releases to the environment.

Air

Boundary samples will be collected using high volume air samplers (Hi-vols) located at relevant and strategic positions around the facility perimeter. An external independent laboratory will test the filter papers by delayed neutron activation analysis or other suitable analysis method.

As the main sources of uranium emissions will come from the fuel pelleting production, the Toronto boundary air monitor program can be used as an indicator of expected environmental uranium levels around the consolidated facility.

Based on an annual boundary uranium concentration measurement that has been steady at 0.001 ug/m^3 over the 2012 and 2016 period at the existing fuel pelleting operation, the average uranium concentrations expected around the consolidated operations would be expected to be within this range plus or minus a factor of 2 or 3 to account varying dispersion characteristics between the Peterborough and Toronto facilities (see. Section 3.3.2 for further details). Maximum airborne uranium concentration measurements are also expected to be well below the Action Level of 0.08 µg/m3 and the MECP ambient air quality objective of 0.3 µg (U in TSP)/m^3 over a 24-hour averaging period (Arcadis, 2018).

Soil

Airborne UO_2 emissions impinge on the ground surface downwind of the release point. Depositions of uranium can be measured by taking small samples of surface soil and analyzing for U-nat. UO_2 is insoluble in water but may be washed into the soil by rainfall, snow etc. Surface uranium levels will indicate deposited emissions. If soil analysis indicates rising natural uranium levels, emissions have increased, and investigation must be made into the cause(s).

Given the negligible quantity of uranium released to air soil monitoring was not historically completed by BWXT NEC around the Peterborough facility. Consistent with practices at the existing fuel pelleting operation, BWXT NEC will be collecting soil samples around the consolidated operations from strategic and relevant locations. Samples will be retrieved by a third-party consultant and analyzed by an independent laboratory by Inductively Coupled Plasma Mass Spectrometry for the amount of natural uranium in parts per million (i.e., µg U/g). The minimum detectable limit is 0.5 parts per million (0.5 µg U/g). Results will be compared to previous years and the Canadian Council of Ministers of the Environment (CCME) guidelines. In Ontario, background levels of uranium in soil are generally below 2.5 µg/g. As presented in section 2.2.9.1, uranium emissions inventory will be comparable to or lower than the emissions profile at existing nuclear fuel pelleting operation, therefore, soil sampling results from the existing nuclear fuel pelleting operation can be used as indicator of expected uranium levels concentrations in public areas around the proposed facility.

Based on results from the 2015 and 2016 BWXT NEC NFPO soil sampling programs, the maximum concentration measured around the existing nuclear fuel pelleting operation was between 0.7 to 13.6 µg of uranium/g of soil, with an average of 2.9 and 2.7 µg of uranium/g of soil measured on nearby industrial/commercial lands and 0.7 to 0.5 µg of uranium/g of soil on residential properties in 2015 and 2016, respectively. These concentrations are below the CCME guidelines of 23 and 33 µg of uranium/g of soil for residential and commercial/industrial locations, respectively (Arcadis, 2018). No health or environmental impacts are therefore expected due to operation of the consolidated operations

Radiation

For the BWXT NEC consolidated operations, Environmental Thermoluminescent Dosimeters (TLDs) monitoring of gamma dose rates will be undertaken. Fence line gamma dose rates will be measured at a number of locations (including a background location).

Since 2016, Environmental TLDs placed at the Peterborough plant boundary have been used to estimate a public gamma dose See Section 3.2.2.

2.3 Uncertainties in the Natural and Physical Environment

Effluent and environmental impact estimations are based on well-established and long running monitoring programs at each of the individual fuel pelleting and fuel bundle assembly operations that measure the key COPCs (uranium, beryllium and gamma radiation) increasing the likelihood of identifying maximum emission cases and reducing the uncertainty in the risk assessment. In the risk assessment, maximum estimated concentrations, emissions and/or measurements were used in the screening, providing a degree of conservatism into the assessment. As new pellet production equipment will be installed, it is expected that uranium emissions will be similar to or lower than those estimated due to improved technologies and controls. Consolidated operations do not impact on beryllium consumption and discharges.

There are some uncertainties in the characterization of the natural and physical environment. In particular, there is limited data on surface and groundwater quality, site-specific groundwater flow and depth and site soil characteristics. There are no human or ecological exposure pathways to contaminants of potential concern (COPCs) from on-site groundwater and no indications to suggest contamination or potential impacts on local groundwater resources. Indirect emissions of COPCs to surface water are very low, with concentrations further decreased during dispersion in the air and mixing in surface waters. As such, human and ecological exposure pathways to COPCs from groundwater and local surface water are trivial and these uncertainties do not affect the risk assessment.

Expansion of the environmental monitoring program to include environmental air (hi-vol) and environmental soil sampling will provide additional data to reduce uncertainty in the expected impacts from consolidated operations.

3 HUMAN HEALTH RISK ASSESSMENT

An HHRA is the evaluation of the probability of health consequences to humans caused by the presence of chemical contaminants at a facility. The requirement for, approach to, and scope of, a HHRA is based on a fundamental understanding of: site conditions, including the nature, extent and distribution of the radiological and chemical hazards; the potential exposure pathways; and opportunities for human receptors that will frequent, use or populate the area on or surrounding the facility.

Under CSA N288.6 (2012), HHRAs apply to off-site receptors (i.e., members of the public) and on-site nonnuclear energy workers (non-NEWs) that are not covered under the facility's radiation protection program or health and safety program. In this report, the receptors considered for the HHRA consist of off-site members of the public. Health and safety of on-site workers will be protected by BWXT NEC's Radiation Protection Program and Conventional Safety Program, which are discussed below.

3.1 Problem Formulation

Problem formulation is a step undertaken early in the ERA process to constrain and focus the ERA on the key questions. For the BWXT NEC ERA, the problem formulation focuses the assessment to the key contaminants and identifies the receptors and exposure pathways that are relevant to the proposed undertaking. The following discussion describes the approach taken to focus the HHRA.

The prime hazards to the environment from the consolidated operations will be uranium, beryllium and gamma radiation through emissions to air and water.

Tier 1 screening did not identify any radiological or non-radiological COPCs requiring preliminary quantitative or detailed quantitative risk assessment, consequently detailed receptor characterization was not required.

Pathways for human exposure considered include:

- *Air inhalation/skin absorption;*
- *Air immersion (external exposure).*
- *Soil deposition gamma and beta ground shine;*
- *Soil re-suspension and inhalation;*
- *Ingestion through backyard gardens; and,*
- *Drinking Water.*

Potential physical stressors to humans identified include noise exposure.

3.1.1 Health and Safety of On-site Workers

Exposure to workers will be considered and controlled through the application of BWXT NECs well-established Occupational Safety and Health Procedures. On-site employees, contractors, and visitors will be protected with the implementation of BWXT NEC's Radiation Protection Safety and Control Area and conventional safety program.

On-site workers, such as BWXT NEC employees, contractors, and visitors will be protected through the "Radiation Protection" Safety and Control Area which covers the implementation of the radiation protection program, in accordance with the *Radiation Protection Regulations*. This program will ensure that contamination and radiation doses received are monitored and controlled.

BWXT NEC has an established radiation protection program to address the hazards from UO_2 and keep employee doses ALARA. The major potential hazard is inhalation of airborne UO_2 particles. A respiratory protection program will be adapted for the consolidated operations. Airborne measurements and surface traces of uranium will continue to be monitored as an indicator of process containment efficiency. Monthly urine samples provided by pelleting operation employees will be used to indicate if inhalation may have occurred and to monitor clearance of uranium from the body. A lesser potential hazard exists in the form of low-level external gamma and beta doses to employees. The BWXT NEC program will ensure that surface and airborne contamination and radiation doses to employees are monitored and controlled.

Whole body, skin and extremity dose measurements will continue to be performed using thermoluminescent dosimeters (TLDs) to ensure compliance with the Canadian Nuclear Safety Commission's radiation dose limits and the ALARA principle.

On-site workers could also potentially be exposed to non-radiological substances. These exposures will be considered and controlled through the application of BWXT NEC's well-established Occupational Safety and Health procedures.

As it is expected that the health and safety of on-site employees, contractors, and visitors will be protected with the implementation of BWXT NEC's "Radiation Protection" Safety and Control Area and conventional safety program, no further risk assessment will be performed for these individuals.

3.1.2 Receptor selection and characterization

A toddler (0.5 – 4 years) was identified as the critical receptor for assessment purposes. However, because the Tier 1 screening did not identify any radiological or non-radiological COPCs requiring preliminary quantitative or detailed quantitative risk assessment, detailed receptor characterization was not required.

3.1.2.1 Receptor Selection

The critical receptor included in the HHRA is consistent with that identified in the 2009 Environmental Impact Statement for the Low Enriched Uranium Fuel Bundle Production Project (GEH-C, 2009). The critical receptor for the general public is defined as the "*most affected neighbour*" in order to be inclusive of all types of receptors.

The MECP, for land use categories where people of all ages are expected to have access (i.e. residential, parkland, institutional), consider the toddler (0.5 – 4 years) to be the more highly exposed receptor. Toddlers are considered to be the more highly exposed receptors because they eat, drink, and breathe more in proportion to body size, and exhibit behaviours (e.g., hand-to-mouth activity) that increased exposure to media such as soil (MOE, 2011). Based on this rationale, and the fact that toddlers could spend most of their time in a residence near the facility, toddlers were identified as the critical receptor.

3.1.2.2 Receptor Characterization

As discussed in Sections 3.2 and 3.3, since the Tier 1 screening did not identify any radiological or non-radiological COPCs requiring preliminary quantitative or detailed quantitative risk assessment, detailed receptor characterization was not required.

3.1.3 Selection of Chemical, Radiological, and Other Stressors

BWXT NEC has a long history of operations in the Peterborough and Toronto facilities which has allowed for the identification, assessment and monitoring of emissions over an extended period of time. Therefore, available data can be used to estimate emissions and hazards associated with the process integration.

The prime hazards to the environment from the consolidated operations will be uranium, beryllium and gamma radiation.

Exposure to uranium can result in both chemical and radiological toxicity. Uranium is classified as a low specific activity radionuclide and emits very low amounts of radiation as compared to certain other isotopes. The main chemical effect associated with exposure to uranium and its compounds is kidney toxicity.

Beryllium is a toxic industrial material. Its effects can occur if sufficient quantities are absorbed into the blood or inhaled. The two major effects are respiratory illness resulting from inhalation of excessive quantities of beryllium dust, and skin reaction, which will take place as a result of direct contact of some beryllium compounds with an open wound, or implantation under the skin.

Release of both uranium and beryllium will be controlled at the source by judicious design of machines, material handling equipment and dust collection systems. Current dust collection system design and controls are described in the Peterborough and Toronto Radiation Protection Manual and the Peterborough Beryllium Safety Manual. The Radiation Protection Manual and protection control procedures will be revised to reflect requirements of the consolidated operations.

In addition to these contaminants, a number of contaminants will also be emitted to air which are associated with furnaces, rotoclone for wet grinding area, spray booth operations, bundle assembly, QA/QC and maintenance activities. These contaminants have been identified in the Peterborough Emission Summary and Dispersion Modelling Report (GHD, 2016) and in the Toronto Emission Summary and Dispersion Modelling Report (Trinity Consultants, 2015).

Consistent with CSA N288.6, noise was also selected as a physical stressor for human receptors.

The tiered approach to HHRA, requires these contaminants to undergo a Tier 1 preliminary screening where conservative estimates of emissions and environmental concentrations are compared to screening criteria. The objective of this preliminary screening process is to identify contaminants of potential concern (COPCs) which are those contaminants that have undergone preliminary screening and have been selected for evaluation in higher tiers of assessment.

3.1.4 Selection of Exposure Pathways

Pathways for human exposure considered include:

- *Air inhalation/skin absorption;*
- *Air immersion (external exposure).*
- *Soil deposition gamma and beta ground shine;*
- *Soil re-suspension and inhalation;*
- *Ingestion through backyard gardens; and,*
- *Drinking Water.*

Exposure through soils and the terrestrial food chain are not expected to be relevant due to the negligible amounts of beryllium and uranium released to air and the low concentration of these substances in soil.

Radiological and non-radiological materials will be released to the environment as a result of the consolidated operations. Consequently, this could result in the emissions to various media, potentially including air, surface water, soil, sediment, groundwater, and other media such as vegetation. Receptors could be exposed to contamination through various pathways, as shown generically in Figure 3.1.

Of the generic pathways shown in Figure 3.1, the primary pathways for COPCs associated with consolidated operations are:

- Air inhalation/skin absorption;
- Air immersion (external exposure).
- Soil deposition gamma and beta ground shine;
- Soil re-suspension and inhalation;
- Ingestion through backyard gardens; and,
- Drinking water.

BWXT NEC will continue its track out control measures to minimize the potential for on-site contamination and associated contamination of stormwater. Therefore, any on-site or off-site contamination of runoff will be associated with the emission of uranium and beryllium through plant stacks and its subsequent deposition to the ground.

Uranium emissions from the consolidated operations are estimated at 10.4 to 17.2 g U/y based on data collected over the 2012 to 2016 period at the existing fuel pelleting operation. Conservatively assuming a depositional radius around the facility of 1 km, the estimated stormwater runoff concentrations assuming equal deposition within this area is:

- average precipitation = 750 mm = 0.750 m
- Impacted area = 3.14 km^2 (very conservative as uranium emissions would be in the form of a very fine particulate and dispersed over a larger area – if for example we assume all stack emissions are deposited in a 2-km radius the average deposited uranium would be 4 times smaller)
- Maximum estimated annual U emissions = 17.2 g
- Assuming all deposited uranium is picked up in precipitation (very conservative as much of the dustfall will work its way into the surface soil horizon)

$$Avg\ Concentration\ of\ U\ in\ Stormwater = \frac{17.2\ g}{0.750\ m * 3140000\ m^2} = 7.3x10^{-6}\frac{g}{m3} = 0.007\ ppb$$

Similar calculations for beryllium, assuming a release rate of 7.96 $x10^{-8}$g/s (from ESDM) or 2.5 g/year yield a concentration of 0.001 ppb of beryllium in stormwater runoff.

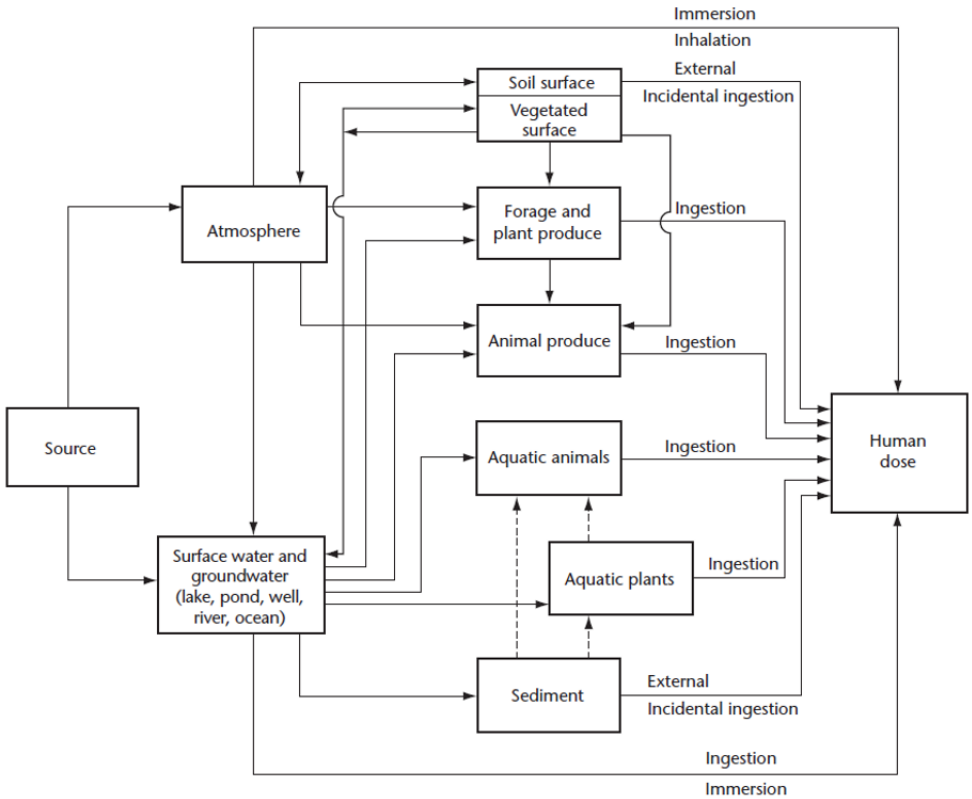
Completing similar calculations for soil deposition, conservatively assuming a soil density of 1.6 g/cm^3 a mixing zone of 5 cm (CSA, 2014) the estimated average annual increase in soil concentrations will be:

$$Avg\ annual\ increae\ in\ U\ in\ Soil = \frac{17.2\ g}{0.05\ m * 3140000\ m^2} * \frac{1\ cm^3}{1.6\ g} * \frac{1\ m^3}{(100\ cm)^3} = \ 6.8\ x10^{-5}\ \frac{\mu g}{g} dry\ weight$$

$$Avg\ annual\ increase\ in\ Be\ in\ Soil = \frac{2.5g}{0.05m * 3140000m^2} * \frac{1\ cm^3}{1.6\ g} * \frac{1\ m^3}{(100\ cm)^3} = \ 1\ x10^{-5}\ \frac{\mu g}{g} dry\ weight$$

Therefore, exposure through soils and the terrestrial food chain are not expected to be relevant due to the negligible amounts of beryllium and uranium released to air and the low concentration of these substances in soil. Exposures through surface water consumption and exposure and the aquatic food chain are also not expected to be relevant due to the negligible amounts of beryllium and uranium released indirectly to surface waters through plant sewer effluent, the low concentrations of uranium and beryllium in stormwater runoff and the absence of any surface waters in the immediate area of the facility. Therefore, given the estimated low concentrations of beryllium and uranium in stormwater runoff and soil and the absence of any soil or groundwater contamination on site, pathways associated with groundwater are also not considered pathways of concern.

Figure 3.1 – Sample Human Pathway Model



Source (CSA, 2012)

3.2 Assessment of Radiological Impact

Radiological materials expected to be released include uranium to air and water. Direct gamma radiation from the facility and internal exposure through pathways such as consumption of locally-sourced food and water is also a consideration.

The estimated annual effective dose as a result of air releases and direct gamma exposure radiation from the combined operation is expected to be a small percentage of the public dose limit. There will be no radiological effects to the public due to the proposed consolidated operations of BWXT NEC, and there is no radiological risk posed to off-site human receptors, thus, no further assessment is required.

Radiological materials will be released to the environment as a result of the consolidated operations at BWXT NEC. In this section, the impacts of radiological releases on human health are assessed at the screening level (Tier 1) first. PQRA (Tier 2 assessment) and DQRA (Tier 3 assessments) is not required based on the screening level review.

Radiological materials expected to be released include uranium to air and water. Direct gamma radiation from the facility and internal exposure through pathways such as consumption of locally-sourced food and water is also a consideration.

Uranium has both radiological and non-radiological (primarily on kidney toxicity) effects. Uranium releases are discussed in more detail in Section 3.3.

3.2.1 Screening Criteria

Radiological releases to air and water will be screened to identify COPCs. The Canadian Nuclear Safety Commission's regulatory dose limit for members of the public, as defined in the *Radiation Protection Regulations,* is 1 mSv (1,000 µSv) per year. The Canadian average effective dose from background radiation is 1.8 mSv per year (CNSC, 2013). The ICRP (Publication 103 at para 268) suggests a risk based constraint for members of the public of 1×10^{-5} per year. Assuming the combined radiological detriment of about 5% per Sievert (ICRP 102 at para e), this converts to an annual dose of about 200 µSv per year which coincidentally, is about 10% of the unavoidable annual dose from natural background (ICRP, 2007). For present purposes, we have assumed an annual reference dose of 200 µSv for the purpose of screening.

3.2.2 Dose to Off-Site Receptors

Off-site receptors could receive radiation doses from direct external exposure to gamma radiation from the BWXT NEC consolidated operations and internal exposure through pathways such as air, water and soil exposure.

Liquid effluent is not included in the calculation of public dose as the effluent from the facility will be discharged directly to city sanitary sewer system and is not used directly for drinking. Further, it is estimated that the liquid effluent discharge will contain less than 1 kg of uranium per year. Based on sampling results from the existing nuclear fuel pelleting operation wastewater treatment holding tanks, the maximum uranium concentration measured prior to dilution in plant sewer systems is estimated to be 2.75 mg/L for the consolidated plant. Allowing for dilution within the municipal treatment system of approximately 17,000 times, based on design flow of 68,200 m^3/day for the Peterborough Wastewater Treatment Plant (City of Peterborough, 2012) and an average discharge of uranium treated effluent approximately 4 m^3/day (see Section 2.2.9.1), and allowing for no removal within the City of Peterborough wastewater treatment processes, the maximum uranium concentration in effluent from the treatment plant would be around 0.0002 mg/L before any dilution in the natural environment. This is well below the Canadian Maximum Allowable Concentration drinking water standard of 0.02 mg/L. Exposures through water consumption and the aquatic food chain are therefore not relevant due to the low concentrations in the natural environment and the absence of any drinking water and surface waters in the immediate vicinity of the facility.

Exposure through ingestion through backyard gardens and internal and external exposure through soils is expected to be minor given that the estimated uranium in soils concentrations are well below the CCME guidelines.

BWXT NEC has developed separate Derived Release Limits for the existing fuel bundle assembly and existing fuel pelleting operations to account for the realistic pathways occurring as a result of air emissions as described in the facilities Radiation Protection Manual (see Table 3.1) to restrict dose to a member of the public to 1,000 µSv per year. The Derived Release Limits assume that a member of the public occupies the BWXT NEC boundary continuously (24 hours per day, 365 days per year).

Table 3.1 – Radiological Exposure Pathways

z	Description
Air immersion	Airborne uranium dioxide particles (UO_2) can expose members of the public via direct radiation. This is accounted for in the current Peterborough and Toronto Derived Release Limits and will be applicable to the consolidated operations
Soil deposition gamma ground shine	Gamma ground shine dose from direct radiation. This is not applicable to the current Peterborough facility site due to the extremely low levels of uranium emissions but is accounted for in the Toronto Derived Release Limit and will be applicable to the consolidated operations
Soil deposition beta ground shine	Beta ground shine dose from direct radiation. This is not applicable to the current Peterborough facility site due to the extremely low levels of uranium emissions but is accounted for in the Toronto Derived Release Limit and will be applicable to the consolidated operations
Soil re-suspension and inhalation	Soil re-suspension and inhalation dose. This is not applicable to the current Peterborough facility site due to the extremely low levels of uranium emissions but is accounted for in the Toronto Derived Release Limit and will be applicable to the consolidated operations
Air inhalation	Airborne uranium dioxide particles (UO_2) can expose members of the public via inhalation. This is accounted for in the current Peterborough and Toronto Derived Release Limits and will be applicable to the consolidated operations

As discussed in annual reports, through direct correlation with the facility Derived Release Limits, over the 2012 to 2016 period, the estimated annual effective dose as a result of air releases for the existing Peterborough fuel bundle assembly operations is estimated to be negligible (~ 0.00 µSv) (GEH-C, 2012 to 2015 and BWXT NEC, 2016). Based on annual reports for the existing nuclear fuel pelleting operation, a marginal increase in dose is expected from the consolidated operations. Through direct correlation with the existing fuel pelleting operation Derived Release Limits over the 2012 to 2016 period, the estimated annual effective dose as a result of air releases and direct gamma exposure radiation from the combined operation is expected to be on the order of 10 µSv/year based on 2012 to 2016 data (GEH-C, 2012-2015 and BWXT NEC, 2016). This dose represents 1% of the 1 mSv (1,000 µSv) per year effective dose limit to a member of the public and 5% of the 0.2 mSv (200 µSv) per year screening criterion for radiological releases to air and water.

Therefore, it can be concluded that there will be no radiological effects to the public due to the proposed consolidated operations of BWXT NEC, and there is no radiological risk posed to off-site human receptors, thus, no further assessment is required.

3.3 Assessment of Non-Radiological Impact

No non-radiological airborne or waterborne substances have been identified as COPCs for further assessment in the HHRA.

Non-radiological releases to the environment will occur as a result of consolidated operations at BWXT NEC. In this section, the impacts of non-radiological contaminants on human health are assessed at the screening level (Tier 1) first. Based on the results of the screening level assessment, PQRA (Tier 2 assessment) and DQRA (Tier 3 assessments) are not required.

3.3.1 Screening Criteria

The non-radiological substances in air and water will be screened to identify COPCs. Screening criteria are identified in each section below.

3.3.2 Air

Non-radiological airborne emissions considered included uranium, beryllium, particulate matter, volatile organic compounds, trace metals, hydrogen and nitrogen oxides. All airborne emissions for the consolidated operations have modelled air concentrations less than 70% of the screening criteria. Furthermore, all non-radiological substances are currently and will continue to be below CNSC licence limits, BWXT NEC Action Levels, BWXT NEC Internal Control Levels MECP Benchmarks limits, and are therefore expected to be negligible.

Therefore, no non-radiological airborne substances have been identified as COPCs for further assessment in the HHRA.

Non-radiological substances, such as Uranium, Beryllium, Particulate Matter (PM), Volatile Organic Compounds (VOCs), Trace Metals, and other miscellaneous contaminants could be released to air as the result of the consolidated operations. The primary airborne emission sources at the consolidated operations will include:

- Uranium from the Uranium Oxide Element Decan Exhaust, Dust Collectors, Rotoclone and Sintering Furnace Exhaust in Building 21;
- Beryllium from three stacks in the Beryllium Area.
- Particulate matter from Sintering Furnace Exhausts, Dust Collectors, Rotoclone, and Sintering Furnace and Cooling Towers;
- Zinc stearate, zinc hydroxide and octadecanoic acid from Sintering Furnace Exhausts;
- Hydrogen from a Pressurized Hydrogen Storage Tank Vent; and
- Nitrogen oxides (NO_x) emissions from the Dryers' Exhaust,

Other miscellaneous minor sources are also located at BWXT NEC, including, but are not limited to a spray booth, Metalas bundle wash area, graphite area, and maintenance areas.

Under current conditions, greenhouse gases and nitrogen oxides (NO_x) are emitted from only the combustion equipment at the site (natural gas fired boilers and hot water heater). These boilers are below the Ontario MECP threshold for negligible sources and are therefore considered insignificant.

BWXT NEC Peterborough has an annual licenced release limit (550 g) for uranium and has established facility specific CNSC approved *Action Levels* for various environmental parameters. BWXT NEC has also established *Internal Control Levels* for various environmental parameters that are set even lower than Action Levels to act as an early warning system. *Internal Control Level* exceedances trigger an internal investigation and corrective actions; however, they are not CNSC reportable events.

The Environmental Protection Act of Ontario (R.S.O. 1990, c. E. 19) and Ontario Regulation 419/05 *Air Pollution – Local Air Quality Regulation* also determine permitted concentrations of contaminant releases, as published in in the MECP publication *Air Contaminants Benchmarks List (ACB List): standards, guidelines and screening levels for assessing point of impingement concentrations of air contaminants* [ACB list] (MOECC, 2017b).

The proposed facility will require an ECA amendment. However, for the purpose of this study, to assess airborne emissions of non-radiological COPCs from BWXT NEC, emission estimates, based on measurements, engineering calculations and emission factors, and modelling of airborne emissions conducted in support of BWXT NEC Peterborough and Toronto ECA applications were used. For each contaminant, the emission summary and dispersion modelling (ESDM) report includes a calculation of the maximum Point of Impingement (POI) concentrations for the averaging periods (10-minute, ½-hour, 24-hour or one year) for which standards exist. The calculations are based on the operating conditions, including start-up and shut-down, where all significant sources are operating simultaneously at their individual maximum rates of production. The maximum emission rates for each significant contaminant emitted from the significant sources were calculated in accordance with section 11 of O.Reg. 419/05.

Based on the ESDM reports (GHD, 2016 and Trinity Consultants, 2015) the estimated maximum POI concentrations are presented in Table 3.2, along with applicable standards. For common contaminants emitted at both facilities (i.e., uranium and particulate matter) or contaminates emitted only from fuel pelleting operations, the maximum POI concentration is presented for both the baseline and consolidated scenarios are presented. All other contaminants in Table 3.2 are expected to have similar emission profiles under baseline and consolidated operations. To better define the impact of airborne emissions from nuclear operations, the POI concentration attributed only to BWXT NEC activities is shown for airborne contaminants that have predicted facility-wide concentrations above 50% of the criteria. Table 3.2 shows that for the airborne contaminants with modelled concentrations approaching the screening criteria the nuclear operation represents a contribution of less than 70% in all cases.

Furthermore, as shown in Table 3.2, all non-radiological substances are below, with most well below, CNSC licence limits, BWXT NEC *Action Levels,* BWXT NEC *Internal Control Levels* and MECP Benchmarks limits, and are therefore expected to be negligible.

Therefore, no non-radiological airborne substances have been identified as COPCs for further assessment in the HHRA.

3.3.3 Surface Water

There are no surface waters present in the vicinity of consolidated operations and limited liquid effluent from the facility, therefore no measurable effects on surface water and sediment components are expected. Uranium and beryllium are the key contaminants in BWXT NEC effluent which discharges to sewer. For discharges to sewer, after passing through the municipal wastewater treatment plant, concentrations of uranium and beryllium are currently and will continue to be will be well below WHO drinking water quality guidelines.

Therefore, no non-radiological waterborne substances have been identified as COPCs for further assessment.

Uranium and beryllium are the key contaminants in BWXT NEC effluent. BWXT NEC releases will be discharged to the plant sewer system where it combines with the waste water from other, non-nuclear operations in the GE Peterborough Plant Complex prior to discharge to the municipal sewer.

There are no surface waters present in the vicinity of consolidated operations and limited liquid effluent from the facility, therefore no measurable effects on surface water and sediment components are expected. Moreover, surface water monitoring data for the most recent five years (2012-2016) from three Provincial Monitoring Network stations (Station IDs: 17002103802, 17002107002 and 17002114402) show a maximum uranium concentration of 3.63 ppb, which is below the drinking water guideline of 20 ppb. However, as effluent will be discharged to the municipal sewer system and ultimately to the natural environment, screening of non-radiological contaminants in this effluent was conducted based on the comparison of effluent concentrations against appropriate screening criteria.

Neither the Peterborough Sewer Use By-Law (By-Law Number 15-075) nor the CCME Model Sewer Use Bylaw (Marbek Resources Canada Ltd., 2009) specify limits for either beryllium or uranium compounds. For purposes of screening, effluent discharges were therefore screened against licence and internal limits as well as drinking water quality standards.

It is noted that the general public has no direct access to sewer discharges and that significant additional dilution is expected in transit to and within the sewage treatment plant with further significant dilution expected when effluent from the municipal sewage treatment plant is discharged to surface waters. Therefore, comparison of BWXT NEC estimated effluent to drinking water quality criteria is extremely conservative.

As shown in Table 3.3, uranium discharges are expected to be well below screening criteria. For common contaminants discharge from both facilities (i.e., uranium and particulate), the highest reported discharge concentration is presented for the consolidate operations. At the point of release to the consolidated operation's sewer, the highest single measured value of beryllium exceeds the *Internal Control Level* as well as the WHO drinking water quality guideline. The maximum annual average concentration also marginally exceeds the *Internal Control Level*. After passing through the municipal wastewater treatment plant, dilution results in concentrations of uranium and beryllium well below WHO drinking water quality guidelines. These contaminants are not assessed further. Therefore, no non-radiological waterborne substances have been identified as COPCs for further assessment.

3.4 Assessment of Physical Stressors

Noise was identified as a potential physical stressor for human health. The consolidated operations will be required to demonstrate conformance to MECP NPC-300 noise criteria during the environmental compliance approvals process. Therefore, it is expected that noise levels from the proposed facility will pose no adverse effects to human health.

Noise is the only physical stressor to be considered for the HHRA, consistent with CSA N288.6-12.

3.4.1 Screening Criteria

The criteria specified in the Ontario Ministry of the Environment, “Environmental Noise Guideline Stationary and Transportation Source – Approval and Planning” Publication NPC-300 (MOE, 2013) are used for the noise assessment:

3.4.2 Noise

Based on the Acoustic Assessment Reports (AARs) prepared by GHD and Trinity Consultants (GHD, 2016a and Trinity Consultants, 2015a), the estimated steady state sound levels at the identified sensitive receptors (Points of Reception - POR) for both Facilities, comply with the NPC300 criteria of 50 -dBA for the 7 a.m. to 11 p.m. period and 45 dBA at the plane of window of noise sensitive spaces for the 11 p.m. to 7 a.m. period as applicable to an urban (Class1) setting.

While additional equipment associated with the pellet operations may increase noise emissions from the consolidated operations, the consolidated operations will be required to demonstrate conformance to MECP NPC-300 noise criteria during the environmental compliance approvals process. Therefore, it is expected that noise levels from the proposed facility will pose no adverse effects to human health.

Table 3.2– Air Quality Screening – Human Health Risk

Contaminant	Total Facility Emission Rate (g/s)	Consolidated BWXT NEC Facility Emission Rate (g/s)	BWXT NEC	Averaging Period (hours)	Air Dispersion Model Used	Maximum Ground Level Concentration (μ/m^3)	ACB Limit Screening Criteria (μ/m^3)	Limiting Effect[2]	Facility-wide Contribution to % of Criteria	Nuclear site Contribution to % of Criteria	Carried Forward to Tier 2 Assessment
Uranium Baseline Operations	0.013 g/yr	0.013 g/yr	100%	Annual	NA	NA	550 g/y emissions	Licence Condition	0.00%		No
	1.57E-7	1.57E-7	100%	Annual	AERMOD	7.47E-05	0.03 (U in PM10)	Health			No
Uranium Consolidated Operations[5]	17.2 g/yr	17.2 g/yr	100%	Annual	NA	NA	750 g/y emissions [(7)]	Licence Condition	3.12%		No
	5.0-6	5.0E-6	100%	Annual	AERMOD	~ 0.0013[6]	0.03 (U in PM10)	Health	~4.5%		No
Particulate Matter Baseline Operations	3.67E-01	5.08E-02	13.9%	24	AERMOD	17.5	120	Particulate	14.6		No
Particulate Matter Consolidated Operations[5]	3.99E-01	8.3E-02	20%	24	AERMOD	~ 20	120	Particulate	16.6		No
Hydrogen Baseline Operation	0	0	0	-	-	-	-	-	-	-	No
Hydrogen Consolidated Operations[5]	0.0236	0.0236	100%	24	AERMOD	~ 65 [6)]	3203	-	<2.1		No
Beryllium[1]	0.027 µg/m3 (at the stack)	0.027 µg/m3 (at the stack)	100%	Sampling Event	NA	NA	0.01	Internal Control Level	-		No
	7.96E-08	7.96E-08		24 Hour	AERMOD	0.00004	0.01	Health	<1%		No
Ethylbenzene	3.01E+00	3.53E-01	23.4%	24	AERMOD	91.8	1000	Health	9.2		No
Benzyl Alcohol	9.19E-01	2.76E-01	30.0%	24	AERMOD	50.5	880	Health	5.7		No
Methyl Isobutyl ketone	1.27E+01	6.21E-01	4.9%	24	AERMOD	575	1200	Odour	47.9		No
2-methoxy-1-methylethyl acetate	1.59E+00	5.38E-02	3.4%	24	AERMOD	51.9	5000	Odour	1.0		No
Toluene	1.59E+01	6.67E-02	0.4%	0.5	Reg. 346	482	2000	Odour	24.1		No
Cyclohexanone	1.20E+00	1.20E+00	100.0%	24	AERMOD	173	400	Health	43.2		No
Triethylenetetramine	5.85E-03	1.04E-03	17.7%	24	AERMOD	0.706	40	Health	1.8		No
n-butyl acetate	1.07E+00	2.08E-02	1.9%	0.5	Reg. 346	32.3	735	Odour	4.4		No
Xylene	1.68E+01	1.22E+00	14.6%	24	AERMOD	567	730	Health	77.7	24.0	No
Carbon Black	8.98E-03	1.17E-03	13.1%	24	AERMOD	0.527	10	Soiling	5.3		No
Barite	3.17E-03	3.17E-03	100.0%	24	AERMOD	0.457	2.5	Health	18.2		No

Contaminant	Total Facility Emission Rate (g/s)	Consolidated BWXT NEC Facility Emission Rate (g/s)	BWXT NEC	Averaging Period (hours)	Air Dispersion Model Used	Maximum Ground Level Concentration (µ/m³)	ACB Limit Screening Criteria (µ/m³)	Limiting Effect[2]	Facility-wide Contribution to % of Criteria	Nuclear site Contribution to % of Criteria	Carried Forward to Tier 2 Assessment
Titanium Dioxide	3.68E-02	2.86E-03	7.8%	24	AERMOD	1.3	34	Health	3.8		No
Magnesium Silicate hydrate (talc)	4.18E-02	9.50E-03	22.7%	24	AERMOD	1.74	2	Health	87.0	68	No
Silica	2.86E-02	1.17E-03	4.1%	24	AERMOD	1.21	5	Health	24.2		No
Epoxy Resin	3.36E-01	1.34E-03	0.4%	24	AERMOD	11	120	Health & Particulate	9.1		No
Bisphenol A Diglycidyl Ether Polymer	5.22E-01	6.58E-02	12.6%	24	AERMOD	17.9	25.2	MAXGLC	71.0		No
Nonylphenol	1.72E-02	3.15E-03	18.4%	24	AERMOD	1.93	30	Health	6.4		No
ethylene glycol n-propanol	7.25E-01	1.08E-02	1.5%	0.5	Reg. 346	21.9	430	Health	5.1		No
Propylene Glycol T-butyl Ether	1.04E-01	1.04E-01	100.0%	24	AERMOD	15	365	Health-	4.1		No
Ethanol	4.48E+00	2.18E-03	0.0%	24	Reg. 346	136	19000	Odour	0.7		No
Mineral Spirits	2.69E+00	1.33E-02	0.5%	0.5	-	(4)	(4)	(4)	(4)		No
Naphtha, Petroleum	1.05E+00	4.96E-03	0.5%	0.5	-	(4)	(4)	(4)	(4)		No
Aromatic 100	1.22E+00	1.12E-01	9.2%	0.5	-	(4)	(4)	(4)	(4)		No
Total Mineral Spirits	5.37E+00	1.30E-01	10.2%	0.5	Reg. 346	163	3000	Odour	5.0		No
Methanol	1.14E+00	9.46E-04	0.1%	24	Reg. 346	30.9	12000	Health	0.3		No
Isopropanol	3.51E+00	3.19E-01	9.2%	24	AERMOD	311	7300	health	4.3		No
Acetone	4.92E+00	1.40E-01	2.8%	0.5	Reg. 346	149	35640	Health	0.4		No
Polyamide Resin	8.63E-04	8.63E-04	100.0%	24	AERMOD	0.124	120	Health & Particulate	0.1		No
n-Butyl Alcohol	3.06E+00	2.88E-02	0.9%	24	Reg. 346	92.6	2760	Health	3.4		No
Total Manganese	3.36E-03	3.60E-06	0.1%	0.5	AERMOD	0.287	0.4	Health	71.8	<1	No
Total Nickel	3.82E-04	2.42E-05	6.3%	Annual	AERMOD	0.00682	0.04	Health	17.1		No
Chromium	9.85E-04	2.17E-04	22.0%	24	AERMOD	0.143	0.5	Health	28.6		No
Orthophosphoric acid	7.87E-05	7.87E-05	100.0%	24	AERMOD	0.864	7	Health	12.3		No
Graphite	6.03E-03	7.50E-04	12.4%	24	AERMOD	1.45	10	Health	14.5		No
Naphthalene	6.79E-03	4.96E-03	73.1%	24	AERMOD	2.93	22.5	Odour	13.0		No
ortho-xylene	2.60E+00	3.01E-02	1.2%	24	AERMOD	86.9	100	-	86.9	4.0	No
1,2,4-Trimethyl Benzene	1.80E+00	2.48E-03	0.1%	0.5	Reg. 346	54.5	680	Health	8.0		No
Ancamine 2480 Curing Agent	1.06E-03	1.06E-03	100.0%	24	AERMOD	0.152	0.213	MAXGLC	71.4		No

<u>Notes</u>

1. The MECP POI limit for Beryllium is 0.01 µg/m^3. The POI is the plant/public boundary. BWXT NEC has established an *Internal Control Level* of 0.01 µg/m^3 air at the stack exit. Dilution between the stack and the plant boundary will also reduce the concentrations at the POI to below legislated limits. As no emissions in excess of the *Internal Control Level,* the maximum ground level concentration will be well below the POI standard.
2. JSL = MECP Jurisdictional Screening Level; MAXGCL =maximum ground level concentration as accepted by; *de minimus* value = if < 0.1 µg/m^3 (24-hour average) or < 0.3 µg/m^3 (1/2-hr average), then impacts can be considered insignificant.
3. Within Acceptable Point of Impingement Concentration (APOIC). If a facility is updating its ESDM report and there is an increase of an APOIC due solely to the use of the updated dispersion model version, then a 5 times increase is permissible by the MECP Standard Development Branch
4. Included in Total Mineral Spirits.
5. Based on total of maximum annual release over 2012 to 2016 period for each facility. Maximum release rate based on aggregate of release rates from individual ESDM reports.
6. Based on existing fuel pelleting operation maximum ground level concentration increased by a factor of three (3) to account for differences in dispersion characteristics between the Toronto and Peterborough buildings.
7. Assumed, based on current existing nuclear fuel pelleting operation limit

Table 3.3 – Surface Water Screening – Human Health Risk

Contaminant[1]	BWXT NEC Undiluted Maximum Effluent (2012 to 2016)	Diluted Maximum Effluent from Peterborough Complex (2012 to 2016)	BWXT NEC Undiluted Average Annual Effluent (2012 to 2016)	Diluted Average Annual Effluent from Peterborough Complex (2012 to 2016)	Screening Criteria	Source	Diluted Maximum Effluent from Peterborough Wastewater Plant[7]	Carried Forward to Tier 2 Assessment
Uranium Baseline Operations	0.24 g/y	0.24 g/y	.006 to 0.24 g/y	.006 to 0.24 g/y	760 kg/y	Licenced Release Limit	-	No
	0.48 mg/L	0.01 mg/L	0.07 to 0.29 mg/L	0.002 to 0.007 mg/L	6 mg/L (per batch)	Action Level [2]	-	No
					0.02 mg/L MAC [3]	Health Canada (2014)	< 0.00002	No
					0.02 mg/L	O.Reg. 169/03[4]	< 0.00002	
Uranium Consolidated Operations	900 g/y[6]	900 g/y	12.02 g/y	0.3 g/y	760 kg/y	Licenced Release Limit	-	No
	3.65 mg/L	unknown	0.47 to 1.02 mg/L	unknown	6 mg/L (per batch)	Action Level [2]	-	No
					0.02 mg/L MAC [3]	Health Canada (2014)	0.0002	No
					0.02 mg/L	O.Reg. 169/03[4]	0.0002	
Beryllium	65.5 µg/L	1.64 µg/L	0.4 to 4.5 µg/L	0.01 to 0.11 µg/L	4.0 µg/L	Internal Control Level [5]		See discussion
					12.0 µg/L	WHO 2009	0.004	No

Notes

1. See Table 2.12 for effluent data.
2. An *Action Level* is defined in the *Radiation Protection Regulations* "as specific dose of radiation or other parameter that, if reached, may indicate a loss of control of part of a licensee's radiation protection program, and triggers a requirement for specific action to be taken." *Action Levels* are also applied to environmental protection and are approved by the CNSC.
3. MAC - maximum acceptable concentrations for drinking water.
4. Prescribed as drinking water quality standards for the purposes of the Safe Drinking Water Act, 2002.
5. The *Internal Control Level* corresponds to the US Environmental Protection Agency Maximum Contaminant Level for beryllium (US EPA, 2016).
6. BWXT NEC maximum annual uranium discharge over 2012 to 2016 period
7. Based on a dilution of 17,000:1 (see Section 3.2.2).

3.5 Risk Characterization

For the radiological emissions, direct gamma radiation and air emissions will be the major pathways. The estimated doses are estimated to be a small percentage of the dose limit. At this level, no adverse radiological effects to human health are expected as a result of the consolidate operations, thus no additional assessment is required.

For non-radiological emissions are generally well below applicable screening criteria and pose no threat of adverse effects to human health. No additional assessment is required.

Noise levels from the operation of BWXT NEC are currently and will continue to be compliant with the NPC-300 for all locations and time periods. Therefore, BWXT NEC operations pose no adverse effects to human health.

The screening level risk assessment takes into account emissions to and concentration in different applicable media including air and surface water and uses conservative estimates of emissions and effects criteria.

For the radiological emissions, direct gamma radiation and air emissions will be the major pathways. Doses from water exposure can be considered trivial due to the very small estimated quantity of uranium, its weak radiological properties and the absence of surface water in close proximity. Uranium in soil concentrations, is expected to be generally at or below Ontario background soil concentrations.

Based on data for the existing fuel pelleting operation, the maximum estimated annual effective dose to the general public as a result of direct gamma radiation and air releases from the consolidated operation is estimated to be approximately 10.44 µSv/y representing 1.0% of the public dose limit, with 9.4 µSv attributable to direct gamma radiation. At this level, no adverse radiological effects to human health are expected as a result of the consolidate operations, thus no additional assessment is required.

Non-radiological contaminants emitted to air and water as a result of the operation at BWXT NEC are generally well below applicable screening criteria and pose no threat of adverse effects to human health. No additional assessment is required.

For noise, the analysis of the modelling results shows that noise levels from the operation of BWXT NEC are compliant with the NPC-300 for all locations and time periods. Therefore, BWXT NEC operations pose no adverse effects to human health.

3.6 Uncertainty Associated with the Human Health Risk Assessment

HHRA was completed based on effluent and environmental monitoring data collected for BWXT NEC individual operations. As new pellet production equipment will be installed, it is expected that uranium emissions will be similar to or lower than those estimated due to improved technologies and controls. Expanded operations do not impact on beryllium consumption and discharges.

Uncertainty could be introduced into the risk assessment during the screening level assessment or risk characterization. This uncertainty can be minimized through the use of longer term data sets, along with the use of conservative assumptions to ensure that human health is protected. A qualitative analysis of the uncertainty associated with the HHRA is presented below.

The HHRA followed the process defined in N288.6 providing a level of assurance that the screening HHRA was completed in an acceptable manner.

There is uncertainty in the selection of the critical receptor and associated behaviours. Given that only a screening level risk assessment was necessary, detailed receptor characteristic were not required.

For the radiological risk assessment, available monitoring data from both BWXT NEC facilities were used along the CNSC accepted approach to calculating the derived release limit. BWXT NEC has reported that calculated doses to the general public using this CNSC approved approach have been consistent, over a number of years, and are well below the regulatory dose limit.

The two key non-radiological contaminants, uranium and beryllium, have been frequently monitored in air emissions and liquid effluent at both sites, increasing the likelihood that the monitored results are representative of actual emissions and allowing to have reliable estimates for the consolidated scenario under analysis.

The detection limits used are very low allowing for the detection of these contaminants in facility emissions. During the screening process, to be conservative, the maximum concentrations of uranium and beryllium detected over a number of years were compared against a range of screening criteria accepted by the CNSC or published by reputable agencies. Further, monitoring results were well below screening criteria, providing additional confidence that the screening criteria are not exceeded. These conservatisms built into the screening process helps ensure that the conclusion of the screening assessment is valid, with a high level of confidence.

For other non-radiological air emissions, the calculations are based on the operating conditions, including start-up and shut-down, where all significant sources are operating simultaneously at their individual maximum rates of production. The maximum emission rates for each significant contaminant emitted from the significant sources were calculated in accordance with s. 11 of O. Reg. 419/05.

The majority of emissions other than beryllium and uranium are attributed to the operation of the spray paint booth and the metallurgical lab which are intermittent operations. In particular, emissions from the spray paint booth represent all potential emissions from all product potentially used and therefore significantly overestimate the total emissions at any given time. Therefore, these emission rates are not likely to underestimate the actual emission rates. Further, screening criteria established by the MECP for its environmental compliance approval process on the basis of scientific review and analysis were used. Conservatively, all emissions from the Peterborough complex, including non-radiological operations not related to BWXT NEC were used in the screening process.

There is uncertainty in the AERMOD model used to predict atmospheric dispersion of air releases and the differing dispersion characteristics attributable to the configuration of buildings at the Toronto and Peterborough sites. These include uncertainty in modelling building-induced turbulence on the effective release height and plume spread and the use of a given meteorological dataset. In general air dispersion models can vary by a factor of two. The air assessment was completed using a methodology established and a model approved by the MECP, based on criteria established by the MECP, and reviewed by the MECP through the environmental compliance approvals process. The conservatisms built into the screening process helps ensure that the conclusion of the screening assessment is valid, with a high level of confidence.

Preliminary analysis of air dispersion characteristics between the existing Toronto and Peterborough sites suggests that dispersion factors between the two sites differ by approximately a factor of two. This is within the range of variability in air dispersion models. As such, ambient air concentration data for the Toronto facility are not expected to differ by more than a factor of two as well, resulting in predicted concentrations well below levels of concern. Maximum ground level predictions for uranium and hydrogen for the existing nuclear fuel pelleting operation were increased by a factor of three to conservatively account for these differences.

There is uncertainty in the expected noise emissions from the consolidated operations as well as in the noise measurements and the modelling. Sound level monitoring units generally have a measurement error of within +/- 1 dBA. For noise modelling, uncertainty arises in the assessment of source sound levels in the noise modelling of sound propagation. The noise assessment for the consolidated operations will be completed using a methodology established and a model approved by the MECP, based on criteria established by the MECP, and reviewed by the MECP through the environmental compliance approvals process. Uncertainty in the expected noise emissions is mitigated by the need to demonstrate conformance to noise criteria established by the MECP. Therefore, it is expected that the uncertainty associated with the noise levels has no impact on the conclusions.

In summary, the assessment method and the conservative assumptions used for the HHRA ensure that the actual risks are not underestimated. Therefore, the uncertainty associated with the assessment has no impact on the conclusions of the HHRA.

4 ECOLOGICAL RISK ASSESSMENT

The prime hazards to the environment from the consolidated operations will be uranium, beryllium and gamma radiation through emissions to air and water.

Tier 1 screening did not identify any radiological or non-radiological COPCs requiring preliminary quantitative or detailed quantitative risk assessment, consequently detailed receptor characterization was not required.

Pathways for ecological exposure considered include:

- *Air inhalation/skin absorption;*
- *Air immersion (external exposure).*
- *Soil deposition gamma and beta ground shine; and*
- *Soil ingestion and resuspension inhalation*

Potential physical stressors to biota include heat, road kill, bird strikes, heat, noise or artificial lighting.

4.1 Problem Formulation

As noted in Section 3.1, Problem formulation is a step undertaken early in the ERA process to constrain and focus the ERA on the key questions. The following discussion describes the approach taken to focus the EcoRA.

4.1.1 Receptor (Valued Ecosystem Component (VEC)) Selection and Characterization

Valued Ecosystem Components identified include:

- *Doses to non-humans;*
- *Soil invertebrates.*
- *Terrestrial vegetation; and*
- *Wildlife communities and species.*

However, because the Tier 1 screening did not identify any radiological or non-radiological COPCs requiring preliminary quantitative or detailed quantitative risk assessment, detailed receptor characterization was not required.

4.1.1.1 Receptor Selection

It is not practical to assess the radiological or non-radiological dose to each species residing in the vicinity of BWXT NEC. For the purpose of the EcoRA, Valued Ecosystem Components (VECs) were chosen for assessment.

VECs, as defined by the Canadian Environmental Assessment Agency, are the features considered important by the proponent, public, scientists or government experts. Importance may be determined on the basis of cultural values or scientific concern. VECs are considered valuable because they are: legally recognized and afforded special protection by law, policy or regulation; and/or recognized by the scientific or professional communities and/or the public as important due to their abundance, scarcity, endangered status, role in the ecosystem or exposure pathway that they represent. Examples of VECs are provincially significant wetlands, fish habitat, species (flora and fauna), and significant landscapes.

Selection of ecological VECs is based on knowledge of the site ecology and habitats as summarized in the Environmental Impact Statement for the Low Enriched Uranium Fuel Bundle Production Project (GEH-C 2009). During the environmental assessment (EA) for the Low Enriched Uranium Fuel Bundle Production Project, a "*Plugged into Peterborough*" newsletter was published in the fall of 2008 and distributed to approximately 3600 households, after the project Guidelines had been approved by the CNSC. This newsletter provided a preliminary list of VECs and included a mail back response card for residents to complete and provide feedback on the list of VECs. No changes or additions were required as a result of input received.

Selection of VECs and indicators was made from members of the terrestrial and aquatic biota found within the "Local Study Area" defined in the EA as the area bounded by High Street to the west, Park Street to the east, Albert Street in the south, and Sherbrooke Street to the north (see Figure 2.2). Criteria used for the selection of VECs and indicators included presence and abundance, sensitivity to changes and ecological niche of the various species of the terrestrial and aquatic environments.

Three potential sub-components were identified as part of the terrestrial environment: terrestrial vegetation (species and communities); and wildlife (species and community) and wildlife habitat. In order to capture changes in these sub-components, a total of six measurable indicators were chosen:

- Earthworms;
- Grass (contamination levels);
- American Robin;
- Deer Mouse;
- Eastern Cottontail; and
- Red Fox.

Potential sub-components associated with the aquatic environment were not considered as there is no aquatic environment present on the site or within the Local Site Study Area.

Table 4.1 identifies the VECs applicable to the BWXT NEC Peterborough operations and provides a rationale for the selection of these VECs.

Table 4.1 – Valued Ecosystem Components

Environmental Components	Sub-components	VECs	Indicator/Receptors	Rationale
Radiation and Radioactivity	Radiation	Doses to non-humans	• Non-human biota as identified by Terrestrial Environment	• Non-human biota is potentially exposed to stressors produced by BWXT NEC • Protection of ecological health
Terrestrial Environment	Soil Quality	Soil invertebrates	• Earthworm	• Protection of ecological health
	Vegetation Communities and Species	Terrestrial Vegetation	• Grass	• Protection of ecological health
	Wildlife Communities and Species	Mammals & birds	• Red Fox (omnivore) • Deer Mouse (omnivore mostly insects) • Eastern Cottontail (herbivore) • American Robin (insectivore)	• Terrestrial species are potentially exposed to stressors produced by BWXT NEC • Protection of ecological health

4.1.1.2 Receptor Characterization

As discussed in Sections 4.2 and 4.3, as the Tier 1 screening did not identify any radiological or non-radiological COPCs requiring preliminary quantitative or detailed quantitative risk assessment, detailed ecological receptor characterization was not required.

4.1.2 Assessment and Measurement Endpoints

Assessment endpoints are directly related to management goals but are usually stated in terms of an attribute of populations or communities. When it is not practical to quantify those attributes, measurements endpoints representing more readily measured or predicted surrogates are used (CSA, 2012). The assessment endpoint for each VEC in this EcoRA is either population success or contaminant level, as shown in Table 4.2.

Table 4-2 – Assessment Endpoints for Indicator Species

VEC/Indicator Species	Assessment Endpoint			
	Individual Success	Population Success	Community Success	Contaminant Level
Grass				X
Earthworm		X		
Northern Redbelly Dace		X		
American Robin		X		
Eastern Cottontail		X		
White-Tailed Deer		X		
Red Fox		X		

4.1.3 Selection of Chemical, Radiological, and Other Stressors

The key stressors to the environment from the consolidated operations will be uranium, beryllium and gamma radiation. Road kill / bird strikes, artificial night lighting and noise were identified as a potential physical stressor.

Radiological and non-radiological stressors used in the EcoRA are identical to those used for the HHRA. Key stressors are uranium, beryllium and gamma radiation.

CSA N288.6 also identifies heat, road kill/bird strikes and intake cooling water as the physical stressors applicable to ecological receptors. Artificial night lighting and noise also have the potential to interact with receptors. The facility does not draw cooling water from a natural water source, so this stressor is not relevant to BWXT NEC.

The tiered approach to EcoRA, requires these contaminants to undergo a Tier 1 preliminary screening where conservative estimates of emissions and environmental concentrations are compared to screening criteria. The objective of this preliminary screening process is to identify contaminants of potential concern (COPCs) which are those contaminants that have undergone preliminary screening and have been selected for evaluation in higher tiers of assessment.

4.1.4 Selection of Exposure Pathways

Pathways for ecological exposure considered include:

- *Air inhalation/skin absorption;*
- *Air immersion (external exposure).*
- *Soil deposition gamma and beta ground shine; and*
- *Soil ingestion and resuspension inhalation*

Radiological and non-radiological materials will be released to the environment as a result of the consolidated operations at BWXT NEC. Consequently, this could result in the emissions to various media, potentially including air, surface water, soil, sediment, groundwater, and other media such as vegetation. VECs could be exposed to contamination through various pathways, an example of which is shown in Figure 4.1.

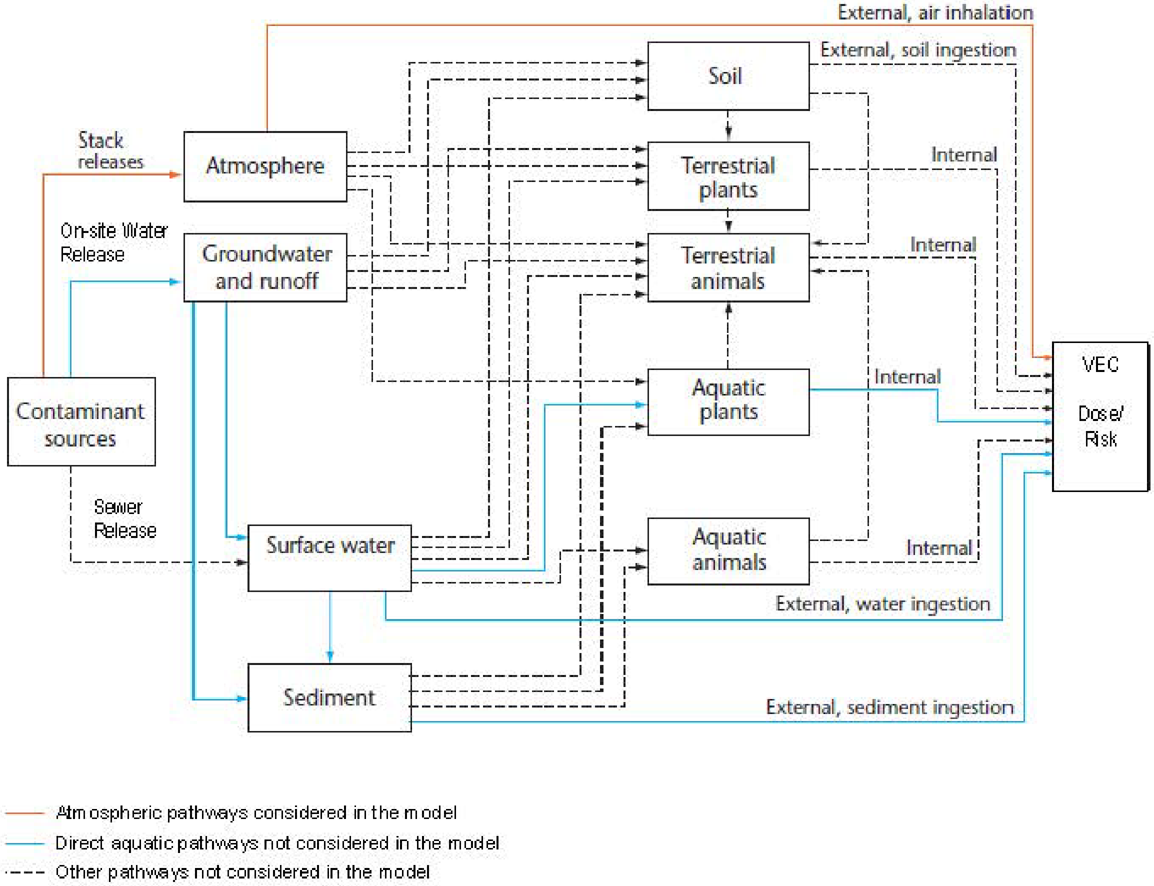
Of the pathways shown in Figure 4.1, the primary pathways for COPCs associated with consolidated operations are:

- Air inhalation/skin absorption; and
- Air immersion (external exposure).
- Soil deposition gamma and beta ground shine; and,
- Soil ingestion and resuspension inhalation.

Exposure through soils and terrestrial plant chain are not relevant due to the negligible amounts of beryllium and uranium released to air and consequent negligible contribution to soil levels. This is confirmed through CNSC IEMP sampling (see Appendix A) which measured uranium and beryllium concentrations in soil for the existing fuel bundle assembly operations that were marginally above background with no uranium in detectable quantities in grass. Soil monitoring results for the existing nuclear fuel pelleting operation suggest that uranium soil concentrations due to consolidated operations will be below applicable CCME guidelines.

Exposures through surface waters and the aquatic food chain are not expected to be relevant due to the small amounts of beryllium and uranium estimated to be released to water (see Section 2.2.9.1), the low concentrations released to the natural environment after dilution through the municipal wastewater treatment plant and the absence of any surface waters in the immediate area of the facility. Exposures through groundwater and surface runoff are not expected.

Figure 4.1 – Sample Ecological Exposure Pathway Model



Source (Adopted from CSA, 2012)

4.2 Assessment of Radiological Impact

Radiological materials expected to be released which may affect non-human biota include uranium to air and direct gamma radiation from the facility and internal exposure through soil and food.

Radiation (external and internal) exposure due to uranium emissions to air will be negligible as the uranium in air concentrations or soil concentrations associated with the operation of BWXT NEC are expected to be negligible, consequently inhalation and soil ingestion are not expected to be of concern. Direct external exposure to gamma radiation is estimated to be well below levels that are known to cause adverse effects. Therefore, it can be concluded that no radiological effects to VECs are expected due to the consolidated operations and no further assessment is required.

Radiological materials will be released to the environment as a result of the consolidated operations at BWXT NEC. In this section, the impacts of potential radiological releases on non-human biota are assessed at the screening level (Tier 1) first. PQRA (Tier 2 assessment) and DQRA (Tier 3 assessments) is not required, based on the screening level review.

Radiological materials releases will include uranium to air and direct gamma radiation from the facility and internal exposure through soil and food ingestion pathways is also a consideration. Exposure through water pathways is considered insignificant based on uranium being a low specific activity radionuclide which emits very low amounts of radiation as compared to other isotopes, the absence any surface waters in the immediate vicinity of the facility and the substantial dilution of uranium through the municipal wastewater treatment plant.

Uranium has both radiological and non-radiological effects. Uranium releases are discussed in more detail in Section 4.3.

4.2.1 Radiation Benchmark

Currently, dose limits to non-human biota have not been set by the CNSC or other regulatory agencies in Canada (CSA, 2012). Radiological releases to air will be screened to identify COPCs. The following dose benchmark values, as recommended in CSA N288.6-12 [2], will be used in this assessment:

- 100 µGy/h for terrestrial biota, and;
- 400 µGy/h for aquatic biota.

In accordance with N288.6-12, risk to radiation will be quantified for each category based on the calculation of a hazard quotient (HQ) defined as:

$$HQ = \frac{Calculated\ radiation\ dose}{Radiological\ criteria\ (Benchmark)}$$

For radiological risk, the HQ is calculated based on the total dose received by each receptor from all radionuclides through all pathways. If the HQ for radiological exposure is less than one, then no adverse effects are likely as levels are below those that are known to cause adverse effects. If the HQ exceeds one, it may be inferred that adverse effects to individuals are possible. In general terms, an increase in exposure is associated with an increase in risk. As the magnitude of the HQ increases so does the potential for environmental effects. An HQ greater than1 indicates that there is the potential for adverse effects and further assessment is required.

4.2.2 Radiation Exposure to VECs

VECs could potentially receive radiation doses from direct external exposure to gamma radiation from the BWXT NEC facility and external and internal exposure through pathways such as air exposure.

Based on 2014 to 2016 TLD data for the existing nuclear fuel pelleting operation, the maximum gamma radiation around the consolidated operations is estimated to be on the order of 42 mR per quarter (19.2 µR/h) providing an upper bound estimate of exposure to biota which is well below the benchmark of 100 µGy/h for terrestrial biota at the fenceline (note: 1 µGy ~ 100 µR).

Radiation (external and internal) exposure due to uranium emissions will be negligible as only between 10.4 and 17.2 g of uranium per year are estimated to be released based on data collected from the existing nuclear fuel pelleting operation over the 2012 to 2016 period.

Moreover, at BWXT NEC NFPO measured airborne concentrations of uranium in the environment were very low, with a maximum value of 0.008 µg U/m^3, with an expectation that values for the consolidated operations would be within a factor of two to three of this level. Further, as per CSA N288.6-12, Clause 7.3.4.2.5, “inhalation exposures to biota are usually minor compared to soil and food ingestion pathways and can be ignored in most EcoRAs. For particulate substances released to air and accumulating over time in the soil, the steady state concentration is usually high enough that soil and food components of dose are dominant”. As discussed in Section 2.2.9.2, uranium in soil concentrations are expected to be at or below the Ontario background level of 2.5 µg U/g dry weight. Therefore, exposure of VECs to facility emissions through soil ingestion is not expected to be of concern.

As a result, direct external exposure to gamma radiation is the only pathway for radiation exposure to VECs. The resulting HQ of approximately 0.016 (assuming continuous exposure at the maximum gamma radiation level measured) is well below one, the value at which no adverse effects are likely as levels are below those that are known to cause adverse effects.

Therefore, it can be concluded that no radiological effects to VECs are expected due to the consolidated operations and no further assessment is required.

4.3 Assessment of Non-Radiological Impact

No non-radiological airborne or waterborne substances have been identified as COPCs for further assessment in the Eco-RA.

Non-radiological releases to the environment will occur as a result of operations at BWXT NEC. In this section, the impacts of non-radiological contaminants on VECs are assessed at the screening level (Tier 1) first. Based on the results of the screening level assessment, PQRA (Tier 2 assessment) and DQRA (Tier 3 assessments) are not required.

4.3.1 Screening Criteria

The non-radiological substances in air will be screened to identify COPCs. CSA N288.6-12, Clause 7.2.5.3.1, indicates that "For non-radiological COPCs, the most restrictive applicable federal or provincial guidelines for environmental quality should be used as screening criteria, if such guidelines are available, because their values are intended to be protective of all or most organisms in the media to which they apply.

4.3.2 Air

Non-radiological airborne emissions considered included uranium, beryllium, particulate matter, volatile organic compounds, trace metals, hydrogen and nitrogen oxides. All airborne emissions for the consolidated operations have modelled air concentrations less than 70% of the screening criteria. Furthermore, all non-radiological substances are currently and will continue to be below CNSC licence limits, BWXT NEC Action Levels, BWXT NEC Internal Control Levels MECP Benchmarks limits, and are therefore expected to be negligible.

Therefore, no non-radiological airborne substances have been identified as COPCs for further assessment in the Eco-RA.

As per CSA N288.6-12, Clause 7.3.4.2.5, "inhalation exposures to biota are usually minor compared to soil and food ingestion pathways and can be ignored in most EcoRAs. For particulate substances released to air and accumulating over time in the soil, the steady state concentration is usually high enough that soil and food components of dose are dominant. Some gaseous substances [e.g. nitrogen oxides (NO_X)] that do not partition well to soil might need to be addressed. These substances are usually addressed relative to air concentration benchmarks, without calculating dose."

For the consolidated operations, greenhouse gases and nitrogen oxides (NO_x) will only be emitted from combustion equipment (natural gas fired boilers and hot water heater). These boilers are below the Ontario MECP threshold for negligible sources and are therefore considered insignificant.

Hydrogen will be emitted from the fuel pellet sintering furnace(s). Hydrogen is a simple asphyxiant and has a maximum environmental concentration of 3,203 µg/m3, which is well below a level of concern and is therefore screened out as insignificant.

Based on estimated uranium emissions from the consolidated operations, the maximum ground level concentration estimated is approximately 0.0013 µg/m3 and the maximum recorded environmental concentration is estimated to be no greater than 0.024 µg (U in Total Suspended Particulate (TSP))/m3. Both values are well below the MECP ambient air quality objective of 0.3 µg (U in TSP)/m3 over a 24-hour averaging period. Uranium emissions will therefore not likely to have potential effects on ecological receptors located on site.

For others non-radiological substances that could be potentially emitted from the consolidated operations, airborne concentrations predicted in BWXT NEC's ESDM (see Section 3.3) were used to screen non-radiological substances, such as Beryllium, Particulate Matter (PM), Volatile Organic Compounds (VOCs), Trace Metals, and other miscellaneous contaminants.

As discussed in Section 3.3, under the current conditions, the maximum POI concentrations modelled for contaminants expected to be emitted by the consolidated operations will be well below limits published in the MECP ACB List, and are therefore not likely to have potential effects on ecological receptors located on site.

Therefore, no non-radiological airborne substances have been identified as COPCs for further assessment.

4.4 Assessment of Physical Stressors

There is expected to be no measurable change to the natural environment that will affect road kill, bird strikes, heat, noise or artificial lighting. As such, none of these stressors will be particularly relevant to BWXT NEC and no further assessment is required.

CSA N288.6 identifies road kill, bird strikes, heat and intake cooling water (not applicable to BWXT NEC) as the physical stressors applicable to ecological receptors. Artificial night lighting and noise also have the potential to interact with receptors. The BWXT NEC Peterborough facility is located in a highly urbanized area which limits the site-specific potential for physical stressors to impact on VECs. For example, there is no cooling water intake from a natural water source. Also, there is expected to be no measurable change to the natural environment that will affect road kill, bird strikes, heat, noise or artificial lighting. As such, none of these stressors will be particularly relevant to BWXT NEC and no further assessment is required.

4.5 Risk Characterization

The estimated doses are estimated to be at or marginally above background. Potential non-radiological contaminants are estimated to be well below applicable screening criteria and pose no adverse effects to the environment.

No physical stressors to non-human biota were identified.

The screening level risk assessment takes into account emissions to and concentration in different applicable media including air and surface water and uses conservative estimates of emissions and effects criteria.

For the radiological emissions, gamma dose rates at the fence line were estimated to be at or marginally above background.

Potential non-radiological contaminants emitted to air and water as a result of the consolidated operations, were estimated to be well below applicable screening criteria and pose no adverse effects to the environment. No additional assessment is required.

There is expected to be no measurable change to the natural environment that will affect road kill, bird strikes, heat, noise or artificial lighting. As such, none of these stressors will be particularly relevant to BWXT NEC and no further assessment is required.

Therefore, the consolidated operations will pose no adverse EcoRA effects.

4.6 Uncertainty Associated with Ecological Risk Assessment

EcoRA was completed based on estimated releases derived from effluent and environmental monitoring data collected from the existing fuel bundle assembly and fuel pelleting operations independently. As previously stated, emissions from the consolidated operations are expected to be no greater than current emissions due to the installation of similar or better performing equipment for the new fuel pellet operation. Therefore, available emission data can provide reliable estimates to assess any potential ecological risks.

Uncertainty could be introduced into the risk assessment during the screening level assessment or risk characterization. This uncertainty can be minimized through the use of longer term data sets, along with the use of conservative assumptions to ensure that human health is protected. A qualitative analysis of the uncertainty associated with the EcoRA is presented below.

The EcoRA followed the process defined in N288.6 providing a level of assurance that the screening EcoRA was completed in an acceptable manner. The two key non-radiological contaminants, uranium and beryllium, have been frequently monitored in air emissions and liquid effluent on an annual basis increasing the likelihood that monitoring results are representative of actual emissions. Detection limits used are very low allowing for the detection of these contaminants in facility emissions.

For other potential non-radiological air emissions, the calculations are based on the operating conditions, including start-up and shut-down, where all significant sources are operating simultaneously at their individual maximum rates of production. The maximum emission rates for each significant contaminant emitted from the significant sources were calculated in accordance with s. 11 of O. Reg. 419/05. Therefore, these emission rates are not likely to underestimate the actual emission rates. Further, screening criteria established by the MECP for its environmental compliance approval process on the basis of scientific review and analysis were used. Conservatively, all emissions from the Peterborough complex, including non-radiological operations not related to BWXT NEC were used in the screening process. The air assessment was completed using a methodology established and a model approved by the MECP, based on criteria established by the MECP, and reviewed by the MECP through the environmental compliance approvals process. The conservatisms built into the screening process helps ensure that the conclusion of the screening assessment is valid, with a high level of confidence.

Preliminary analysis of air dispersion characteristics between the Toronto and Peterborough sites suggests that dispersion factors between the two sites differ by approximately a factor of two. This is within the range of variability in air dispersion models. As such, ambient air concentration data for the existing nuclear fuel pelleting operation are not expected to differ by more than a factor of two as well, resulting in predicted concentrations well below levels of concern. Maximum ground level predictions for uranium and hydrogen for the existing nuclear fuel pelleting operation were increased by a factor of three to conservatively account for these differences.

During the screening process, to be conservative, the maximum concentrations of uranium and beryllium and maximum monitored gamma radiation levels detected over a number of years were compared against a range of screening criteria published by reputable agencies, and, in the case of the radiation risk assessment, N288.6 recommended benchmark criteria. Further, monitoring results were well below screening criteria, providing additional confidence that the screening criteria are not exceeded. These conservatisms built into the screening process helps ensure that the conclusion of the screening assessment is valid, with a high level of confidence.

There is some uncertainty in the selection of critical human receptors, VECs and exposure pathways assumed and the relevance of selected VECs to First Nations. Additional consultation with First Nations has been initiated to obtain additional insight on VECs important to First Nations. Given the very low levels of emissions, screening was undertaken based on abiotic concentrations, minimizing any uncertainty in the selection of VEC and exposure pathways assumed.

In summary, the assessment method and the conservative assumptions used for the EcoRA ensure that the potential risks of the consolidated operations are not underestimated. Therefore, the uncertainty associated with the assessment has no impact on the conclusions of the EcoRA.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Overall, estimated emissions associated with consolidated operations at the Peterborough facility, and associated risks are determined to be low.

5.1.1 Human Health Risk Assessment

5.1.1.1 Radiological Exposure

The screening level HHRA concluded that emissions of radioactive materials from the consolidated operations will be very low, with a maximum estimated annual effective dose to the general public as a result of direct gamma radiation and air releases from operations of about 10.44 µSv/y, with 9.4 µSv attributable to direct gamma radiation, representing 1.0% of the CNSC public annual dose limit of 1,000 µSv and 5.2% of the screening annual dose criterion of 300 µSv Exposure to water releases and external gamma radiation are also estimated to be trivial. Based on the screening level risk assessment, it is concluded that estimated emissions of radiological materials resulting from BWXT NEC consolidated operations will pose no adverse effects to human health. Further assessment of the impact of radiological materials on human health is not required

5.1.1.2 Non-Radiological Exposure

The screening level HHRA concluded that emissions of non-radioactive contaminants from the facility will be below, and often substantially below, MECP POI standards based on human health and odour considerations. Exposure to water releases is also estimated to be trivial based on the concentrations and quantities released. Based on the screening level risk assessment, it is concluded that emissions of non-radiological substances resulting from BWXT NEC consolidated operations will pose no adverse effects to human health. Further assessment of the impact of non-radiological contaminants on human health is not required.

5.1.1.3 Physical Stressors

Noise is the only physical stressor requiring consideration. The screening level HHRA concluded that noise levels will be below MECP established criteria. Based on the screening level risk assessment, it is concluded that potential noise profile from BWXT NEC consolidated operations will pose no adverse effects to human health. Further assessment of the impact of non-radiological contaminants on human health is not required.

5.1.2 Ecological Risk Assessment

5.1.2.1 Radiological Exposure

The screening level EcoRA concluded that potential emissions of radioactive materials from the facility resulted in exposure to non-human well below the benchmark criteria of 400 µG/h for terrestrial biota. Based on the screening level risk assessment, it is concluded that emissions of radiological materials resulting from BWXT NEC consolidated operations will pose no adverse effects to non-human biota. Further assessment of the impact of radiological materials on non-human biota is not required.

5.1.2.2 Non-Radiological Exposure

The screening level EcoRA concluded that emissions of non-radioactive contaminants from the facility were below, and often substantially below, MECP POI standards. Exposure to water releases is also estimated to be trivial based on the concentrations and quantities released. Based on the screening level risk assessment, it is concluded that potential emissions of non-radiological substances resulting from BWXT NEC consolidated operations will pose no adverse effects to non-human biota. Further assessment of the impact of non-radiological contaminants on non-human biota is not required.

5.1.2.3 Physical Stressors

The screening level EcoRA concluded that BWXT NEC consolidated operations will pose no physical stressors on VECs. Further assessment of the impact of physical stressors on VECs is not required.

5.2 Recommendations for the Monitoring Program

Based on the results of the HHRA and EcoRA, there are no specific recommendations for changes in the effluent or environmental monitoring programs; however, as noted in the ERA, effluent and environmental monitoring programs will be updated to reflect current practices at the existing fuel pellet operations to provide a level of monitoring which has proved to be adequate and effective for that operation.

5.3 Risk Management Recommendations

Based on the results of the HHRA and EcoRA, there are no specific recommendations for changes in risk management practices.

6 QUALITY ASSURANCE / QUALITY CONTROL

A foundational document for this risk assessment is the 2009 Low Enriched Uranium Fuel Bundle Production Project. Based on a project description submitted by GEH-C to the CNSC, the CNSC determined that a screening level environmental assessment (EA) of the proposed project was required and issued environmental assessment Guidelines on August 1, 2008. These guidelines identified the scope of the assessment, the basis for carrying out the EA and the focus of the assessment on relevant issues and concerns. This process provide transparency by communicating the EA process to stakeholders.

The ERA was conducted by Arcadis Canada Inc. (Arcadis) in accordance with the requirements of Arcadis' Quality Management System. The Arcadis Quality Management System is ISO 9001 registered and the scope of the ISO 9001:2008 registration covers "environmental consulting services to the nuclear fuel cycle".

BWXT NEC collects emissions and environmental monitoring data in accordance with Peterborough EHS documents in the EHS series, including:

- EHS-P-EMS-1.0P – Environmental Management System Manual
- EHS-P-E-1.0P – Air
- EHS-P-E-2.0P – Water
- EHS-P-BMS-001P, Beryllium Safety Manual
- EHS-WI-RPM-ENV-001P – In-Stack Air Sampling
- EHS-WI-RPM-ENV-002P – Liquid Effluent Sampling
- EHS-WI-RPM-ENV-003P – Boundary Radiation Monitoring
- EHS-WI-BSM-005P, Beryllium Stack Air Sampling
- EHS-WI-BMS-008P, Beryllium Water Sampling

BWXT NEC also operates these monitoring programs in accordance with the *Licensed Activity Quality Assurance Program* documentation (BMS-### series), including BMS-BP-004; BMS-P-001 to 016; BMS-P-41 BMS-P-42; and BMS-P-057.

BWXT NEC maintains the following external registrations which promote quality assurance/quality control in its effluent and environmental monitoring programs:

- International Standards Organization (ISO) 9001:2015 *Quality management system; and*
- Canadian Standards Association (CSA) Z299.1-1985 *Quality management system;*

External registrations require both ongoing internal audits of internal practices and programs by BWXT NEC as well as external audits by registration bodies.

All data used in the risk assessment has been submitted to and reviewed by regulatory agencies, including:

- GE Hitachi Nuclear Energy Canada Inc. and BWXT NEC Annual Compliance Reports prepared in accordance with Canadian Nuclear Safety Commission's *Annual Compliance Monitoring and Operational Performance Reporting Requirements for Class 1 A & B Nuclear Facilities* and reviewed by the CNSC;
- Emission Summary and Dispersion Modelling Reports (ESDM) reviewed by the MECP Approvals Branch;
- Acoustic Audit Reports (AAR) reviewed by the MECP Approvals Branch.

Under BWXT NEC NFAO's Environmental Compliance Approval (Air) Number 0330-9HDR8, both the ESDM and AAR must be kept up to date, with annual reports submitted to the MECP.

7 REFERENCES

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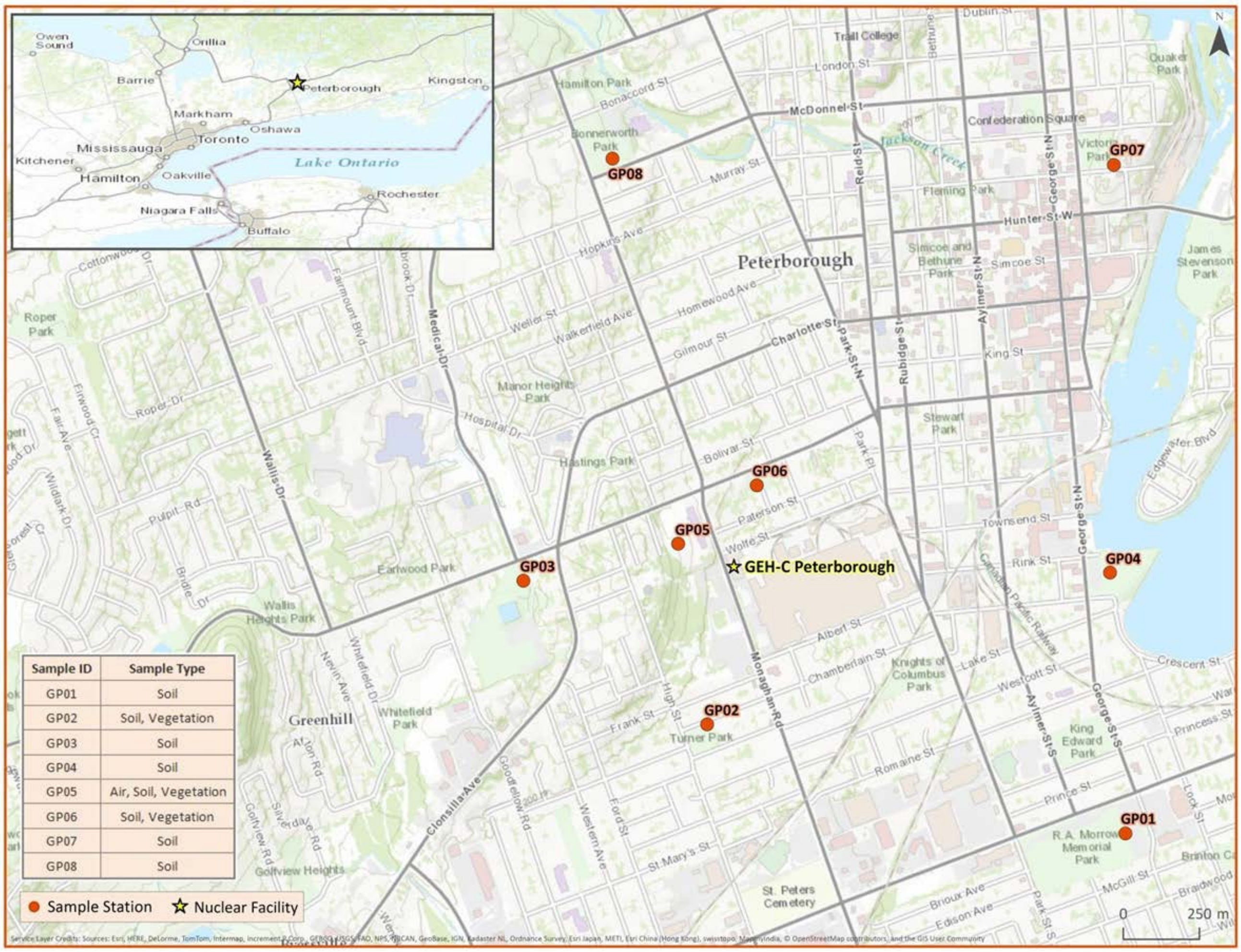
APPENDIX 7-A

BWXT NEC Peterborough CNSC IEMP

APPENDIX A – BWXT NEC PETERBOROUGH CNSC IEMP

To complement existing and ongoing compliance activities and site monitoring programs, the CNSC implemented an Independent Environmental Monitoring Program (IEMP) to verify that the public and environment around CNSC-regulated nuclear facilities are not adversely affected by releases to the environment. This verification is achieved through independent sampling and analysis by the CNSC. This program applies to the BWXT NEC Peterborough site. In 2014, samples were collected in publicly accessible areas beyond the BWXT NEC Peterborough site perimeter and included soil, air and wild vegetation. IEMP sampling was conducted at the locations shown in Figure A.1. The sampling program focused on uranium, which is a nuclear substance because it decays at a slow rate by emitting alpha radiation and beryllium, which is used as part of the fuel bundle manufacturing process.

Figure A.1 – CNSC IEMP 2014 Environmental Sampling Locations



Source (CNSC e-Doc 4823854, October 2016)

CNSC IEMP Radiological Emissions

The CNSC IEMP completed limited sampling of environmental air, vegetation and soil quality around the facility in 2014. The concentrations of uranium and beryllium in vegetation (grass) samples were below the laboratory method detection limit (<0.1 mg/kg dry weight) (CNSC 2016).

Air

THE IEMP collected one sample each of uranium and beryllium in air at the location shown in Figure A.1. The measured airborne uranium concentration was 0.0013 µg/m^3 (CNSC 2016) and was well below the MECP ambient air quality objective of 0.03 µg (U in PM10)/m^3 over a 24-hour averaging period (ACB list) corresponding to the sample collection period. The measured airborne beryllium concentration was 0.000077 µg/m^3 (CNSC 2016) and was well below the MECP 24-hour ambient air quality objective of 0.01 µg/m^3 based on health considerations (ACB list).

Soil

Airborne UO2 emissions must impinge on the ground surface downstream of the release point. Depositions of uranium can be measured by taking small samples of surface soil and analyzing for U-nat. UO2 is insoluble in water but may be washed into the soil by rainfall, snow etc. Surface uranium levels will indicate deposited emissions. If soil analysis indicates rising natural uranium levels, emissions have increased and investigation must be made into the cause(s).

Under the CNSC's IEMP soil samples were collected in 2014 in publicly accessible areas outside the BWXT NEC Peterborough site perimeter fence. Uranium in soil concentrations measured ranged from 2.6 to 4.7 µg/g dry weight while beryllium in soil concentrations measured ranged from 0.7 to 1.1 µg/g dry weight at eight locations.

IEMP uranium in soil samples results were marginally higher than the Ontario background levels which is generally below 2.5 µg/g but were well below the CCME guidelines of 23 µg/g dry weight for parkland and residential uses. IEMP beryllium in soil samples results were marginally higher than the Canadian background average level in soil of 0.75 µg/g (arithmetic mean, SD=0.99, n=9876, range=0.25 to16 µg/g) (CCME 2015) but were well below the CCME guidelines of 4 µg/g dry weight for parkland and residential uses.

Vegetation

The concentrations of uranium and beryllium in vegetation samples were below the laboratory method detection limit.

Conclusions

The CNSC concluded that "The concentrations of uranium and beryllium in air and soil samples were below available guidelines. The concentrations of uranium and beryllium in vegetation samples were below the laboratory method detection limit. No health or environmental effects are expected at these levels." (CNSC, 2016).

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