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ONTARIO POWER GENERATION

Report

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Predictive Effects Assessment for Pickering Nuclear Safe Storage – 2022 Addendum Report

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PREDICTIVE EFFECTS ASSESSMENT FOR PICKERING NUCLEAR SAFE STORAGE – 2022 ADDENDUM REPORT

P-REP-07701-00006 R001

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PREDICTIVE EFFECTS ASSESSMENT FOR PICKERING NUCLEAR SAFE STORAGE – 2022 ADDENDUM REPORT

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Revision Number	Date	Comments
R0	10-May-2022	Initial issue of report.
R1	31-Mar-2023	Revision of report to address the following: • To reflect OPG's plan to pursue continued operation of Pickering Nuclear Generating Station until 2026. • Changes made to address regulatory comments on the PEA.

LAND ACKNOWLEDGMENT

The lands and waters on which the Pickering Nuclear Generating Station (PNGS) is situated are the treaty and traditional territory of the Michi Saagiig and Chippewa Nations, collectively known as the Williams Treaties First Nations.

PNGS is within the territory of the Gunshot Treaty and the Williams Treaties of 1923. The Gunshot Treaty Rights were reaffirmed in 2018 in a settlement with Canada and the Province of Ontario.

OPG respectfully acknowledges that the Williams Treaties First Nations are the stewards and caretakers of these lands and the waters that touch them, and that they continue to maintain this responsibility to ensure their health and integrity for generations to come.

As a company, OPG remains committed to developing positive and mutually beneficial relationships with the Williams Treaties First Nations.

ALDERVILLE FIRST NATION
BEAUSOLEIL FIRST NATION
CURVE LAKE FIRST NATION
GEORGINA ISLAND FIRST NATION
HIAWATHA FIRST NATION
SCUGOG ISLAND FIRST NATION
RAMA FIRST NATION

LIST OF ACRONYMS AND SYMBOLS

ACRONYMS

ADCP	Acoustic Doppler Current Profiler
AIFB	Auxiliary Irradiated Fuel Bay
BAF	Bioaccumulation Factor
BMF	Biomagnification Factor
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CAAQS	Canadian Ambient Air Quality Standards
CANDU	CANada Deuterium Uranium
CCME	Canadian Council of Ministers of the Environment
CCW	Condenser Cooling Water
CNSC	Canadian Nuclear Safety Commission
COPC	Contaminant of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSA	Canadian Standards Association
CSM	Conceptual Site Model
DC	Dose Coefficient
DFO	Fisheries and Oceans Canada
DN	Darlington Nuclear
DRL	Derived Release Limit
DSC	Dry Storage Container
ECA	Environmental Compliance Approval
ECCC	Environment and Climate Change Canada
EcoRA	Ecological Risk Assessment
EMP	Environmental Monitoring Program
ERA	Environmental Risk Assessment
ESA	Endangered Species Act
ESDM	Emission Summary and Dispersion Modelling
FDS	Fish Diversion System
GCM	General Circulation Models
GWMP	Groundwater Monitoring Program
GWPP	Groundwater Protection Program
HC	Health Canada
HHRA	Human Health Risk Assessment
HPECI	High Pressure Emergency Coolant Injection
HTO	Tritium Oxide
IAD	Inactive Drainage
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IFB	Irradiated Fuel Bay
IJC	International Joint Commission

IPCC	Intergovernmental Panel on Climate Change
MECP	Ministry of Environment, Conservation and Parks
MISA	Municipal Industrial Strategy for Abatement
NCRP	National Council on Radiation Protection and Measurement
NOAA	National Oceanic and Atmospheric Administration
NSCA	Nuclear Safety and Control Act
NWTP	New Water Treatment Plant
OBT	Organically Bound Tritium
OF	Occupancy Factor
OPG	Ontario Power Generation
PEA	Predictive Effects Assessment
PHC	Petroleum Hydrocarbons
PN	Pickering Nuclear
PNGS	Pickering Nuclear Generating Station
PNIC	Pickering Nuclear Information Centre
POI	Point of Impingement
PWMF	Pickering Waste Management Facility
QA	Quality Assurance
RAB	Reactor Auxiliary Bay
RB	Reactor Building
RBE	Relative Biological Effectiveness
RBSW	Reactor Building Service Water
RCM	Regional Climate Models
RCP	Representative Concentration Pathways
RLWMS	Radioactive Liquid Waste Management System
SAR	Species at Risk
SW	Service Wing
TAB	Turbine Auxiliary Bay
TF	Transfer Factor
TMB	Training and Mock-Up Building
TRV	Toxicity Reference Value
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
U.S. EPA	United States Environmental Protection Agency
VBRS	Vacuum Building Reactor Sump
VEC	Valued Ecosystem Component

SYMBOLS

Environmental Partitioning Parameters

$C_{s(fw)}$	=	concentration in sediment (Bq/kg fw)
C_w	=	concentration in water (Bq/L)
K_d	=	distribution Coefficient (L/kg solid)

Ecological Radiological Dose Parameters

C_s	=	sediment concentration (Bq/kg fw)
C_t	=	whole body tissue concentration (Bq/kg fw)
C_w	=	water concentration (Bq/L)
D_{ext}	=	external radiation dose (µGy/d)
D_{int}	=	internal radiation dose (µGy/d)
DC_{ext}	=	external dose coefficient ((µGy/d)/(Bq/kg))
$DC_{ext,s}$	=	external dose coefficient (in sediment) ((µGy/d)/(Bq/kg))
$DC_{ext,ss}$	=	external dose coefficient (on sediment surface) (µGy/d)/(Bq/kg))
DC_{int}	=	internal dose conversion factor ((µGy/d)/(Bq/kg))
OF_s	=	occupancy factor in sediment (unitless)
OF_{ss}	=	occupancy factor at sediment surface (unitless)
OF_w	=	occupancy factor in water (unitless)
OF_{ws}	=	occupancy factor at water surface (unitless)

Ecological Tissue Concentration Parameters

BAF	=	bioaccumulation factor (L/kg or kg/kg)
BMF	=	biomagnification factor (unitless)
C_f	=	average concentration in food (Bq/kg fw)
C_m	=	water concentration (Bq/L)
C_t	=	whole body tissue concentration (Bq/kg fw)
C_x	=	concentration in the ingested item 'x' (Bq/kg fw)
I_x	=	ingestion rate of item 'x' (kg fw/d)
TF	=	ingestion transfer factor (d/kg)

Specific Activity Model for Tritium Parameters

$1\text{-}DW_a$	=	water content of the animal (L water /kg-fw)
$1\text{-}DW_p$	=	water content of the plant (L water /kg-fw plant)
BAF_{a_HTO}	=	bioaccumulation factor for tritium oxide (animals)
BAF_{p_HTO}	=	bioaccumulation factor for tritium oxide (plants)
DW_a	=	dry/fresh weight ratio for animal tissue (L water/kg-fw)
DW_{aa}	=	dry weight of aquatic animal tissue per total fresh weight (kg dw/kg fw)
DW_{ap}	=	dry weight of aquatic plant per total fresh weight (kg dw/kg fw)
DW_p	=	dry/fresh weight ratio for the plant/food (L water/kg-fw plant)
F_{OBT}	=	fraction of total tritium in the animal tissue in the form of OBT as a result of HTO ingestion
F'_{OBT}	=	OBT/HTO ratio in the animal as a result of HTO ingestion (unitless)
$f_{w\text{-}dw}$	=	fraction of the animal water intake that results from the metabolic decomposition of the organic matter in food
$f_{w\text{-}pw}$	=	fraction of the animal water intake derived from water in plant/food

f_{w-w} = fraction of the animal water intake derived from direct ingestion of water
ID_{aa} = isotopic discrimination factor for aquatic animal metabolism (unitless)
ID_{ap} = isotopic discrimination factor for aquatic plant metabolism (unitless)
K_{af} = fraction of food from contaminated sources
K_{aw} = fraction of water from contaminated sources
$P_{HTOfood\_animal}$ = transfer of HTO to animals through food ingestion (unitless)
$P_{HTOwater\_animal}$ = transfer of HTO to animals through water ingestion (L/kg-fw)
$P_{OBTfood\_animal}$ = transfer of OBT to animals through food ingestion (unitless)
$P_{OBTwater\_animal}$ = transfer of OBT to animals through water ingestion (L/kg-fw)
WE_a = water equivalent of the animal tissue dry matter (L water/kg dw product)
WE_{aa} = water equivalent of the aquatic animal dry matter (L/kg dw)
WE_{ap} = water equivalent of the aquatic plant dry matter (L/kg dw)
WE_p = water equivalent of the plant/food dry matter (L water/kg dw product)

Specific Activity Model for Carbon-14 Parameters

BAF_{C14} = bioaccumulation factor for carbon-14 (aquatic animals)
S_a = stable carbon content in the aquatic animal/invertebrate/plant (gC/kg-fw)
S_w = mass of stable carbon in the dissolved inorganic phase in water (gC/L)

EXECUTIVE SUMMARY

The Pickering Nuclear (PN) site, located in the City of Pickering on the north shore of Lake Ontario, is comprised of the PN Generating Station (PNGS) and the Pickering Waste Management Facility (PWMF). The PNGS is comprised of six operating CANada Deuterium Uranium (CANDU) reactors and two units (Units 2 and 3) in safe storage. Ontario Power Generation (OPG) plans to pursue continued operation of PNGS until 2026, with Unit 1 shut down by September 2024, Unit 4 by December 2024, and Units 5 to 8 by December 2026. The shut-down activities at PNGS will involve four distinct phases:

(1) A 2- to 3-year **Stabilization Phase** for each of the six operating units and the station as a whole, from current operating states to their respective safe storage states. Stabilization activities will include defueling and dewatering reactor units.

(2) A 25- to 30-year **Storage with Surveillance Phase** to allow for natural decay of radioactivity. Activities during this phase include the ongoing operation of the Irradiated Fuel Bays (IFBs) and the continued transfer of spent fuel to dry storage containers (DSCs). Current planning anticipates that used fuel transfer to DSCs will be completed within 6-10 years of the last unit transitioning to its safe storage state. Monitoring the natural decay of radioactivity within the remaining reactor systems will continue to approximately 2050.

(3) A 10-year Staged **Dismantling and Demolition Phase** to remove on-site structures and package wastes for long-term management.

(4) A 5-year **Restoration Phase** to allow lands to be released and repurposed for alternative uses. At the end of this phase, the PN Generating Station would be released from regulatory control.

A predictive effects assessment (PEA) for PN Safe Storage was completed in 2017 (Golder and Ecometrix, 2017) to identify changes from the baseline environmental and human health conditions resulting from the activities associated with shut-down activities during Stabilization Phase and the Storage with Surveillance Phase. The first ten years of the Storage with Surveillance Phase was assessed in detail and was considered to bound the remainder of the Storage with Surveillance Phase. The baseline conditions were characterized in an Environmental Risk Assessment (ERA) in 2017, which has been updated in 2022 (Ecometrix, 2023). These reports were completed to support the licensing process. The conclusion of the 2017 PEA was that, based on the assessment, there were no predicted potential adverse effects to humans nor to ecological receptors from the activities proposed to take place during the Stabilization and Storage with Surveillance Phases.

Objectives and Methodology of the PEA Addendum Report

To support the mid-term operating licence review that is expected to occur in 2023, this PEA Addendum Report is prepared to document/demonstrate that human health and the environment will continue to be protected during shutdown, based on updated baseline environmental conditions and current operational assumptions for the Stabilization and Storage with Surveillance Phases. The 2017 PEA assumed continued operations of PNGS until 2024; whereas in this PEA Addendum Report continued operations of PNGS is assumed until 2026. This change is reflected in the timeline of activities described in the report.

This PEA Addendum report focuses on identifying and documenting changes to previous assumptions in order to evaluate whether those changes could have an impact on the previously established bounding conditions, and was prepared following the guidance of Canadian Standards Association (CSA) N288.6-12, *Environmental Risk Assessment at Class I Nuclear Facilities and Uranium Mines and Mills* (CSA, 2012) and Version 1.1 of REGDOC 2.9.1 (CNSC, 2017).

The general approach to this PEA Addendum includes the following key steps:

(1) Review of the existing and future conditions, including:

   a. Changes to baseline conditions to determine whether the 2017 PEA remains bounding for current conditions.
   b. Revised assumptions and plans for the Stabilization and Storage with Surveillance Phases that could result in a change or an increase in interaction with the environment. Changes that would result in a decrease in interaction with the environment (e.g., reduced emissions) are not discussed further since the change would be bounded by the 2017 assessment.
   c. Current and predicted future conditions of the Lake Ontario receiving environment to consider whether any changes would affect the outcome of the surface water models supporting the 2017 PEA.

   Updated assumptions that represent changes that are not encompassed by the 2017 PEA are carried forward for re-evaluation in the Tier 1 screening assessment.

(2) Update the Tier 1 Assessment. In this PEA update, revised assumptions are evaluated to determine if the changes would result in conditions no longer encompassed by the bounding case established in the 2017 PEA. For any conditions not bounded by the 2017 PEA, updated exposure concentrations are developed and used to screen against criteria or benchmarks protective of human health and the environment. As in the 2017 PEA, any revised environmental conditions which exceeded screening values, as well as contaminants of potential concern considered to be of public interest (i.e., radionuclides), are carried forward to the Tier 2 Assessment.

(3) Update the Tier 2 Assessment. An updated Tier 2 Assessment is completed for future environmental interactions that are not bounded by the 2017 PEA.

(4) Based on the results of the updated Tier 1 and Tier 2 Assessments, update the recommendations for future monitoring and/or mitigation of environmental and health effects.

Results / Conclusions of the Updated Assessments

The 2017 PEA evaluated the potential environmental interactions resulting from proposed activities occurring during the Stabilization and Storage with Surveillance Phases. The environmental components considered relevant to the evaluation in 2017, which are also considered in the 2022 PEA Addendum Report, included atmospheric (including air and noise), surface water flow and quality (including thermal effects and impingement & entrainment effects), sediment quality and transport, groundwater, and soil quality.

The results of the updated Tier 1 and 2 assessments conclude that no potential adverse effects are predicted from the updated assumptions which have been evaluated in this 2022 PEA Addendum report.

The Tier 1 Assessment concludes that the assessment of human health at potential critical group locations, and ecological health in the outfall and at Frenchman's Bay are bounded by the 2017 PEA and no further quantitative assessment is warranted in the 2022 PEA update. Dose to human receptors during the Stabilization Phase is bounded by the operational dose presented in the ERA. The Tier 2 Assessment focuses on an updated assessment of potential ecological risks in the forebay during the Storage with Surveillance Phase.

As a result of the reduced flows into the station and the assumed removal of the Fish Diversion System (FDS) during the Storage with Surveillance Phase with DFO's prior approval, the assessment of the forebay as potential habitat is updated in the Tier 2 assessment. The constituents of potential concern in the evaluation include tritium, carbon-14, cobalt-60, cesium-134, and cesium-137. The predictive ecological risk assessment concludes that there are no potential adverse effects since all predicted doses to ecological receptors in the forebay during the Storage with Surveillance Phase are below the aquatic benchmark of 9.6 mGy/d and the terrestrial benchmark of 2.4 mGy/d.

Potential entrainment and impingement effects are re-assessed in the Tier 2 assessment due to the current plan for a higher flow rate of 250,500 m^3/day through the PN U5-8 intake compared to the 2017 PEA assumption of 50,000 m^3/day during the Storage with Surveillance Phase, along with the assumed removal of the FDS with prior approval from DFO. This flow of 250,500 m^3/day translates to a maximum velocity of 11.5 mm/s. This maximum velocity remains less than the mean swim speed of pertinent local fish species considered in the PEA, which range from 221 mm/s for Northern Pike to 3,612 mm/s for White Sucker; therefore, impingement rates will decrease because of the significant reduction in flow volume into the station. The proposed flow during the Storage with Surveillance Phase when cooling requirements are reduced will be

2.9 m^3/s, which is less than the flow of 5.5 m^3/s identified as the volume of flow where entrainment may be of concern (US EPA, 2014). Therefore, entrainment remains negligible.

Recommendations

Based on the conclusions of the 2022 PEA Addendum, no additional risk management recommendations are identified. Continuation of implementation, periodic review, and update of environmental monitoring programs, will ensure the continued protection of human health and the environment.

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1.0 Introduction

The Pickering Nuclear (PN) site is located in the City of Pickering on the north shore of Lake Ontario at Moore Point, about 32 km east of downtown Toronto and 21 km west of Oshawa. The PN site is comprised of the PN Generating Station (PNGS), with six operating CANada Deuterium Uranium (CANDU) pressurized heavy water reactors, and two units in safe storage. The Pickering Waste Management Facility (PWMF) is also located on the PN site and is comprised of two sites. The PWMF Phase I site is located southeast of PN Unit 8, adjacent to the east side of the station security fence, and the PWMF Phase II site is located approximately 500 m north-east of the power generating facilities in the East Complex, with its own distinct "protected area".

Ontario Power Generation (OPG) plans to pursue continued operation of PNGS to 2026 (OPG, 2022). A licence extension application will be submitted for the plan to shut down the remaining six PN reactor units beginning September 2024 with Unit 1, December 2024 with Unit 4, and by December 2026 for Units 5-8. Following shutdown, activities at PNGS would involve four distinct phases (Figure 1.1):

(1) A 2- to 3-year **Stabilization Phase** per unit and the station as a whole, from current operating states to their respective safe storage states. Stabilization activities will include defueling and dewatering reactor units. PN U2 and U3 have been in a safe storage state since 2010 and are not included in this phase.

(2) A 25- to 30-year **Storage with Surveillance Phase** to allow for natural decay of radioactivity. Activities during this phase include the ongoing operation of the Irradiated Fuel Bays (IFBs) and the continued transfer of spent fuel to dry storage containers (DSCs). Current planning anticipates that used fuel transfer to DSCs will be completed within 6-10 years of the last unit transitioning to its safe storage state. Monitoring the natural decay of radioactivity within the remaining reactor systems will continue to approximately 2050.

(3) A 10-year **Staged Dismantling and Demolition Phase** to remove on-site structures and package wastes for long-term management.

(4) A 5-year **Restoration Phase** to allow lands to be released and repurposed for alternative uses. At the end of this phase, the PN Generating Station would be released from regulatory control.

A predictive effects assessment (PEA) for PN Safe Storage, consistent with CSA N288.6-12, was completed in 2017 to identify changes from the baseline environmental and human health conditions resulting from the activities associated with the Stabilization Phase and the Storage with Surveillance Phase. The first ten years of the Storage with Surveillance Phase (i.e., up to 2039) was assessed in detail and was considered to bound the remainder of the Storage with Surveillance Phase. After the first ten years of the Storage with Surveillance Phase it is assumed all the used fuel will have been transferred from the IFBs to dry storage containers (DSCs) in the PWMF (i.e.., Safe Storage dry phase). The baseline conditions were characterized in the 2017 Environmental Risk Assessment (ERA) (Ecometrix and Golder, 2018), and the ERA was updated in 2022 (Ecometrix, 2023).

To support the mid-term operating licence review that is expected to occur in 2023, this PEA Addendum report was prepared to document/demonstrate that human health and the environment will continue to be protected during shutdown, based on updated baseline environmental conditions and current operational assumptions for the Stabilization and Storage with Surveillance Phases.

The dates presented within Figure 1.1 are conceptual and are used to illustrate the chronology of the main activities associated with the shutdown of PNGS. The assumptions considered in the PEA Addendum report are specific to activities which are expected to occur during the phases considered (i.e., Stabilization Phase and Storage with Surveillance Phase) and are generally independent of exact timelines unless otherwise noted within the assessment. The 2017 PEA assumed continued operations of PNGS until 2024; whereas current planning in this PEA Addendum Report assumes continued operations of PNGS until 2026. This update is reflected in the timeline of activities presented within Figure 1.1.

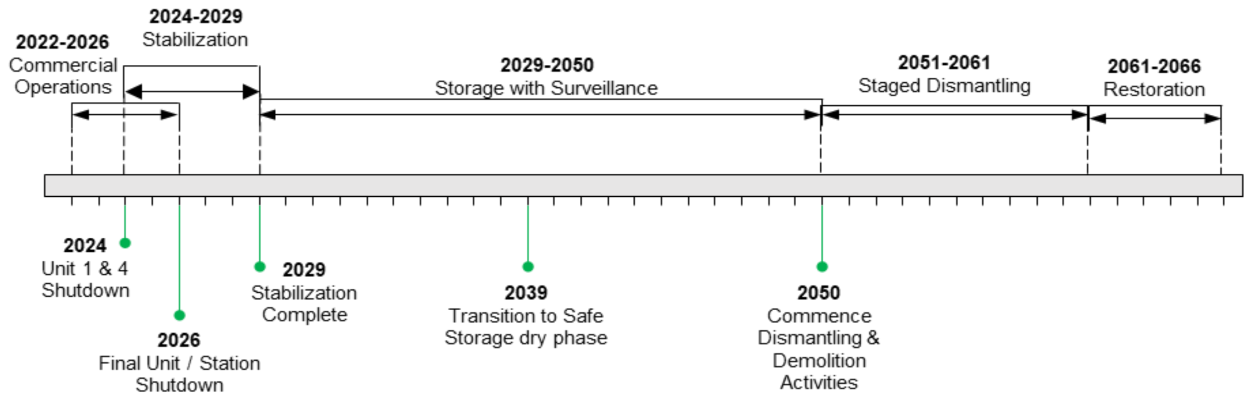


Figure 1.1: Conceptual Timeline for the Continued Operation and Shutdown Phases of PNGS

1.1 Project Overview

The Stabilization of the remaining six Pickering Nuclear reactor units will be conducted in a stepwise manner, transitioning them from their current operating states to their respective safe storage states. Some of the specific details of the Stabilization Phase activities are not yet finalized; however, assumptions were made to provide for a conservative (i.e., worst case) assessment of effects resulting from the transition and safe storage state.

The main elements of the Stabilization and Storage with Surveillance Phases presented in the 2017 PEA have not changed and are listed below.

- Removal of all nuclear fuel from the reactor units and transfer of the fuel to an Irradiated Fuel Bay (IFB) for approximately up to 10 years of cooling. Continued operation/surveillance of the IFBs and Auxiliary Irradiated Fuel Bay (AIFB) are required until all irradiated fuel is transferred into DSCs for safe interim storage at the PWMF.

- Draining and storage of approximately 3,000 Mg of heavy water. The heavy water will be stored at PNGS and the PN Generating Station inventory will provide supplies to other facilities as required. Periodic transfer of heavy water within the PN Site, as well as off-site, will be undertaken as needed.

- Stabilization of all other systems that are no longer required and can be safely removed from service. Stabilization includes removal of chemicals no longer required (i.e., boiler treatment and reactor control chemicals), as well as removal of transient substances (e.g., gases, liquids, oil, filters, refrigerants, resins, etc.) for collection, recycling and/or disposal through approved pathways.

- Management of waterborne emissions will continue in compliance with regulatory limits through the radioactive liquid waste management system (RLWMS) and inactive drainage systems.

- Operation and maintenance of the support systems required for the Stabilization and Storage with Surveillance activities within the PN Generating Station include heating, lighting, security, ventilation, and fire protection. This will also include operation of an alternative building heating system or source during the winter months to replace the steam heat no longer being produced by the operating units.

- Shut down of the condenser cooling water (CCW) pumps. For the purposes of the PEA, it is assumed that limited amounts of water will continue to be taken in from Lake Ontario to meet the safety and operational needs of the PN Generating Station in the Stabilization and Storage with Surveillance Phases. This consists mainly of IFB cooling.

- Maintenance and monitoring of all buildings in a safe and secure state. Temporary buildings (e.g., mobile office and storage trailers) may be removed from the PN Generating Station site. Demolition is not proposed within the protected area (i.e., the area immediately surrounding the reactor buildings and support services) as part of the Stabilization and Storage with Surveillance activities. Some buildings may be removed from the areas surrounding the protected area (i.e., the East Complex). Remaining structures, buildings and systems will be monitored and maintained in a safe state. Other PN Generating Station site features (e.g., parking areas) will be maintained as an industrial landscape in a state that will prevent the areas from becoming naturalized.

- Maintenance of environmental monitoring and protection programs and activities in accordance with the requirements specified in the licence(s) by the Canadian Nuclear Safety Commission (CNSC) and in accordance with appropriate regulations and standards.

1.2 Regulatory Context

The *Nuclear Safety and Control Act* (NSCA) mandates the CNSC to regulate the nuclear industry in a manner that prevents unreasonable risk to the environment and makes adequate provision for environmental protection, in conformity with international obligations. This mandate is reflected in the General Nuclear Safety and Control Regulations under the NSCA, and in the CNSC Regulatory Document REGDOC 2.9.1 "Environmental Protection: Environmental Principles, Assessments and Protection Measures, Version 1.2" (CNSC, 2020). OPG is required to follow Version 1.1 of REGDOC 2.9.1 under their current PNGS Nuclear Power Reactor Operating Licence (LCH-PR-48.00/2028-R004), effective April 27, 2021. Versions 1.1 and 1.2 do not differ in the stated requirements pertaining to environmental protection measures.

REGDOC 2.9.1 outlines the CNSC's environmental protection framework, including the environmental protection measures a licensee would take for a given project or licence application. The Stabilization and Storage with Surveillance Phases of the PN reactor unit shut down is not a designated project under the *Canadian Environmental Assessment Act* (2012) nor the *Impact Assessment Act* (2019). However, the Project does have potential for interactions with the environment, which requires the CNSC to conduct an Environmental Protection Review under the NSCA. The PEA is part of the supporting technical documentation submitted to the CNSC, which will form the basis of the CNSC's Environmental Protection Review.

The 2017 PEA and this PEA Addendum for the Stabilization and Storage with Surveillance Phases have been prepared following the guidance of Canadian Standards Association (CSA) N288.6-12, *Environmental Risk Assessment at Class I Nuclear Facilities and Uranium Mines and Mills* (CSA, 2012) and Version 1.1 of REGDOC 2.9.1 (CNSC, 2017). The 2017 PEA and PEA Addendum predict the potential adverse effects to human health and the environment from the activities taking place during the Stabilization and Storage with Surveillance Phases.

The most recent ERA for PN (i.e., the 2022 PN ERA) (Ecometrix, 2023) was completed in accordance with CSA N288.6-12 (CSA, 2012) and REGDOC 2.9.1 Version 1.1. It assesses the baseline existing conditions at the PN site focused on the five-year period from 2016 to 2020 but incorporates other years of data when necessary. The scope looked at the potential effects of nuclear and hazardous substances released from the facility on the human and ecological environment, as well as potential effects from physical stressors. The 2022 PN ERA forms the basis of the PEA and should be consulted for detailed information on current operational conditions on the PN Site.

1.3 Summary of the 2017 Predictive Effects Assessment

1.3.1 Objectives and Scope of the 2017 PEA

The main goal for the 2017 PEA was to characterize and illustrate how the environment and human health will continue to be protected during the Stabilization and Storage with Surveillance Phases. Specifically, the objectives of the 2017 PEA were to:

- Identify changes from the current operational state to the Safe Storage state and to assess which changes result in changed environmental emissions or effects in the Stabilization or Storage with Surveillance Phases;
- Evaluate the risk to human and ecological receptors based on the future scenarios;
- Identify the specific objectives for environmental monitoring; and
- Provide supporting documentation for the licensing of future Stabilization and Storage with Surveillance activities of PN.

Since many of the changes to the environment during the Stabilization and Storage with Surveillance Phases are expected to reduce any existing effects on the environment that are associated with PNGS in its operating state, the 2017 PEA was focused on pathways that may introduce new or modified effects on the environment.

The 2017 PEA used the same spatial boundaries defined in the 2017 PN ERA (Ecometrix and Golder, 2018) to identify applicable human and ecological receptors for assessment. For the assessment of human health, receptors within 20 km of PNGS were considered. Human receptors were represented by the six potential critical groups defined in OPG's Environmental Monitoring Program (EMP) (OPG, 2021a), with the addition of a future industrial/commercial worker located outside PN operations but within the existing PN site boundary. The human receptors considered in the 2017 PEA are shown on Figure 1.3. For the ecological risk assessment, valued ecosystem components (VECs) were identified on-site and within the immediate PNGS boundary which included the area within the 914-m exclusion zone and the near-field receiving waters, including Frenchman's Bay, as shown on Figure 1.2 and Figure 1.4. The same spatial boundaries have been adopted for the 2022 PN ERA and for this PEA Addendum.

The 2017 PEA did not include the operations at the PWMF as it operates separately under the Waste Facility Operating Licence issued by the CNSC. The 2017 PEA report did discuss the waste operation to the extent there are inter-relationships with the Stabilization and Storage with Surveillance activities.

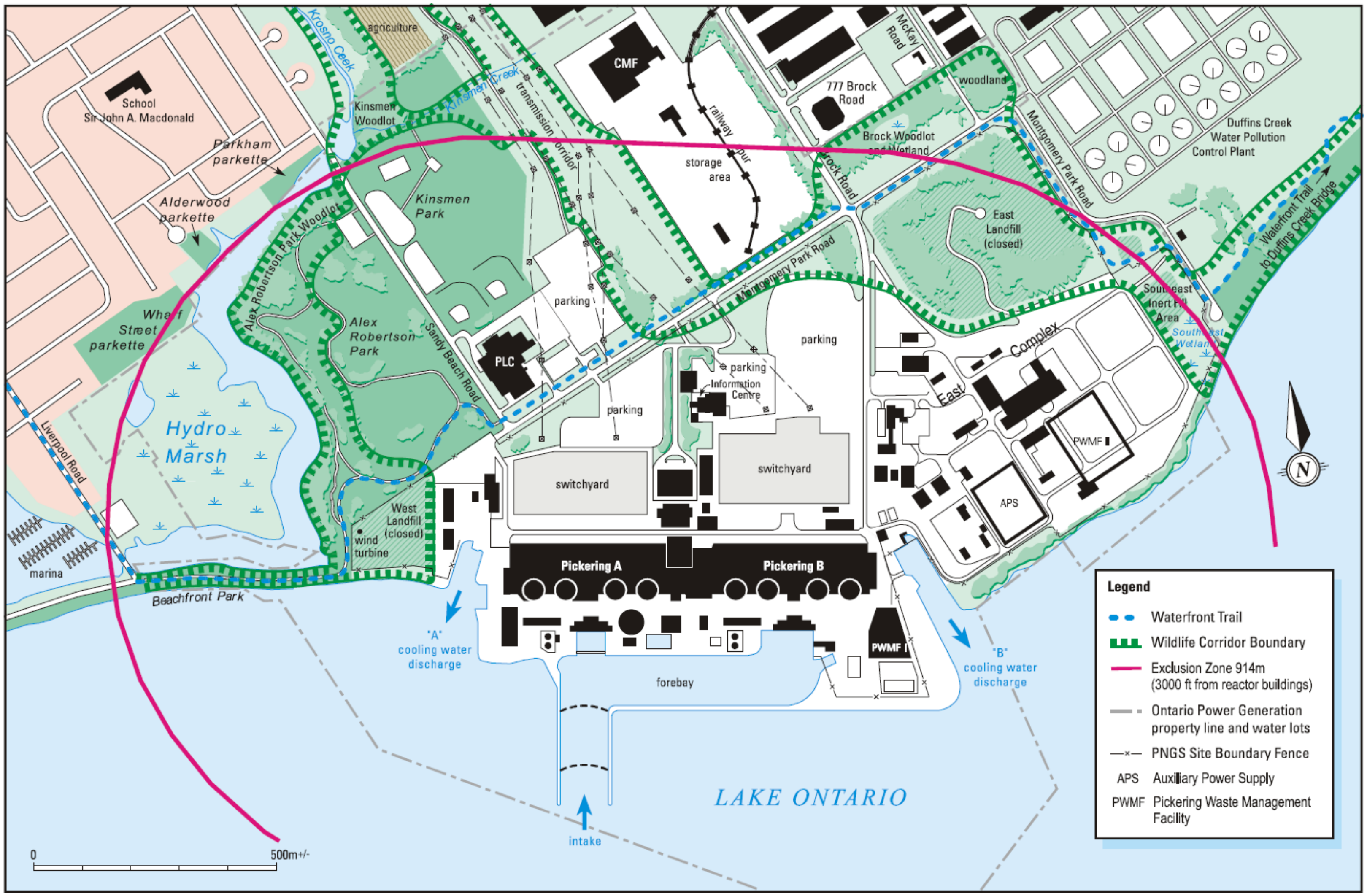


Figure 1.2: Conceptual Layout of PNGS (Golder and Ecometrix, 2017)

Figure 1.3: Human Receptor Locations Assessed in the 2017 Predictive Human Health Risk Assessment

Figure 1.4: Area of Assessment for the 2017 Predictive Ecological Risk Assessment (Golder and Ecometrix, 2017)

1.3.2 Methodology of 2017 PEA

The 2017 PEA followed the ERA approach based on guidance from CSA N288.6-12. CSA N288.6-12 does not provide detailed guidance on predictive effects assessment scenarios; therefore, the ERA approach was modified. Figure 1.5 provides a schematic outline of the PEA approach that was undertaken in 2017 and has also continued to be adopted to perform updated assessments presented in this PEA Addendum report.

Existing conditions, including descriptions of existing PN facilities, were described in the PN ERA, using data available over the 2011 to 2015 period (Ecometrix and Golder, 2018). Future conditions and operations during the Stabilization and Storage with Surveillance Phases were described in detail in Section 3 of the 2017 PEA. These assumptions were used to develop two tiers of assessment:

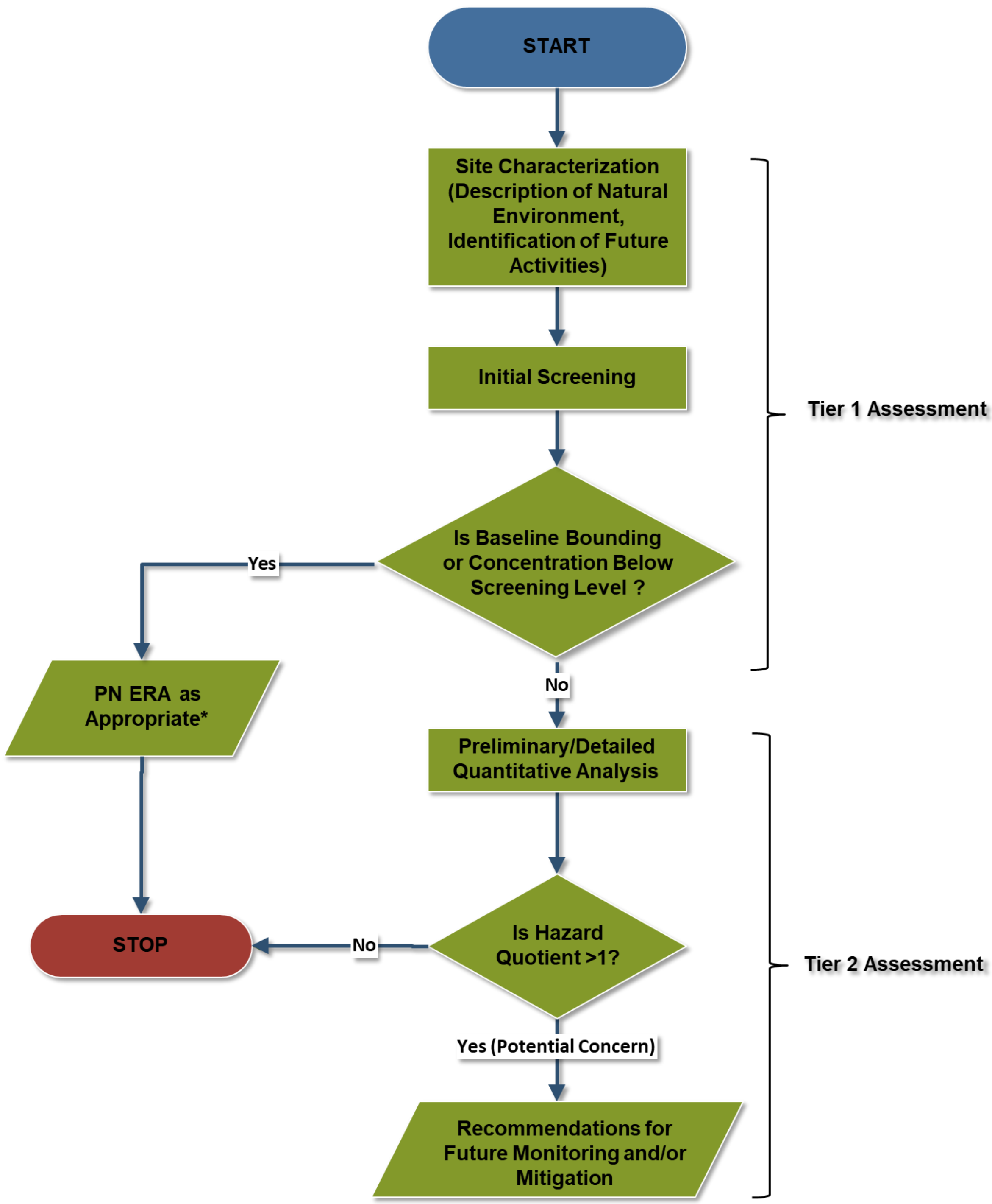
- An initial screening (Tier 1 Assessment); and
- A preliminary/detailed quantitative analysis (Tier 2 Assessment).

The Tier 1 Assessment included an evaluation of potential interactions of Stabilization and Storage with Surveillance activities with the environment to identify the receptors, exposure pathways, contaminants of potential concern, and physical stressors that may warrant further assessment. Each interaction was evaluated as having decreased, increased, or no/negligible change to the environment compared with current operational conditions, if applicable.

Where interactions were likely to result in decreased or no/negligible changes to the environment compared with current conditions, these interactions were not considered further in the PEA, as they were considered to be bounded by the assessment described in the PN ERA (Ecometrix and Golder, 2018). Where interactions were likely to result in increased changes to the environment, the potential change to current conditions was further described and evaluated to determine if Tier 2 evaluation was needed. Predicted environmental conditions which exceeded screening values, as well as contaminants of concern considered to be of public interest (i.e., radionuclides) were carried forward to the Tier 2 Assessment.

The Tier 2 Assessment included a human health and ecological risk assessment conducted in accordance with CSA N288.6-12 and focused only on elements carried forward from the Tier 1 Assessment.

Based on the findings of the Tier 1 and Tier 2 Assessments, recommendations were presented describing any revisions to the monitoring program or risk management needed to accommodate the future environmental conditions.



* Where the baseline condition is bounding, the scope within the PN ERA which represents the bounding condition is used and a Tier 2 Assessment is not needed in the PEA.

Figure 1.5: Predictive Effects Assessment Methodology Illustration (Golder and Ecometrix, 2018)

1.3.3 Results of 2017 Tier 1 Assessment

Section 4 of the 2017 PEA presented the results of the Tier 1 initial screening assessment. The evaluations included consideration of noise, air quality, surface water flow, surface water quality, sediment quality and transport, groundwater, and soil quality. At the time of the 2017 PEA, operational conditions for noise, sediment quality and transport, groundwater, and soil quality were considered bounding in both the Stabilization and Storage with Surveillance Phases. Additional results of the Tier 1 Assessment were as follows:

- Air Quality – At the time of the 2017 PEA, operational conditions were considered bounding for radiological and non-radiological emissions with two exceptions. In the Stabilization Phase, two heating steam boilers were expected to be operating, instead of one during operational conditions. The additional emissions associated with the extra boiler was screened out. In the Storage with Surveillance Phase, it was identified that future industrial/commercial workers may be present closer than assessed in the PN ERA. Although the Tier 1 Assessment concluded there would be no adverse effects, the potential radiological dose to the workers was evaluated in the Tier 2 Assessment.

- Surface Water Flow – At the time of the 2017 PEA, operational conditions were considered bounding in the Stabilization Phase. During the Storage with Surveillance Phase, when the Fish Diversion System (FDS) is proposed to be removed and the cooling water flow will be reduced, effect on fish entrainment and impingement was carried forward to the Tier 2 Assessment.

- Surface Water Quality – At the time of the 2017 PEA, operational conditions were considered bounding for water quality in the Stabilization Phase, with exception of emissions from the additional heating steam boiler, which were screened out. During the Storage with Surveillance Phase, discharges to Lake Ontario and to the forebay were evaluated and screened out for further evaluation. Radionuclides were retained in the Tier 2 Assessment considering public interest. The reduction in the extent and temperatures within the thermal plume due to the reduction in thermal releases was also carried forward to the Tier 2 Assessment.

1.3.4 Results of 2017 Tier 2 Assessment

Section 5 of the 2017 PEA presented the results of the Tier 2 Assessment. The results of the predictive human health and ecological risk assessment for radionuclides during the Storage with Surveillance Phase were as follows:

- Radiological effects on human health - The maximum predicted dose from emissions during the Storage with Surveillance Phase to a future industrial/commercial worker at the Engineering Services Buildings was estimated to be 0.002 millisieverts per annum (mSv/a), which is a fraction of the regulatory public dose limit of 1 mSv/a. The Human Health Risk Assessment (HHRA) found no discernable effects anticipated due to exposure of potential critical groups to radioactive releases from PN during the Storage with Surveillance Phase.

- Radiological effects on VECs – Exposure, dose and risk calculations were performed for ecological receptors at the PN outfall, forebay, and Frenchman's Bay. The estimated doses to all ecological receptors were below the aquatic benchmark of 9.6 milligray per day (mGy/d) or terrestrial benchmark of 2.4 mGy/d (UNSCEAR, 2008).

- Thermal Effects – In general, the 2017 PEA found that the lake near the discharge will be returned to a thermal condition typical of the nearshore zone of Lake Ontario. The cooler waters after shutdown will offer a thermal regime and aquatic habitats that are more similar to regional conditions.

- Effects on Impingement and Entrainment due to removal of FDS – The 2017 PEA found that the predicted volumetric flow and velocity of water through the forebay during the Storage with Surveillance Phase was significantly less than US EPA (2014) threshold values that would suggest impingement and/or entrainment risk. However, the 2017 PEA also assumed that a more robust evaluation would be conducted if OPG sought regulatory concurrence to cease use of the FDS as an impingement mitigation measure.

1.3.5 Conclusions and Recommendations of the 2017 PEA

The 2017 PEA concluded that no potential adverse effects were predicted from the proposed Stabilization and Storage with Surveillance Activities.

Given the current robust effluent and environmental monitoring programs at the PN site, which will continue, there were no specific recommendations for effluent or environmental monitoring changes based on the 2017 PEA. No new mitigation measures were proposed.

1.4 Quality Assurance and Quality Control

The previous 2017 PEA, and this PEA Addendum, made use of environmental monitoring data. These data are derived from chemical and radiochemical analyses of samples collected from effluent streams and environmental media around the PN site. The environmental data provided by OPG were collected by qualified staff and analyzed by qualified performing laboratories under the Environmental Monitoring Program (EMP), such as the station chemistry laboratory and the Whitby Health Physics Laboratory. The EMP has its own quality assurance (QA) program that encompasses activities such as sample collection, laboratory analysis, laboratory quality control, and external laboratory comparison (OPG, 2019a).

Throughout the planning and preparation of the PEA Addendum, all staff worked under an ISO 9001:2015 certified Quality Management System. All work was internally reviewed and verified. Reviews included verification of data and calculations, as well as review of report content and formatting. Comments have been dispositioned and addressed as appropriate by report revisions. The review process has been documented through an electronic paper trail of review comments and dispositions.

2.0 Objectives and Scope of the PEA Addendum Report

This PEA Addendum report was prepared to support the mid-term operating licence review for PNGS expected to occur in 2023. The primary objective of the PEA Addendum report is to document/demonstrate that human health and the environment will continue to be protected following shutdown, based on updated baseline environmental conditions and current operational assumptions for the Stabilization and Storage with Surveillance Phases.

Specifically, the PEA Addendum report will:

- Review and identify any changes to the key project assumptions and inputs that were considered in the 2017 PEA based on current assumptions for the Stabilization and Storage with Surveillance Phases;
- Consider changes to the environmental baseline conditions that have been described in the 2022 ERA and whether these have the potential to impact the conclusions of the 2017 PEA;
- Identify any revised assumptions or environmental conditions no longer bounded by the 2017 PEA;
- Evaluate the risk to human and ecological receptors from chemical, radiological and/or physical stressors, as needed, based on assumptions or environmental conditions no longer bounded by the 2017 PEA; and
- Update the conclusions and recommendations of the 2017 PEA.

The PEA Addendum report does not include a complete description of the existing environmental conditions; as well as the systems and structures in operation at PNGS. These are described in the 2022 PN ERA (Ecometrix, 2023) which considers annual monitoring data collected over the 2016-2020 period and includes a five-year periodic review of the ERA as required by CSA N288.6-12 (CSA, 2012).

Detailed descriptions for the Stabilization and Storage with Surveillance activities have remained largely unchanged from the detailed descriptions provided in Section 3 of the 2017 PEA, which collectively established an “upper bounding” case as a conservative measure to assess for potential effects. The PEA Addendum does not repeat these descriptions but instead focuses on identifying and documenting changes to the previous assumptions to evaluate whether these changes could have an impact on the previously established bounding conditions.

The time frame relevant for the PEA continues to include the 2-3 year Stabilization Phase for each unit and the first 10 years of the Storage with Surveillance Phase.

In the 2017 PEA, the PWMF was considered out of scope since it operates under a separate Waste Facility Operating Licence issued by the CNSC. In this report, the PWMF operations are considered to determine the potential impact of storing higher activity fuel (e.g., fuel that has had less time to decay) in the DSCs compared to current baseline conditions.

3.0 Methodology of the PEA Addendum Report

The general approach for evaluating changes to project assumptions and their effects on human health and the environment during the Stabilization and Storage with Surveillance Phases follows a similar framework as that used in the 2017 PEA and described in Section 1.3.2. The key steps taken in this PEA Addendum include:

(1) Review of existing and future conditions. This includes:

a. Changes to the understanding of baseline conditions. The baseline conditions have been updated in the 2022 PN ERA (Ecometrix, 2023). The 2022 PN ERA incorporated the results of existing annual monitoring programs at PNGS over the 2016-2020 period. These results and an assessment of whether the updated baseline could impact the 2017 PEA conclusions, are summarized in Section 4.0.

b. Revised assumptions and plans for the Stabilization and Storage with Surveillance Phases provided through documents and correspondence with OPG. Updated assumptions are documented in Section 4.2. Any changes that would result in a decreased interaction to the environment (e.g., reduced emissions) is not discussed since the change would be bounded by the 2017 PEA.

c. Current and predicted future changes to the Lake Ontario receiving environment to consider whether any changes can affect the outcome of the surface water models which supported the 2017 PEA.

(2) Re-evaluate Tier 1 Assessment assumptions that may no longer be bounding. Updated assumptions that represent a change or an increase to previous bounding conditions are carried forward for re-evaluation in the Tier 1 screening assessment. Revised assumptions are evaluated to determine if the changes would result in conditions no longer within the upper bounding case established in the 2017 PEA. For any conditions not bounded by the 2017 PEA, updated exposure concentrations are developed, and used to screen against screening criteria protective of human health and the environment. This updated Tier 1 Assessment is documented in Section 5.0.

(3) Complete an updated Tier 2 Assessment for the future environmental interactions that are no longer bounded by the 2017 PEA and did not meet screening criteria. As will be described in subsequent sections, there are no exceedances of screening criteria for non-radiological parameters in the updated Tier 1 Assessment, but an updated assessment of risks from radiological emissions is conducted for ecological receptors in the forebay. The assessment is documented in Section 6.0.

(4) Based on the results of the updated Tier 1 and Tier 2 Assessments, provide recommendations for future monitoring and/or mitigation of environmental and health effects.

The methodology steps described above are consistent with the general methodology that was followed in the preparation of the 2017 PEA. The general methodology for the 2017 PEA was presented previously in Section 1.3.2 and on Figure 1.5.

4.0 Update of Existing and Future Conditions

4.1 Baseline Conditions Update

The 2022 ERA provides an update to the 2017 ERA, based on the five-year review and update cycle. The 2022 ERA focused on the five-year period from 2016 to 2020, but incorporated other years of data when necessary. The 2022 update to the 2017 ERA was based on first conducting a periodic review of the ERA according to the recommendations in Clause 11 of CSA N288.6-12. The periodic review looks at changes to site ecology and surrounding land use, changes to the physical facility or facility processes, new environmental monitoring data, new or previously unrecognized environmental issues, and scientific advances. The periodic review is documented in Table 1.5 of the 2022 PN ERA. Overall, the changes identified through the periodic review did not result in major changes that would impact the assumptions made for the ERA.

The 2022 ERA generally relied on environmental monitoring data that was collected as part of the updated baseline environmental sampling program that was undertaken in 2015/2016, along with available data from 2016 to 2020. The main sources of updated data that would be relevant for the PEA included:

- Updated Emission Summary and Dispersion Modelling (ESDM) Reports which predict the maximum air concentration at the property line (Point of Impingement, POI) for each contaminant of potential concern (COPC). The ESDM reports demonstrated that the PN site was operating in compliance with s. 20 of O. Reg. 419/05 for each calendar year over the 2016-2020 period.

- Radiological emissions to air and water from 2016 to 2020 and environmental monitoring data (air, water, soil, fish, fruits, garden vegetables, etc.) from the annual EMP.

- Non-radiological emissions to water from 2016 to 2020 monitoring under the Environmental Compliance Approval (ECA) or Municipal Industrial Strategy for Abatement (MISA) program.

- Ongoing monitoring from 2016 to 2020 of groundwater at the PN site. A groundwater protection program (GWPP) and groundwater monitoring program (GWMP) compliant with CSA (2017) N288.7-15 Standard "Groundwater protection programs at Class I nuclear facilities and uranium mines and mills" was implemented at the end of 2020.

A microscrubber was installed on the U4 stack in 2020 and placed into service in 2021. The microscrubber transfers airborne tritium emissions to the waterborne release stream (the RLWMS for controlled release to the CCW). As a result, it is expected that there will be a decrease to the baseline tritium airborne emissions from U4. This change was not reflected in the 2022 ERA since it was placed into service outside the ERA timeframe of 2016-2020. This change is further discussed in the updated Tier 1 Assessment in Section 5.1.2.1.

4.1.1 Indigenous Engagement

OPG initiated engagement with the Williams Treaties First Nations (WTFN) in July 2021 to seek feedback on the list of Valued Ecosystem Components (VECs) that would be used in the 2022 PN ERA. OPG received feedback from meeting participants and this feedback was considered in the development of the VEC list for the 2022 PN ERA (see (Ecometrix, 2023) for discussion on WTFN feedback). The 2022 PN ERA serves as an updated baseline on which the PEA is based.

OPG recognizes that while the assessment of effects from the Pickering Safe Storage project has been satisfied from the Western scientific perspective, it may not fully address the impact on Indigenous inherent and treaty rights as they are understood today. OPG endeavors to continue to work with Indigenous nations and communities to develop more fulsome and ongoing engagement. For future iterations of the PEA, OPG plans to engage with Indigenous nations and communities early in the process, prior to the drafting of the PEA. The PEA will include a summary of what OPG heard from the Indigenous nations and communities and how this feedback has been considered in the assessment.

4.2 Stabilization and Storage with Surveillance Phase Activities Update

A description of the Stabilization and Storage with Surveillance activities for the identification of potential interactions with the environment was provided in Section 3.0 of the 2017 PEA. At the time, it was recognized that the specific details of activities during each phase were still under development by OPG, and therefore a conservative upper bounding case was established.

Through discussions with the OPG Safe Storage group, known updates to the assumptions used to establish the upper bounding case in the 2017 PEA have been documented in Table 4.1. The first three columns of the table repeat the previous assumptions that were presented in Table 3-1 of the 2017 PEA. The last two columns identify any changes or updates to the assumptions. Updated assumptions are identified for further evaluation in the Tier 1 Assessment (i.e. Section 5.0) if they are considered to result in a change or increase in potential interactions with the environment. Any change that will result in a decreased interaction with the environment is not discussed further, since this change would remain bounded by the 2017 PEA.

4.2.1 Changes to Systems, Structures or Activities

Based on the updated information summarized on Table 4.1, assumptions which could change or increase potential interactions with the environment were related to air emissions, surface water flow and quality, and sediment quality and transport.

Table 4.1: Summary of Stabilization and Storage with Surveillance Phase Activities and Identification of Updated Assumptions

System, Structure or Activity and Section in 2017 PEA	2017 PEA		Updates Identified	
	Stabilization Phase	Storage with Surveillance Phase	Stabilization Phase	Storage with Surveillance Phase
Reactor Building Systems (Section 3.1)	• The Reactor Building systems will cease operation for nuclear fission and heat generation. • Fuel will be removed, heavy water systems drained, moderator system flushed, and all other liquids, wastes and potentially hazardous transient materials will be removed. • Building ventilation and stack monitoring will remain operational. • The Reactor Building active drainage sumps will remain operational. • Heavy water will be transferred to storage systems on-site, with periodic transfers off-site as required.	• Surveillance will commence to ensure Reactor Building systems are maintained in a safe state. • Operation of ventilation will be reduced and run only as required for occupational safety and building integrity. • Sumps will be isolated from the active drainage system. • Heavy water storage on-site will continue, with periodic transfers off-site as required.	• 1,500 Mg of the approximately 3,000 Mg heavy water that will be drained from the units will be transferred to the Darlington Heavy Water Management Building – West Annex, following the Darlington Unit 1 refurbishment. The timing of the transfer will be confirmed at a later date but will likely occur during the Stabilization Phase. The heavy water sent to Darlington for storage would ideally be reactor moderator grade water of high chemical purity. Heavy water upgrading would be done at Pickering until the last unit is shut down. **This updated assumption is further evaluated in the Tier 1 Assessment for the Atmospheric Environment under Air Emissions – Radiological (Section 5.1.2.1**).	• No updates
Reactor Auxiliary Bay (RAB), Irradiated Fuel Bays (IFB) and Auxiliary Irradiated Fuel Bay (AIFB) (Section 3.2)	• The RAB systems will remain in operation to accommodate the shutdown of the reactor units, the defueling, and the removal of other equipment. • Systems no longer required will be taken out of service and left in a safe state, with the equipment remaining in place. • The IFBs and AIFB will remain in normal operation.	• Surveillance will commence to ensure RAB is maintained in a safe state. • The IFBs and AIFB will remain in normal operation until all contents can be transferred to dry storage. • Select monitoring equipment will remain operational. • Fuel will be transferred to DSCs and transportation to the PWMF will continue. • Once no longer required, PN U1-4 IFB, PN U5-8 IFB and AIFB may be drained.	• No updates	• No updates
Turbine Hall and Turbine Auxiliary Bay (TAB) (Section 3.3)	• Electricity generating equipment (e.g., turbines and generators) associated with each reactor unit will cease operation as units are shut down. • As equipment within the TAB is no longer required, it will be taken out of service and left in a safe state with equipment remaining in place (some exceptions may be made for equipment that can be resold). • TAB basement sump pumps will remain in operation.	• Current steam emissions from PN U1 and U4, and PN U5-8 will no longer exist during the Surveillance Phase. • Surveillance will commence to ensure TAB is maintained in a safe state. • Heating and ventilation will be provided, to the extent required. • Operation of the TAB basement sumps will continue to maintain the groundwater level below the basement floor.	• No updates	• No updates
Service Wing (Section 3.4)	• No changes.	• Service Wing operation will decrease as PN operations are reduced.	• No updates	• No updates

System, Structure or Activity and Section in 2017 PEA	2017 PEA		Updates Identified	
	Stabilization Phase	Storage with Surveillance Phase	Stabilization Phase	Storage with Surveillance Phase
Standby Generators and Emergency Power (Section 3.5)	• The generators will continue to be tested and relied on to supply back-up power and water to PN Generating Station systems while fuel remains in the reactor units.	• A single back-up power source (e.g., one emergency power generator) will be required.	• No updates	• No updates
Building Heating and Ventilation (Section 3.6)	• Adequate building heating and ventilation will continue to be supplied. • An alternative heating source/supply (e.g., a boiler in addition to the Auxiliary Boiler) is proposed to supply the powerhouse with adequate heat.	• Building heating and ventilation will be supplied to the extent necessary to satisfy occupational safety and maintain system and building integrity. • Less heat (i.e., less heating boiler use) will be required than in the Stabilization Phase.	• An alternative heating source (e.g., a boiler in addition to the Auxiliary Boiler) will not be required during the Stabilization Phase because it is expected that the Auxiliary Boiler will be sufficient to meet heating requirements during the Stabilization Phase. • Discussion is provided in the Auxiliary Boiler row of this table.	• The Auxiliary Boiler will not be used for primary or back-up heating supply during the Storage with Surveillance Phase because there will be a transition to electrical heating sources. • Discussion is provided in the Auxiliary Boiler row of this table.
Condenser Cooling Water (CCW) and Reactor Building Service Water (RBSW) Systems (Section 3.7)	• CCW pumps will be taken out of service as reactor units are shut down. • Select CCW pumps may continue to operate following the shutdown of reactor units to facilitate Stabilization activities.	• CCW pumps will be fully shut down by the end of the Stabilization Phase and will not function during the Storage with Surveillance Phase. • Cooling water for the IFBs is likely to be provided by the RBSW system.	• No updates.	• For PN U5-8, the expected CCW flow rate through the PN U5-8 side is 2,899 L/s (250,500 m^3/day) during the Storage with Surveillance Phase, higher than the assumed flow rate of 578 L/s (50,000 m^3/day) in the 2017 PEA. With regards to water quality, the updated CCW flows are bounded by the conditions assumed for the 2017 PEA, because the higher flow rate will provide greater dilution, resulting in reduced discharge concentrations at the outfall. • The increased CCW flow through the PN U5-8 side, relative to the 2017 PEA, will change the discussion on impingement and entrainment (I&E). **Implications of increased CCW flow on I&E is discussed in the Tier 1 Assessment for Surface Water Flow (Section 5.2.1.1).** • The increased CCW flow will further reduce the temperature difference between the discharged water temperature from the outfall and the water intake temperature (i.e., ΔT) because of greater dilution of warm water. Thus, with respect to ΔT, the assessment of thermal effects on fish species in the 2017 PEA (refer to Section 7.3.3 of the 2017 PEA) is bounding. The increased CCW flow may change predicted sediment deposition patterns. **This updated assumption is further evaluated in the Tier 1 Assessment for Sediment Quality and Transport (Section 5.3).**

System, Structure or Activity and Section in 2017 PEA	2017 PEA		Updates Identified	
	Stabilization Phase	Storage with Surveillance Phase	Stabilization Phase	Storage with Surveillance Phase
Electrical Transmission Facilities (Section 3.8)	• Main output transformers and generating system transformers associated with each unit will be taken out of service and placed into a safe state following the shutdown of the reactor units. • Select station service transformers and switchyard equipment may remain in operation to supply power to the facility. Any transformers no longer required would be placed in a safe storage state.	• The output transformers and the transmission yard will be de-energized and disconnected from the PN Generating Station, with the exception of service transformer(s) needed to supply power to the PN site during the Storage with Surveillance Phase.	• No updates	• No updates
Oil and Chemical Storage Building (Section 3.9)	• Waste consolidation activities and transportation off-site will increase.	• Operations will continue, though waste consolidation and transportation activities will be reduced.	• No updates	• No updates
Administration, Engineering Services, Security Buildings and Pickering Nuclear Information Centre (PNIC) (Section 3.10)	• No changes [relative to Commercial Operations].	• The Administration, Engineering Services Buildings (ESBs), and PNIC will be left in a safe and vacant state when no longer needed. • The Engineering Services Buildings, and Pickering Nuclear Information Centre may be leased to future industrial/commercial workers (i.e., a new tenant). • Security buildings will remain operational.	• The Engineering Services Buildings and PNIC will likely be demolished between 2025 and 2026 as they near end of life. • The Administration building will be maintained to support the decommissioning project and to house key decommissioning staff. • The assumption of the 2017 PEA remains bounding. • The demolition of the ESBs and PNIC or other on-site buildings may result in the temporary production of noise and dust associated with construction activities. However, it is assumed that best management practices will be implemented as part of any work plan to mitigate against dust and other construction-related impacts, and no further assessment is considered necessary.	• The Administration building will be maintained to support the decommissioning project and to house key decommissioning staff. • The ESBs and PNIC will have been demolished and will no longer be leased out. • The 2017 PEA assumption that buildings will be leased to future industrial/commercial workers is bounding, because the future industrial/industrial worker was assessed as the nearest receptor to the plant (shown on Figure 1.3; also refer to Section 4.1.3 of the 2017 PEA). This receptor would be bounding of exposure and dose from any on-site building leased out. Therefore, no further assessment is required.
High Pressure Emergency Coolant Injection (HPECI) Facilities (Section 3.11)	• No changes while fuel remains in the reactor units. • Once the reactor units are all defueled, the HPECI will be drained and all associated equipment placed in an inactive safe state. • HPECI water will be discharged via an approved pathway.	• HPECI facilities will no longer be in operation and will be in an inactive safe state.	• No updates	• No updates

System, Structure or Activity and Section in 2017 PEA	2017 PEA		Updates Identified	
	Stabilization Phase	**Storage with Surveillance Phase**	**Stabilization Phase**	**Storage with Surveillance Phase**
New Water Treatment Plant (NWTP) (Section 3.12)	• Once the demineralized water demand has been substantially reduced, the transition to an alternative supply may be warranted, such as a scaled down mobile water treatment system.	• Demineralized water requirements will be minimal and may be met by an alternative means, such as a mobile water treatment system.	• A mobile water treatment system is no longer part of the plans. Instead, demineralized water will be brought from off-site, and stored in tanks at the PN site. New pumps and controls will be added to hook up with the existing network to supply active loads during safe storage. • Considering the updated assumption, no discharges are anticipated to be associated with water treatment to meet demineralized water requirements, and the 2017 PEA assumptions are bounding.	A mobile water treatment system is no longer planned during the Storage with Surveillance Phase. The 2017 PEA considered non-radiological discharges from a mobile water treatment system during the Storage with Surveillance Phase and found that predicted concentrations of contaminants from water treatment are below screening levels (refer to Section 4.2.3.2.1.1 of the 2017 PEA). Considering that no water treatment is currently planned, the assessment of non-radiological discharges from a mobile water treatment system in the 2017 PEA is bounding for lake water quality. No further assessment is needed.
Pickering Waste Management Facility (PWMF) (Section 3.13)	• No changes, the PWMF will continue to receive, process and store DSCs.	• No changes, the PWMF will continue in full operation to receive, process and store DSCs until all the fuel has been removed from the IFBs and they have been decommissioned.	• A Licence Amendment for PWMF is being sought from CNSC to load 6- to 10-year fuel to the DSCs (from previous 10-year minimum), to free up bay space for the defueling of PN U5-8. A dose rate assessment has been completed for OPG considering the higher activity (lower aged) fuel for Storage Building 3 (SB3). **The results of the dose rate assessment are further evaluated in the Tier 1 Assessment for the Atmospheric Environment (Section 5.1.2).**	• No additional updates
Waste Management (radiological and non-radiological) (Section 3.14)	• Radioactive and non-radiological solid and liquid wastes will continue to be generated and managed as they are during normal operations.	• There will be a reduction in wastes produced. • Waste will continue to be managed in accordance with accepted procedures and licence requirements.	• No updates	• No updates
Site Drainage and Waterborne Emissions (Section 3.15)	• Drainage systems, including stormwater runoff, sewage, active and inactive drainage systems will remain operational. • Draining of systems may result in additional flow to the RLWMS (e.g., upgraders), but it will be discharged as in current operations. • Additional materials may be generated for discharge via the inactive drainage; however, approval will be obtained for the disposal options. • The volumes of active and inactive liquid emissions generated will be gradually reduced as operations are terminated.	• All types of waterborne emissions will be reduced. • Stormwater volumes will remain the same. • All drainage systems, including stormwater runoff, sewer, and active and inactive drainage systems will remain operational to the extent necessary to meet operational and regulatory requirement. • Inactive drainage will be re-routed to RLWMS, RBSW or the PN U5-8 discharge channel.	• No updates	• Inactive drainage will not be re-routed to RLWMS, RBSW or the PN U5-8 discharge channel. The revised strategy for inactive drainage is to discharge to the respective PN U1-4 or PN U5-8 CCW intake duct. As a result, less active discharges will be diverted to the RLWMS, and the 2017 PEA assessment of lake water quality remains bounding. • Inactive drainage discharge to the PN U5-8 CCW intake duct will be drawn back into the station along with the cooling water intake. Any potential impacted water will be diluted prior to discharge, as was the case in the 2017 PEA. This change does not affect the 2017 PEA bounding

System, Structure or Activity and Section in 2017 PEA	2017 PEA		Updates Identified	
	Stabilization Phase	**Storage with Surveillance Phase**	**Stabilization Phase**	**Storage with Surveillance Phase**
	• If no CCW pumps are in service, the waterborne emissions will be conducted as assumed for the Storage with Surveillance Phase.			condition and the increased CCW flow noted above will reduce predicted discharge concentrations. Therefore, no further assessment is needed for inactive drainage to the PN U5-8 side. • Inactive drainage discharge to the PN U1-4 CCW intake duct will eventually be a source of tritium to the forebay because there is expected to be no intake flow through the PN U1-4 intake duct. This discharge to the forebay is a new source that was not evaluated in the forebay screening for the 2017 PEA. **This update is further evaluated in the Tier 1 Assessment for the Surface Water Environment – Forebay Water Quality (Section 5.2.2.1)**
Supporting Services and Activities (Section 3.16 of 2017 PEA)				
Screenhouses, Forebay, Intake Channel, and Intake and Discharge Ducts	• Will remain operational and continue to operate as in the current operations. • The CCW duct may not be used when the CCW pumps cease operations at the end of the Stabilization Phase.	• The forebay will continue to be an operating intake, but with substantially reduced flows. • The PN U5-8 discharge channel will be used to discharge cooling water, however, flows (likely via RBSW) will be substantially reduced.	• No updates	• The forebay will continue to be an operating intake that is reduced from operational conditions but will be increased from the 2017 PEA assumption., as discussed in the CCW and RBSW systems row (i.e. Section 3.7 of the 2017 PEA). • The 2017 PEA predicted that the forebay would become a sediment depositional area (refer to Section 4.3.2 of the 2017 PEA). Less sedimentation in the forebay is expected to occur due to the higher expected intake flow rate. This change is considered bounded in the assessment in the 2017 PEA. No further assessment is needed. • The inactive drainage system will discharge to the respective PN U1-4 or PN U5-8 CCW intake duct after unit shut-down. However, for PN U1-4, with no CCW flow, inactive drainage will report eventually to the forebay. See discussion in the previous row. **This update is further evaluated in the Tier 1 Assessment for the Surface Water Environment (Section 5.2.1)**
Fish Diversion System (FDS)	• The FDS will continue to be installed seasonally as necessary while any number of CCW pumps remain in operation.	• The FDS will be removed from service (assumed prior approval to remove FDS has been obtained)	• No updates	• No updates

System, Structure or Activity and Section in 2017 PEA	2017 PEA		Updates Identified	
	Stabilization Phase	Storage with Surveillance Phase	Stabilization Phase	Storage with Surveillance Phase
Tempering Water Duct	• No changes.	• No changes.	• No updates	• No updates
Auxiliary Boiler (Existing steam boiler, fueled with fuel oil, which provides back-up heating steam supply for the PN site during commercial operations).	• The Auxiliary Boiler may be used as a primary or back-up building heating supply.	• The Auxiliary Boiler may continue to be used as a primary or back-up heating supply.	• The existing Auxiliary Boiler will be upgraded and modified to supply steam for building heating and process steam during the Stabilization Phase. The upgrades to the Auxiliary Boiler include installation of a new air dryer, replacement of the feed water pump, and a new oxygen sensor; these upgrades will not increase the air emission rate from the Auxiliary Boiler. • Operation of the Auxiliary Boiler during the Stabilization Phase is bounded by the 2017 PEA and current operational conditions assessed for the 2022 ERA, both of which consider full-time operation of the Auxiliary Boiler.	• The Auxiliary Boiler will no longer be relied upon for primary or back-up heating supply during the Storage with Surveillance Phase because the plan is to transition to electrical heating sources. • The use of the Auxiliary Boiler during the Storage with Surveillance Phase was assessed in the 2017 PEA and remains the bounding scenario because there will no longer be air and noise emissions and blow down discharges resulting from the operation of the Auxiliary Boiler. • Screening for airborne COPCs in the 2017 ERA and PEA did not consider future updates to the Canadian Ambient Air Quality Standards (CAAQS) for nitrogen oxide and sulphur dioxide, and future updates to Ontario Regulation 419/05 Schedule 3 for sulphur dioxides. In addition, the modeling of point of impingement (POI) concentrations for the 2017 PEA was based on the 2015 ESDM report which used the models in the Appendix to Ontario Regulation 346. In 2018 all modelling of contaminants transitioned to AERMOD which is now adopted by the Ministry of Environment, Conservation and Parks (MECP). **These regulatory updates are discussed in the Tier 1 Assessment for the Atmospheric Environment under Air Emissions – Non-Radiological (Section 5.1.2.2).**
Other Supporting Services	• The East and West Annex will see reduced activity over time. • The East Complex may continue to be used as is, with operations reduced over time. • Upgraders will continue to be used to upgrade heavy water. Necessary process steam may be supplied by the building heating boilers.	• The East Complex, East and West Annex will no longer be required and will be largely vacant. • The East Complex will be maintained as an industrial landscape to limit naturalization. • Upgraders will no longer be in service.	• No updates	• No updates

4.2.2 Pickering Waste Management Facility

The operation of the PWMF, consistent with the 2017 PEA assumption, involves the processing and storage of DSCs containing used fuel with a minimum of ten (10) years of decay. There are plans to store some higher activity fuels (lower age, with 6 years of decay) in Storage Building 3 (SB3) on the PWMF Phase II site to free up space for additional fuel in the IFB. In addition, Storage Building 4 (SB4) has been constructed to the south of SB3 to increase capacity as shut-down progresses. This change is discussed in the updated Tier 1 Assessment in Section 5.1.2.2, Radiological Doses from the PWMF Phase II Expansion.

4.3 Updated Lake Data Review

The 2017 PEA considered changes to water quality in Lake Ontario during the Stabilization and Storage with Surveillance Phases. This assessment was required due to the reduction in cooling water flows. A hydrodynamic surface water model (RMA10) was developed to predict changes to lake currents, sediment transport and water temperature under current operational conditions and during the Storage with Surveillance Phase. The model details were previously presented in Appendix A of the 2017 PEA report (Golder and Ecometrix, 2017). The predicted changes in surface water flow were used to assess potential effects to water quality, sediment quality and transport. A mass balance model was developed to determine concentration factors for the forebay.

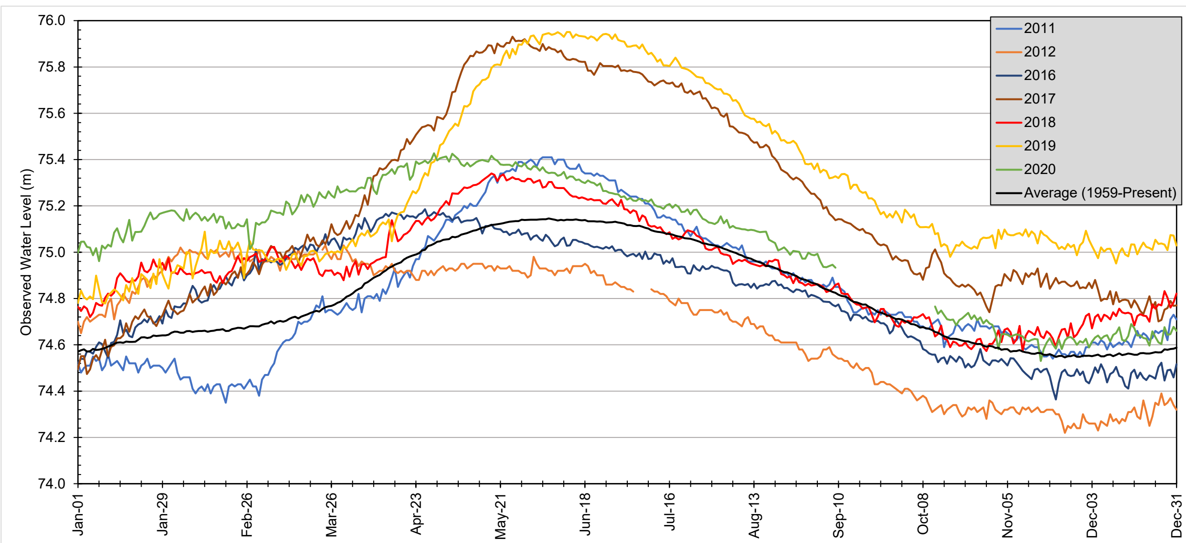
The key changes to the assumptions for surface water modelling are the potential increase in cooling water intake flow from 50,000 m^3/day assumed in the 2017 PEA to 250,500 m^3/day, and the re-routing of groundwater inputs from the TAB inactive drainage sumps and Vacuum Building Ramp Sump (VBRS) into the CCW intake ducts (and eventually the forebay for PN U1-4). The latter is discussed in Section 5.2.2.1 and Section 5.4. As discussed previously in Table 4.1 under CCW and RBSW Systems, an increased flow with the same cooling requirements during the Storage with Surveillance Phase may further reduce the temperature difference between the water intake and discharged water, and this is not considered to be an increased interaction with the environment. With respect to lake water quality, these changes will reduce the predicted COPC concentrations in the outfall during Storage with Surveillance due to the increased flow and dilution. Therefore, the scenario considered in the 2017 PEA remains the bounding condition with respect to lake water quality.

An additional data review has been completed to evaluate whether changes over time, if any, to the Lake Ontario receiving environment has the potential to affect the outcome of the surface water models which supported the 2017 PEA.

Lake water physical conditions relevant to surface water modelling were compared between the 2017 PEA conditions (based on the 2011 to 2012 data) and present-day conditions (based on relevant data between 2016-2020, extended to additional years as necessary). The relevant physical conditions include water level, water temperature and current speed, as discussed in further detail in the subsequent sections. Water levels are relevant to the boundary conditions of the forebay model, while water temperature and current speed are relevant to the boundary conditions of the RMA10 model.

4.3.1 Water Levels

Water level data considered as part of the review included analysis of daily lake water levels from Fisheries and Oceans Canada (DFO) for the Toronto Harbour Station (13320), to compare recent water levels (2016-2020) with those used in the 2017 study which were limited to 2011 and 2012. A comparison of daily average water levels measured at Toronto Harbour Station is presented on Figure 4.1. Figure 4.1 illustrates that water levels were highest during 2017 and 2019 over the years shown, and that 2012 was a low-water level year.



Note: Gaps in the measured data indicate missing points from the downloaded data. Missing data is typically the result of instrument malfunctions, maintenance, or errors.

Figure 4.1: Measured Daily Average Ontario Water Levels (Station 13320, Toronto Harbour)

Short-term variations of the water levels are a driving factor in forcing water into and out of the forebay. Using the forebay model and hourly water level data, the daily exchange flows between the forebay and the lake were estimated for the period 2018 to 2020 to see if the forebay exchange rate is different during high level years such as 2019, compared to low water level years (i.e., 2012). The frequency of exchange flow rates for the modelled years from the 2017 PEA (2011-2012) and recent data (2018-2020) are shown on Figure 4.2.

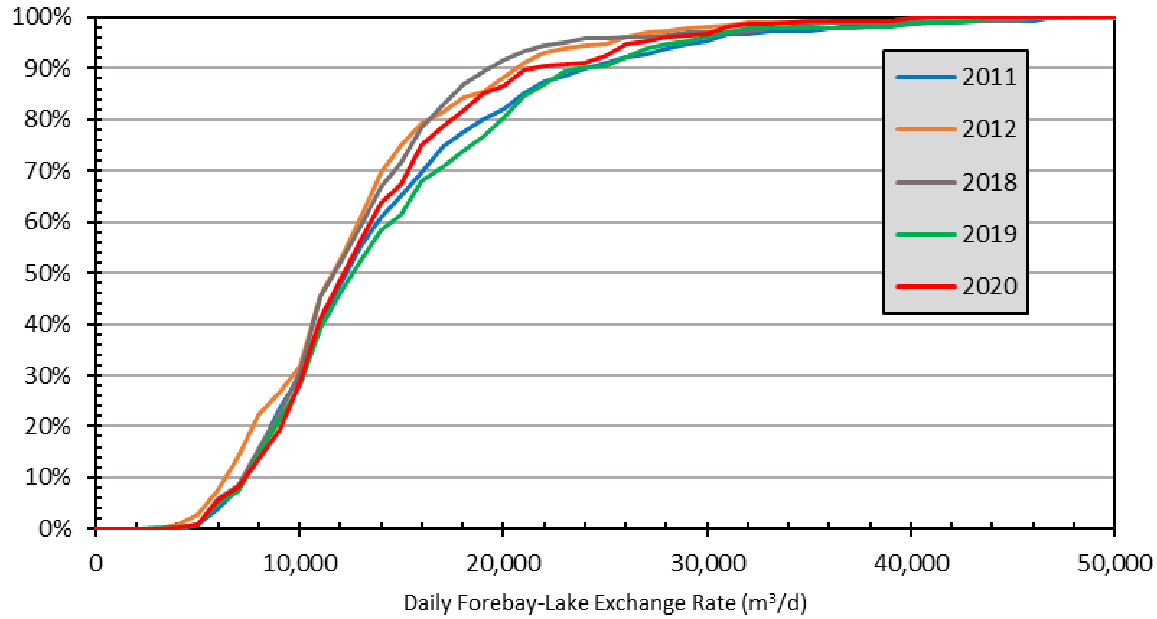


Figure 4.2: Frequency of Estimated Daily Water Level Driven Forebay Exchange Rates Using the Forebay Model

In Figure 4.2, each year has a minimum exchange rate of approximately 5,000 m^3/d, representing the forebay exchange rate during calm conditions. Storm events lead to increased exchange rates in the forebay, and account for most of the variability between the 2017 PEA period (2011-2012) and recent years (2018-2020). As shown in Figure 4.2, there are slightly lower frequencies of daily forebay-lake exchange rates in the 15,000 to 30,000 m^3/d range in 2019 and slightly higher frequencies in 2018. These do not appear to be correlated with lake water levels, considering that 2018 was an average water level year (Figure 4.1). In the forebay model update, both high-water level years (i.e. 2019) and low-water years (i.e. 2012) are considered, as well as relatively higher or lower daily forebay-lake exchange rates (2018 and 2019, respectively), to cover the full range of conditions that could be expected in the forebay. The forebay model is further described in Section 5.2.

An increase in water levels could also lead to increased potential for overtopping of the groyne due to wave runup. This would lead to increased flushing in the forebay and thus higher dilution. Since wave overtopping is expected to result in higher dilution, and the forebay model does not consider wave overtopping; therefore, the forebay model provides conservative results.

4.3.2 Water Temperature

Water temperature is relevant to the lake hydrodynamic model, since temperature is one factor affecting lake current patterns. Data from a Lake Ontario meteorological buoy location were gathered from the National Oceanic and Atmospheric Administration (NOAA) to compare lake temperatures over the years 2002 to 2020 (NOAA, 2021), which includes values used in the 2017

PEA and recent years. The buoy collects water temperatures between June to October of each year, as shown on Figure 4.3.

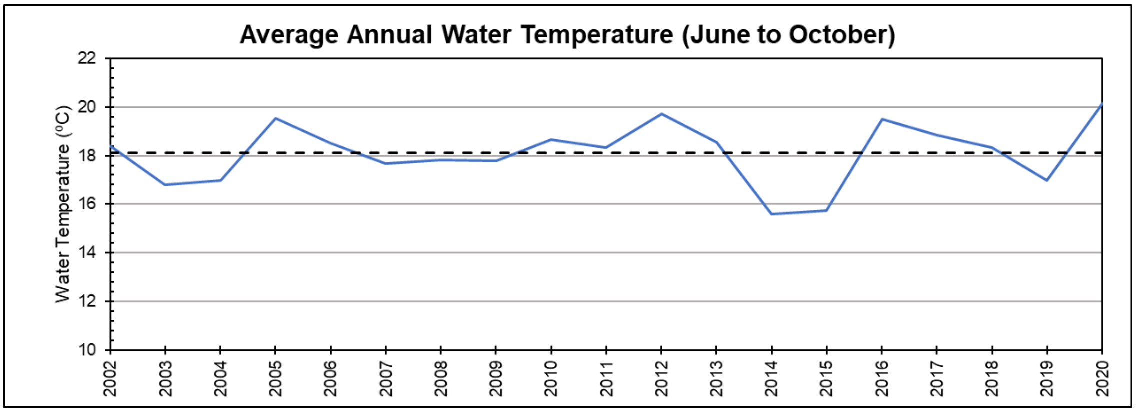


Figure 4.3: Annual Average Water Temperature at Buoy 45012

The graph does not show any identifiable long-term temperature trend over the period examined. A regression analysis of the data presented in Figure 4.3 results in a statistically insignificant trend of 0.027±0.114 °C/year (e.g., the 95% confidence interval of the slope includes zero). The water temperature in 2020 appears to be higher than previous years due to the buoy being placed in the lake later than usual (e.g., buoy deployed in late June as opposed to early May), as significant warming of the lake occurs from May to June. Peak water temperatures typically occur in August. Daily water temperature for 2011 and 2012 was plotted alongside recent data to compare conditions, presented on Figure 4.4.

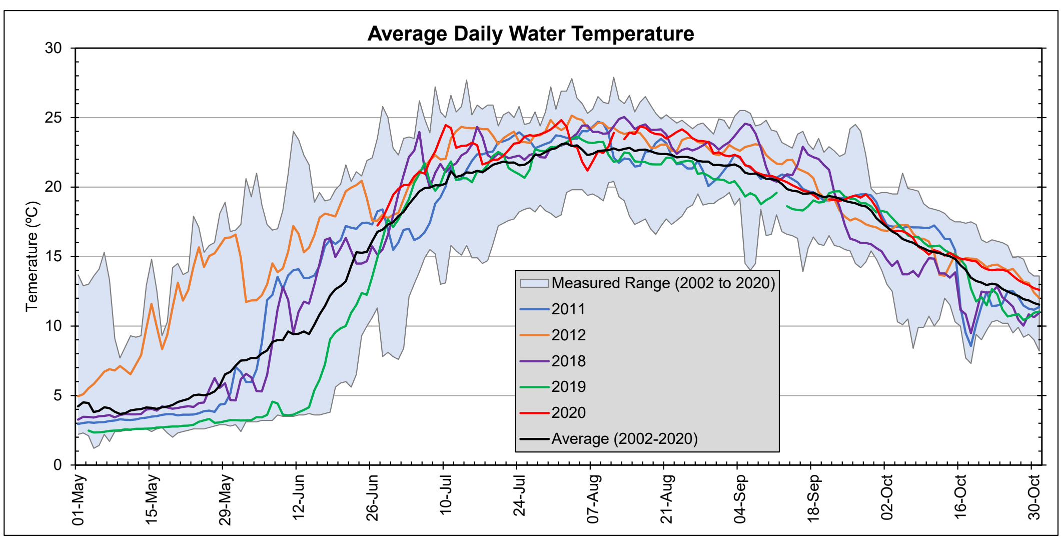


Figure 4.4: Average Daily Water Temperature (Buoy 45012)

The year 2011 showed a typical seasonal pattern in water temperature, while 2012 had a relatively warm spring. In the present-day period, 2018 and 2020 were showed as a typical seasonal pattern, while 2019 had a relatively cool spring. The 2012 warm spring data used in the 2017 PEA may be considered representative of future trends in lake water temperature as air temperatures are expected to increase due to climate change (discussed further in Section 4.4) and correspondingly, water temperatures to a lesser degree. Average annual water temperature during the 2011-2012 period was similar to present-day water temperature conditions.

4.3.3 Water Currents

Measured lake currents from an OPG-operated Acoustic Doppler Current Profiler (ADCP) located just off PNGS were gathered to compare to values used in the 2017 PEA. Readings from a depth of 1 m above the bottom (approximately 8 m below surface) were used for consistency with historical data. The current speeds examined are primarily shoreline currents as those are most important for plume transport. Current speed data collected between 2016 and 2020 were compared to the frequency analysis in the 2017 PEA to determine if changes to current speeds and directions occurred.

The distribution of current speed and direction was compared between the previously modelled periods (2011 to 2012) and recent (2016-2020) data, as shown on Table 4.2 and Table 4.3. The current speed distributions of the data sets are similar, although there are slight shifts in the current direction distribution. As the currents in Lake Ontario are the result of wind, the slight differences in current direction could be a result of variations in wind patterns and the frequency of wind events between years. As a result, it is expected that the hydrodynamic modelling completed for the 2017 PEA provides a reasonable representation of the current conditions and that the concentration factors provided in the 2017 PEA can be used for the current update of the PEA to represent present-day conditions in Lake Ontario.

Table 4.2: Current Speed and Direction Distribution (Modelled Periods from 2017 PEA)

Current Speed	Current Direction																Total
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
< 0.01 m/s	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	1.2%
0.01 to 0.05 m/s	1.2%	1.2%	1.5%	1.1%	1.2%	1.0%	0.5%	0.4%	0.6%	1.1%	1.8%	3.1%	3.3%	1.9%	1.4%	1.2%	22.4%
0.05 to 0.10 m/s	0.5%	0.7%	1.2%	3.4%	4.9%	2.9%	0.7%	0.2%	0.1%	0.6%	3.0%	8.4%	5.3%	0.5%	0.3%	0.3%	33.0%
0.10 to 0.20 m/s	0.0%	0.1%	0.3%	7.5%	13.7%	2.1%	0.1%	0.1%	0.0%	0.2%	2.1%	5.8%	2.2%	0.0%	0.0%	0.0%	34.3%
0.20 to 0.30 m/s	0.0%	0.0%	0.0%	1.9%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%	0.0%	0.0%	0.0%	8.4%
0.30 to 0.40 m/s	0.0%	0.0%	0.0%	0.1%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.6%
0.40 to 0.50 m/s	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.50 to 0.60 m/s	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
> 0.60 m/s	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**1.8%**	**2.0%**	**3.1%**	**14.1%**	**26.0%**	**6.1%**	**1.3%**	**0.8%**	**0.8%**	**1.9%**	**7.0%**	**17.9%**	**11.2%**	**2.5%**	**1.8%**	**1.7%**	**100.0%**
Minimum	0.007	0.004	0.005	0.000	0.011	0.006	0.003	0.002	0.006	0.008	0.002	0.003	0.006	0.001	0.004	0.004	0.000
Maximum	0.113	0.163	0.168	0.328	0.392	0.226	0.135	0.117	0.108	0.125	0.350	0.352	0.263	0.111	0.098	0.101	0.392
Average	0.042	0.047	0.058	0.132	0.152	0.086	0.059	0.051	0.033	0.050	0.079	0.091	0.075	0.039	0.033	0.035	0.102

Table 4.3: Current Speed and Direction Distribution (2016 to 2020)

Current Speed	Current Direction																Total
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
< 0.01 m/s	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	1.1%
0.01 to 0.05 m/s	0.6%	1.2%	1.4%	1.5%	1.3%	1.0%	0.8%	0.7%	0.9%	1.2%	2.1%	2.8%	2.2%	1.5%	1.1%	0.8%	20.9%
0.05 to 0.10 m/s	0.3%	0.7%	1.3%	3.0%	3.6%	1.5%	0.4%	0.2%	0.3%	0.9%	4.9%	8.3%	1.8%	0.5%	0.3%	0.2%	27.9%
0.10 to 0.20 m/s	0.0%	0.1%	0.5%	13.5%	8.2%	0.6%	0.1%	0.1%	0.1%	0.3%	4.3%	7.1%	0.4%	0.1%	0.0%	0.0%	35.3%
0.20 to 0.30 m/s	0.0%	0.0%	0.1%	10.2%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	1.4%	0.0%	0.0%	0.0%	0.0%	13.0%
0.30 to 0.40 m/s	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	1.8%
0.40 to 0.50 m/s	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
0.50 to 0.60 m/s	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
> 0.60 m/s	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**1.0%**	**2.0%**	**3.4%**	**29.8%**	**13.6%**	**3.2%**	**1.3%**	**1.0%**	**1.3%**	**2.4%**	**12.2%**	**19.8%**	**4.5%**	**2.1%**	**1.5%**	**1.1%**	**100.0%**
Minimum	0.003	0.003	0.003	0.001	0.000	0.002	0.002	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.000
Maximum	0.154	0.242	0.344	0.510	0.384	0.231	0.199	0.179	0.227	0.251	0.439	0.453	0.216	0.148	0.126	0.132	0.510
Average	0.044	0.049	0.070	0.181	0.115	0.070	0.045	0.040	0.042	0.057	0.102	0.104	0.056	0.040	0.036	0.038	0.116

Notes for Table 4.2 and Table 4.3:

1. Modelled periods (2011 and 2012) based on data used for 2017 PEA modelling; September 4, 2011 to December 24, 2011 and March 29, 2012 to July 10, 2012.
2. Values highlighted in yellow indicate most frequent current speeds and directions.

4.4 Climate Change Considerations

The potential effects of climate change on future physical conditions in Lake Ontario relevant to surface water modelling were considered based on regional climate models for the Great Lakes Basin, and specifically for Lake Ontario. These considerations have been in the context of the time frame covered under the scope of the 2017 and current PEA, which includes up to the first 10 years of the Storage with Surveillance Phase, expected to take place between approximately 2029 to 2039 (Figure 1.1).

The continued increase in projected global carbon emissions has the potential to have lasting impacts on Lake Ontario, by the end of the century, through the greenhouse effect. The anticipated effects on lake characteristics are dependent on the climate model and emissions scenario used. Representative Concentration Pathways (RCP), the primary climate scenarios used in the sources researched, are defined by the Intergovernmental Panel on Climate Change (IPCC) as potential greenhouse emissions trajectories to the end of the century, consisting of four scenarios of increasing severity. General Circulation Models (GCM) simulate physical processes of the atmosphere, land surface and oceans in response to increasing emissions but rarely account for the presence of freshwater bodies such as the Great Lakes. While useful, GCMs are limited in their ability to accurately provide information for areas of a smaller scale. Regional Climate Models (RCM) bridge this gap by downscaling GCM data, focusing on a specific region with a higher resolution. The use of general vs regional models can lead to different conclusions based on the level of detail each model provides. For this review, RCMs were the primary model type used within the sources that were researched.

In general, trends suggest that in the Great Lakes Basin and Lake Ontario:

- Water temperature (annual average) is expected to increase in Lake Ontario by 0.7°C by mid-century (Ouranos, 2017). With respect to the time period of the PN PEA, water temperatures are predicted to increase between 0.26°C and 2.9°C by 2039. As the site discharges from PNGS during the Storage with Surveillance Phase are non-thermal and small in volume, changes to the behaviour of the plumes associated with PNGS as a result of increase to water temperature are not expected between now and 2039.

- Water levels will likely increase. Older references predicted water levels would drop at a rate of approximately 0.005 m/year, which would lower the water level by approximately 0.09 m by 2039 (Gronewold et al., 2013). More recent methods suggest modest drops and indicate older methods over-estimated evapotranspiration (ELPC, 2019). Lake level modelling using a net basin supply approach for several global mean air temperature increases (Seglenieks and Temgoua, 2022) predicts an increase in the mean Lake Ontario water level as a result of climate change. While there is no timeframe associated with the predicted changes, the likely changes to the mean water level of Lake Ontario by 2039 are small (i.e., less than a few centimetres). Additionally, the modelling suggests that the frequency of high and low water years will also increase (i.e., more variation from year to year) and as such short-term decreases of the water level during the Storage with Surveillance Phase are still possible. Changes will be mitigated to some extent by water level management under International Joint Commission (IJC) authority.

- Extreme weather events (intense precipitation and drought) are expected to increase (ELPC, 2019), which may lead to increased variability in Lake Ontario water levels. This is likely to increase the exchange rates between the forebay and the lake, on average.
- Earlier warming in the spring will change the seasonal pattern of surface water temperature in Lake Ontario, with warming to 10°C occurring approximately 30-45 days earlier each year by the end of the century (Ouranos, 2017). The warm spring data used in the 2017 PEA, with 10°C reached in mid-May in 2012 (vs typical mid-June, see Figure 4.4) may be considered representative of such future conditions.

While changes to Lake Ontario water level and water temperature as result of climate change are predicted to occur over the next century, the magnitude of these changes by 2039 are expected to be minor. The expected patterns that may be observed by 2039 as a result of climate change are considered to be represented by the lake conditions considered for the 2017 PEA because the gradual increase in average water temperatures will be minor relative to changes to the receiving environment as a result of reduction of the thermal plume (i.e. returning of the lake temperature to "natural" conditions after cooling needs are substantially reduced); extreme weather events may increase exchange rates between the forebay and the lake, thus reducing residence time of any contaminants in the forebay; and the earlier warming observed in 2011-2012 are already considered representative of future warming conditions.

In summary, the hydrodynamic surface water model developed for the 2017 PEA is considered to provide a reasonable representation of future conditions to the time frame of the PEA (i.e. Stabilization Phase and the first 10 years of the Storage with Surveillance Phase), and the concentration factors used in the 2017 PEA are still applicable.

5.0 Updated Tier 1 Assessment

New baseline conditions, operational assumptions, or predicted future changes to environmental conditions were evaluated in Section 4 to determine if any changes could result in a change or increase to the previous Tier 1 assessment presented in the 2017 PEA. Any assumptions which would result in a decrease in predicted interactions with the environment are not discussed further in the Tier 1 assessment. The key changes carried forward for Tier 1 assessment include:

- Updated baseline air emissions over the 2016-2020 period;
- Updated dose rate assessment for the PWMF, assuming the storage of 6-year decayed used fuels in SB3 and 10-year used fuels in SB4;
- Re-screening of Auxiliary Boiler emissions against future air quality guidelines/standards for sulphur dioxide and nitrogen oxides;
- An increase of CCW intake flows from 50,000 m^3/day through the PN U5-8 side to 250,500 m^3/day; and
- Groundwater contributions from the VBRS to the forebay and inactive drainage from the U1-4 TAB foundation sumps to the U1-4 CCW intake duct, eventually discharging to the forebay.

5.1 Atmospheric Environment

5.1.1 Noise

No changes to the 2017 PEA assumptions were identified in Section 4.2 and Table 4.1 which would affect the bounding conditions of the 2017 PEA assessment. As per the conclusion in the 2017 PEA, the current operations that were assessed in the 2017 and 2022 PN ERAs are considered bounding.

5.1.2 Air Quality

5.1.2.1 Radiological Air Emissions

<u>Stabilization Phase</u>

As identified in Table 4.1 (Reactor Building Systems), current planning is that approximately 1,500 Mg of heavy water will be transported to the Darlington Nuclear (DN) site for storage towards the end of the Stabilization Phase. The movement of heavy water to the DN site may result in some additional releases of tritium to air during the Stabilization Phase. However, PN currently transports heavy water to Darlington on a routine basis to modulate tritium concentration in the heavy water inventory. Assuming that the existing process and practices of transporting heavy water are adhered to during the Stabilization Phase, and that the frequency for transporting heavy water will not be greater than the current frequency, no additional impact on tritium release should result during heavy water transport that would differ from current operational conditions; therefore, no further assessment is needed.

A microscrubber was installed on the U4 stack in 2020 and placed into service in 2021. The microscrubber transfers airborne emissions to the waterborne release stream (the RLWMS for controlled release to the CCW). The reduction in airborne emissions of tritium has been confirmed through the monitoring of airborne and waterborne emission data associated with U4 after installation. Prior to installation, an assessment of the dose impact of installing the microscrubber was conducted, and the assessment predicted a reduction or no change in total dose to receptors, due to the relatively lower contribution of waterborne emissions to total dose. The microscrubber is expected to run continuously until U4 is shut down. Because the microscrubber will help to decrease tritium airborne emissions while in operation, the baseline tritium emissions established for the 2017 PEA and documented in the 2022 ERA for the 2016-2020 period is likely to be the same or slightly higher than the expected baseline in 2021-onwards while the microscrubber is in operation. However, as discussed in Section 4.1.2.2.1 of the 2017 PEA, data from PN U2 and U3 have demonstrated that tritium emissions during the draining, flushing, and drying process for each reactor unit is substantially lower than the emissions during operational conditions. Consistent with the 2017 conclusion, regardless of whether or not the microscrubber is in operation, the air emissions during the Stabilization Phase are considered to be bound by current operational conditions.

<u>Storage with Surveillance Phase</u>

In the 2017 PEA, estimates of tritium and carbon-14 emissions were predicted to decrease during the Storage with Surveillance Phase as the atmospheric emission sources associated with operations are taken out of service. Emission rates in the 2017 PEA estimated the emissions from remaining sources and from historical data (i.e., average emissions) from 2010 to 2015. The assumptions for estimation of bounding airborne tritium and C-14 emissions are provided in Appendix B. The emissions for some of the remaining systems that will continue to operate during the Storage with Surveillance Phase were estimated in the PEA by using the collected data following shut-down of U3, currently in Safe Storage; or based on a percentage of the 5-year average emissions for each facility, determined by the estimated level of activity that would continue during the Storage with Surveillance Phase.

The 2017 PEA estimated tritium and carbon-14 emission rates by estimating the extent to which remaining sources would be operated relative to current operating conditions or based on reference emissions from U3 during the period following shut-down, defueling and dewatering. It was estimated that the overall tritium emission during the Storage with Surveillance Phase would be 1.77×10^{14} Bq/year, lower than the 2010-2015 average of 5.2×10^{14} Bq/year. The overall carbon-14 emission was estimated to be no more than 2.96×10^{10} Bq/year, lower than the 2010-

2015 average of 2.0×10^{12} Bq/year. As shown in Table 5.1, these conclusions remain applicable to the 2016-2020 average emission rates calculated from the annual EMP reports (Ecometrix, 2023).

Table 5.1: Existing Versus Predicted Atmospheric Emissions – Tritium and Carbon-14

Contaminant	2016-2020 Annual Emissions (1) (Bq/year)	Predicted Emissions – Storage with Surveillance (2) (Bq/year)
Tritium	6.40×10^{14}	1.77×10^{14}
Carbon-14	2.72×10^{12}	2.96×10^{10}

Notes:
(1) (Ecometrix, 2023)
(2) (Golder and Ecometrix, 2017)

5.1.2.2 Radiological Doses from the PWMF Phase II Expansion

The operation of the PWMF, consistent with the 2017 PEA assumption, involves the processing and storage of DSCs containing used fuel with a minimum of 10 years of decay. Dose rate calculations were performed in the PWMF Safety Analysis Report for DSC storage buildings 1 to 3 when filled to nominal design capacity assuming storage of at least 10-year decayed used fuel (OPG, 2018a). The expected dose rates at boundary locations determined in the PWMF Safety Analysis Report are presented and discussed in the 2022 PN ERA.

There are plans to store some higher activity (lower age) fuels in Storage Building 3 (SB3) on the PWMF Phase II site to free up space for additional fuel in the IFB. In addition, construction of Storage Building 4 (SB4) was completed in December 2020 and OPG received CNSC acceptance of the commissioning in March 2021 and the building is currently operational. A dose rate assessment was completed by OPG to determine the expected dose rates from the storage of up to 100 DSCs containing 6-year decayed used fuel in SB3 (representing approximately 20% of the building capacity). A dose rate assessment was also completed for SB4, assuming storage of DSCs containing some 10-year decayed used fuel (representing approximately 40% of the building capacity). The receptor locations used in the assessment are shown on Figure 5.1 and their distance from the storage buildings are shown in Table 5.2.

The receptor locations range from distances of 175 m to 840 m from the origin location within the PWMF Phase II site. Receptor locations PW24 and PW26 (shown on Figure 5.1) are located 407 m to the east and 440 m to the northeast, respectively, and are representative of locations at and beyond the existing PWMF protected area surrounding SB3 and SB4. The dose rate at the Montgomery Park Road turnaround (PW24) represents the location at the PNGS eastern property boundary fence, and is a representative bounding location for the dose assessment because it was found to receive a higher dose relative to PW26 (Montgomery Park Road turnaround), when considering both SB3 and SB4 (discussed below in this section and shown on Table 5.4).

Table 5.2: Receptor Locations Considered in the Dose Rate Assessment

Dose Point	Distance from PWMF(1) (m)	Location Description
PW10	175	1 ft below roof peak of the TMB
PW24	407	Montgomery Park Rd turnaround
PW26	440	Bend in bike path northeast of PWMF Phase II
LS03	840	Off shoreline
LS04	594	Off shoreline
LS05	460	Lake, 282 m off shoreline
LS06	419	Lake, 144 m off shoreline
LS07	405	Lake, where shoreline intersects with land site boundary

Notes:
(1) Calculated using distance from the origin location (x,y,z) = (0,0,0), which corresponds to a location near the center of SB4
(2) TMB = training and mock-up building

Figure 5.1: Receptor Locations Evaluated in the SB3 and SB4 Dose Rate Assessment

Table 5.3 presents a comparison of the existing predicted dose rate contribution from DSC loading of SB3 against the loading of some 6-year aged fuels (100 DSCs were assumed to contain 6-year aged fuel). The comparison shows that the predicted dose rate for the 6-year aged fuel at receptor locations is not expected to increase by more than a factor of 1.38 to 3.11 depending on location, compared to the 10-year aged fuel.

Table 5.3: Dose Rate Comparison of Existing and Revised Fuel Age Assumptions

Dose Point	Dose Rate Contribution from Existing DSC loading of SB3, Best Estimate (µSv/h)	Dose Rate Contribution from 6-yr(1) aged fuel DSC loading of SB3, Best Estimate (µSv/h)	Ratio of Dose Rates
PW10	5.27E-02	7.27E-02	1.38
PW24	4.23E-04	7.36E-04	1.74
PW26	4.62E-04	7.90E-04	1.71
LS03	8.33E-07	2.59E-06	3.11
LS04	1.16E-05	3.09E-05	2.66
LS05	7.13E-05	1.66E-04	2.33
LS06	1.54E-04	3.01E-04	1.96
LS07	2.72E-04	5.05E-04	1.86

Notes:
(1) Assumes 100 of the DSCs stored in SB3 contain 6-year aged fuel.

Table 5.4 presents the individual and combined best estimate dose rate contributions from SB3 (that stores a maximum of 100 DSCs containing 6-year aged used fuel) and SB4 (that stores DSCs containing at least 10-year aged used fuel). A conservative annual dose is also presented in Table 5.4, based on a yearly occupancy of 2,000 hours at on-land locations (23% occupancy), and 87.6 hours at off-shore locations (1% occupancy), consistent with occupancy assumptions for the industrial/commercial worker and sport fisher potential critical groups, respectively.

PW24 (at the PNGS eastern boundary fence) had the highest predicted annual dose of no more than 3.56 µSv/a, based on a dose rate of 1.78×10^{-3} µSv/hr, and occupancy rate of 23%. PW24 is approximately 407 m from the center of SB4 and can be considered to be representative for both current and future industrial/commercial workers who are assumed to be located farther away, as shown on Figure 5.1. The dose rate is also protective of people walking by the PN fence line. The predicted annual dose of 3.56 µSv/a at PW24 is below 10 µSv/a (radiation safety requirement for the PWMF) and well below the public dose limit for radiation protection of 1000 µSv/a, as described in the Radiation Protection Regulations under the *Nuclear Safety and Control Act*. The 2017 PEA (Golder and Ecometrix, 2017) predicted the total radiological dose to a future Industrial/Commercial worker during the Storage with Surveillance Phase to be 2 µSv/a. The combined dose from PNGS and PWMF to the future Industrial/Commercial worker during the Storage with Surveillance Phase would be 5.56 µSv/a, well below the public dose limit.

LS07 (located to the east of the PWMF Phase II site at the shoreline) had a highest predicted annual dose of no more than 0.14 μSv/a, based on a dose rate of 1.64×10^{-3} μSv/hr and an occupancy rate of 1%, consistent with the occupancy assumed for the Sport Fisher. The 2017 PEA (Golder and Ecometrix, 2017) predicted the total radiological dose to a future Sport Fisher during the Storage with Surveillance Phase to be 0.21 μSv/a. Taking the dose from the PWMF into account, the combined dose from PNGS and PWMF for the Sport Fisher during the Storage with Surveillance Phase would be 0.35 μSv/a, well below the public dose limit.

Considering that the predicted combined doses from the PNGS and PWMF are well below the public dose limit, no further Tier 2 Assessment will be considered for annual dose to human receptors from the PWMF.

Table 5.4: Dose Rates from SB3 and SB4

Dose Point	Dose Rate Contribution from DSCs in SB3 (6-yr aged fuel), Best Estimate (μSv/h)	Dose Rate Contribution from DSCs in SB4 (10-yr aged fuel), Best Estimate (μSv/h)	Combined Dose Rate Contribution from SB3 and SB4, Best Estimate (μSv/h)	Dose Rate Contribution from SB3 and SB4, Best Estimate + 2σ uncertainty (μSv/h)	Annual Dose Based on Best Estimate + 2σ uncertainty, Adjusted for Occupancy (1) (μSv/a)
PW10	7.27E-02	1.96E-02	9.23E-02	9.61E-02	192 (2,4)
PW24	7.36E-04	9.64E-04	1.70E-03	1.78E-03	3.56 (2,5)
PW26	7.90E-04	4.76E-04	1.27E-03	1.30E-03	2.60 (2,5)
LS03	2.59E-06	7.20E-06	9.79E-06	1.07E-05	0.00094 (3,5)
LS04	3.09E-05	9.39E-05	1.25E-04	1.33E-04	0.012 (3,5)
LS05	1.66E-04	4.22E-04	5.88E-04	6.32E-04	0.055 (3,5)
LS06	3.01E-04	6.77E-04	9.78E-04	1.01E-03	0.088 (3,5)
LS07	5.05E-04	1.05E-03	1.55E-03	1.64E-03	0.14 (3,5)

Notes:

(1) The presented annual doses include only the contribution from SB3 and SB4 and does not include other PWMF radiation sources. The contribution of radiation sources from DSCs and Dry Storage Modules stored at the PWMF Phase I site to the direct external radiation field at the limiting locations around the Phase II site are negligible.
(2) Based on an occupancy of 2,000 hours per annum (23% occupancy).
(3) Based on an occupancy of 87.6 hours per annum (1% occupancy).
(4) Less than the 0.5 μSv/hr (1,000 μSv/a) effective dose limit for non-Nuclear Energy Workers (NEWs)
(5) Less than 10 μSv/a (1% of the public dose limit, 1 mSv/a)

For ecological receptors, the dose rates at the PWMF Phase II Protected Area fence were considered. The whole body dose rate for humans in close proximity to SB3 (assuming storage of up to 100 DSCs containing 6-year aged fuel) and SB4 would be no more than 0.85 μSv/h at the west fence line, as shown in Table 5.5. It is difficult to translate the human effective dose to a whole body absorbed dose for various wildlife species with different geometries; however, it has been assumed that the whole body effective dose for humans (μSv/hr) is equivalent to the whole body absorbed dose for wildlife (μGy/h). Thus, a tissue absorbed dose of 0.85 μGy/h from the PWMF Phase II site is assumed for biota. This is well below the terrestrial dose benchmark of 100 μGy/h for terrestrial and riparian receptors. The maximum dose predicted in the 2022 ERA for terrestrial ecological receptors at the PN site from PNGS during operational conditions ranges from 8.42×10^{-4} mGy/d (3.51×10^{-2} μGy/h) to 3.46×10^{-3} mGy/d (1.44×10^{-1} μGy/h), which comprises a negligible addition to the dose from the PWMF. No further Tier 2 Assessment will be considered for annual dose to ecological receptors from the PWMF. Additional context regarding the terrestrial dose benchmark is found in Section 6.3.1.

Table 5.5: Dose Rates at PWMF Phase II Protected Area Fence from DSCs in SB3 and SB4

Protected Area Fence Location	Maximum Dose Rate Along the PWMF Phase II Protected Area Fence from SB3 (μSv/h)	Maximum Dose Rate Along the PWMF Phase II Protected Area Fence from SB3 and SB4 (μSv/h)	Estimated Tissue Absorbed Dose Rate from SB3 and SB4(2) (μGy/h)
North	0.21	0.21(1)	0.21
South	0.02	0.71	0.71
East	0.14	0.56	0.56
West	0.13	0.85	0.85
West (extended)	0.03	0.16	0.16

Notes:

(1) The contribution to the dose rate at the north fence from DSCs stored in SB4 was not calculated as part of this analysis, but due to distance to the fence and shielding from SB3, contributions from SB4 are expected to be much lower than those from SB3.

(2) It is assumed that the whole body effective dose for humans (μSv/h) is equivalent to the whole body absorbed dose for wildlife (μGy/h).

5.1.2.3 Non-Radiological Air Emissions

As per Table 4.1 under Supporting Services and Activities, primary or back-up heating during the Stabilization Phase will be provided by the existing Auxiliary Boiler, which will be upgraded and modified to provide steam for building heating and process steam. During the Storage with Surveillance Phase, the Auxiliary Boiler will not be used for primary or back-up heating supply and therefore this phase is bounded by the Stabilization Phase.

To support the prediction of effects, the 2018 to 2020 ESDM reports for the PN site included a third scenario (Scenario 3), which assumed full-time operation of the Auxiliary Boiler starting in 2024 (i.e., start of Stabilization Phase) as a single source. Air contaminants modelled for the Auxiliary Boiler source in the 2018 to 2020 ESDM reports included benzo(a)pyrene, carbon dioxide, hexavalent chromium, cobalt, fluoride, lead, nickel, nitrogen oxides, and sulphur dioxides (Ortech, 2019, 2020, 2021). Under Scenario 3, the concentrations of all contaminants were below the MECP Schedule 3 POI limit. Nitrogen oxides represent the most significant contaminant associated with the operation of the Auxiliary Boiler, as this contaminant is closest to the MECP POI limit.

The current assumption represents a change from the bounding scenario presented in the 2017 PEA, which assumed that the Auxiliary Boiler, plus an additional steam heating boiler, both powered by fuel oil, would provide alternative heating supply once all reactor units have been shut down. The 2017 PEA concluded that the concentrations of contaminants associated with combustion products from the boilers were all below their then-applicable limits at the point of impingement. Although the change represents a decreased interaction with the environment (emissions will be lower than previously predicted), the predicted air emissions during the Stabilization Phase will be considered in the context of changing air emission guidelines related to nitrogen oxide and sulphur dioxide concentrations.

5.1.2.3.1 Ontario Regulation 419/05 Schedule 3 Limits for Sulphur Dioxide

In March 2018, the MECP posted a decision notice to update the air standards for sulphur dioxide, with a phase-in period of five years (Environmental Registry of Ontario number 013-0903). The new sulphur dioxide standards in Schedule 3 of the O. Reg. 419/05 will take effect on July 1, 2023. The current 1-hour average air standard of 690 μg/m^3 will reduce to 100 μg/m^3 based on respiratory morbidity; and an annual average standard of 10 μg/m^3 will be introduced, based on vegetation damage.

As shown in Table 5.6, the POI concentrations of sulphur dioxide will continue to be in compliance with the future Schedule 3 POI limit coming into effect in 2023.

Table 5.6: Comparison of Emissions Associated with Auxiliary Boiler Operation Against Current and Future O. Reg. 419/05 Schedule 3 Limits

COPC	Averaging Time	Point of Impingement Concentration under Scenario 3 (μg/m^3)(2)	O. Reg. 419/05 Schedule 3 – February 1, 2020 (μg/m^3)	O. Reg. 419/05 Schedule 3 - July 1, 2023 (μg/m^3)
Sulphur Dioxide	1-hr	1.2	690	100
	24-hr	0.1	275	-
	Annual	0.019(1)	-	10

Notes:
None of the POI Concentrations exceed the 2020 or 2023 O. Reg. 419/05 Schedule 3 limits.
"-" = not available
(1) Adjusted to an annual concentration by multiplying the modelled 24-h POI concentration by a factor of $(1/365)^{0.28}$ (MOECC, 2017)
(2) Based on modelled Scenario 3 from the 2020 ESDM report, which assumes full-time operation of the Auxiliary Boiler. The modelled values in the 2020 ESDM report were used because they were higher than those modelled in 2018 or 2019 which also considered Scenario 3.

5.1.2.3.2 Canadian Ambient Air Quality Standards

The Canadian Ambient Air Quality Standards (CAAQS) are human and ecological health-based standards developed by the Canadian Council of Ministers of the Environment (CCME) to support the implementation of a new Air Quality Management System to guide work on air emissions across Canada. The 2020 CAAQS for sulphur dioxide and nitrogen dioxide came into effect on December 10, 2017 and will remain in effect until December 31, 2024, after which time the 2025 CAAQS will come into effect (CCME, 2020a, 2020b).

Table 5.7 presents a screening of the maximum POI concentration modelled under Scenario 3 in the 2020 ESDM report (Ortech, 2021) against the CAAQS. The comparison shows that the 1-hour concentration for nitrogen oxides is predicted to exceed the 2020 and 2025 CAAQS. There are no exceedances of the 2020 or 2025 CAAQS for sulphur dioxide.

Table 5.7: Comparison of Emissions Associated with Auxiliary Boiler Operation Against Current and Future CAAQS

COPC	Averaging Time	Point of Impingement Concentration Under Scenario 3 (µg/m³)(3)	2020 CAAQS(1) (µg/m³)	2025 CAAQS(1) (µg/m³)
Nitrogen Oxides	1-hr	**137**	113 (60 ppb)	79 (42 ppb)
	24-hr	11.5	-	-
	Annual	-	32 (17 ppb)	23 (12 ppb)
Sulphur Dioxide	1-hr	1.2	183 (70 ppb)	170 (65 ppb)
	24-hr	0.1	-	-
	Annual	0.019(2)	13 (5 ppb)	10 (4 ppb)

Notes:
Shaded / bolded = exceeds current or future CAAQS
(1) 1 ppb NO_2 = 1.88 µg/m³; 1 ppb SO_2 = 2.62 µg/m³
(2) Adjusted to an annual concentration by multiplying the modelled 24-h POI concentration by a factor of $(1/365)^{0.28}$
(3) Based on modelled Scenario 3 from the 2020 ESDM report, which assumes full-time, continuous (365 days per year) operation of the Auxiliary Boiler, which would not be the case in reality. The modelled values in the 2020 ESDM report were used because they were higher than those modelled in 2018 or 2019 which also considered Scenario 3.

It is noted that the CAAQS were not developed to evaluate POI concentrations at a facility boundary; the 1-hour standard is intended to be compared against a 3-year average of the annual 98th percentile of the daily maximum 1-hour average concentration, and the annual standard is intended to be compared against the arithmetic average over a single calendar year of all 1-hour average concentrations over the year. These standards are intended to be maintained over one or more air zones and are not intended to be applied to a specific facility (CCME, 2020a). Furthermore, the potential critical group receptors considered for the PEA are located beyond the POI boundary.

Table 5.8 presents the comparison of estimated annual average NOx exposure point concentrations for each of the six potential critical group receptors that were assessed in the 2022 ERA to show that the predicted emissions associated with Auxiliary Boiler operation are below the future CAAQS values. The predicted POI concentration of nitrogen oxides associated with Auxiliary Boiler operation are also below the MECP Schedule 3 POI limit and therefore it is not included in Table 5.8 comparison.

The calculation of the transfer parameter from source to air (P_{01}) was presented in the 2022 ERA (Ecometrix, 2023), and the residency assumptions for each of the receptors are consistent with past ERAs and the 2017 PEA. It is assumed that the sport fisher is fishing near the PN site 1% of the time and the industrial/commercial worker located 0.95 km from the PN site is working near the PN site 23% of the time. The rest of the potential critical group receptors are present at their locations 100% of the time.

The assessment presented in Table 5.8 does not include the future industrial/commercial worker (0.37 km from the PN site) because the PEA assumes that leasing of site buildings to future industrial/commercial users is not expected to occur until the Storage with Surveillance Phase, and thus they will not be exposed to emissions during the Stabilization Phase from Auxiliary Boiler operation. Nitrogen oxide emissions from other sources are minimal compared to those generated by Auxiliary Boiler operation. In the 2020 ESDM report for PNGS (Ortech, 2021), 79% of the nitrogen oxide emission rate is attributable to the Auxiliary Boiler (1.39 g/s from the Auxiliary Boiler, vs. 1.76 g/s from the facility in total).

The comparison of the maximum emission rates against the CAAQS for nitrogen oxides in Table 5.8 concludes that all exposure point concentrations are below the current and future CAAQS. As such, COPCs associated with boiler operation are not retained for further evaluation in the Tier 2 Assessment.

To evaluate potential effects on ecological receptors from nitrogen oxides, it is appropriate to evaluate chronic long-term air concentrations against chronic ecological health-based values, since full-time operation of the Auxiliary Boiler is expected. The 24-hr POI concentration for nitrogen oxides of 11.5 µg/m^3, shown in Table 5.7, was obtained from the 2020 ESDM Report (Ortech, 2021), and converted to an annual POI concentration by multiplying the 24-hour concentration by a factor of $(1/365)^{0.28}$ (as per Section 17, clause (3) of O. Reg. 419/05). The resulting annual POI concentration is estimated to be 2.2 µg/m^3, which is much lower than the 2025 CAAQS of 23 µg/m^3 (considered protective of humans and the environment), as well as additional ecological health-based values discussed in the next paragraph.

Based on available literature on ecological health-based values, adverse effect levels for NOx under long-term exposure are 5,000 µg/m^3 for plants (Doull et al., 1980) and 47,000 µg/m^3 for dogs which can be applied generally to small mammals (Heck, 1964). Considering the estimated annual POI concentration of 2.2 μg/m^3 is much lower than these adverse effect levels in plants and small mammals, no adverse effects are expected from NOx on ecological receptors.

Considering the estimated annual POI of 2.2 μg/m^3 for nitrogen oxides is below the annual CAAQS of 23 μg/m^3 and orders of magnitude below the ecological adverse effect levels listed above, it is expected that ecological receptors within the site boundary would also be protected.

Table 5.8: Comparison of Potential Critical Group Exposure Point Concentrations of NO_x to 2020 and 2025 CAAQS during the Stabilization Phase

Potential Critical Group	Approx. Distance from PN (km)(1)	Wind Sector (Direction to)(1)	Transfer Parameter from Source to Air, P_{01} (s/m^3)(1)	Emission Rate (g/s)(2)	Annual Average NOx Concentration – pro-rated for Residency(3)	2020 CAAQS (annual) $\mu g/m^3$	2025 CAAQS (annual) $\mu g/m^3$	% 2020 CAAQS (annual)	% 2025 CAAQS (annual)
Sport Fisher	0.5	S	9.37E-06	1.39	0.13	32	23	0.4%	1%
Industrial/Commercial	0.95	NNE	2.02E-06	1.39	0.65			2%	3%
Urban Resident	1.35	WNW	9.78E-07	1.39	1.36			4%	6%
Correctional Institution	3.1	NNE	2.75E-07	1.39	0.38			1%	2%
Farm	6.9	NE	7.67E-08	1.39	0.11			0.3%	0.5%
Dairy Farm	10.25	NNE	4.94E-08	1.39	0.07			0.2%	0.3%

Notes:

(1) From 2022 ERA (Ecometrix, 2023)

(2) Emission rate for the Auxiliary Boiler (1.39 g/s) under Scenario 3 (Ortech, 2021)

(3) Calculated using Transfer parameter P_{01} (s/m^3) * Emission Rate (g/s) * $1x10^6$ * Residency Factor. Residency Factor is 1 for all receptors except for the Sport Fisher, who spends 1% of their time near the PN site, and the commercial/industrial worker who spends 23% of time near the PN site, consistent with previous assessments.

5.1.3 Summary of Updated Tier 1 Assessment – Atmospheric Environment

- The updated 2016-2020 baseline emissions from the site were compared against the predicted emissions during the Storage with Surveillance Phase determined in the 2017 PEA, for which no updates have been identified. The comparison finds that the overall predicted C-14 and tritium emissions during the Storage with Surveillance Phase remain well below current baseline conditions. Therefore, no further Tier 2 Assessment is required.

- There may be increased movement of heavy water on the PN site including a potential transfer of approximately 1,500 Mg of heavy water to the DN site towards the end of the Stabilization Phase. Assuming the same existing process and practices are in place for transporting heavy water, no additional impact on tritium release is expected. This change is not carried forward to the Tier 2 Assessment.

- A microscrubber was installed on the U4 stack in October 2020 and was placed into service in 2021. The microscrubber is expected to reduce airborne emissions of tritium. This change may reduce airborne tritium emissions for the baseline condition but will not change previous conclusions regarding tritium emissions during the Stabilization and Storage with Surveillance Phases once Unit 4 is taken out of service. This change is not carried forward to the Tier 2 Assessment.

- PWMF dose rates resulting from the storage of up to 100 DSCs containing 6-year decayed used fuels in SB3 and additional storage in the newly constructed SB4 were considered. The expansion of the PWMF Phase II site will accommodate storage capacity requirements as shut-down proceeds. The predicted annual dose at the PNGS east property boundary of no more than 0.00356 µSv/a, based on SB3 and SB4 filled at design capacity, is well below the public dose limit for radiation protection of 1 mSv/a. The maximum dose rate along the PWMF Phase II protected area fence of 0.85 µGy/hr is well below the terrestrial dose benchmark of 100 µGy/hr. No further Tier 2 Assessment is considered necessary for the PWMF Phase II site expansion.

- The existing Auxiliary Boiler will be upgraded and modified to be the primary source of building heating and process steam during the Stabilization Phase, and an alternative heating source, considered in the 2017 PEA, is no longer required. In addition, there will be a transition to electrical heating sources during the Storage with Surveillance Phase. These changes represent a decreased interaction with respect to air emissions and noise. Re-evaluation of predicted air emissions from the Auxiliary Boiler confirmed that the air concentrations at potential critical group locations would be less than the O. Reg. 419/05 POI limit for sulphur dioxide which comes into effect on July 1, 2023; and CAAQS for nitrogen oxide and sulphur dioxide which were introduced in 2020 and will decrease further by 2025. No further Tier 2 Assessment is required.

5.2 Surface Water Flow and Quality

5.2.1 Surface Water Flow

The 2017 PEA assumed that the PN water balance will change in a step-wise manner during the Stabilization Phase, from its operational configuration described in the 2022 PN ERA (Ecometrix, 2023), to its final configuration during the Storage with Surveillance Phase. The most significant change will result from the gradual shutting down of the CCW pumps. The 2017 PEA predicted that cooling water flows will reduce from the current 14,100,000 m^3/day (combined discharge from the PN U1-4 and PN U5-8 discharge ducts) to less than 15% of that (i.e. 1,600,000 to 2,100,000 m^3/day) at the end stages of the Stabilization Phase, based on operation of two CCW pumps (Golder and Ecometrix, 2017). At the very end of the Stabilization Phase (e.g., with no reactors operating and the units defueled) the Storage with Surveillance Phase flows (50,000 m^3/day) will apply (Golder and Ecometrix, 2017). There are no increased effects to the forebay during the Stabilization phase due to the increase in the assumed flow rate from 50,000 m^3/day (used in the 2017 PEA) to 250,500 m^3/day because the fish diversion system will still be in place. Therefore the 2017 PEA assumptions for surface water flow are considered bounding for the Stabilization Phase.

During the Storage with Surveillance Phase, the 2017 PEA assumed that cooling water flows would be limited to meeting cooling water requirements for the IFBs which were estimated to be less than 1% of current requirements (Golder and Ecometrix, 2017). To understand the changes to the nearshore hydraulic environment because of the reduced flow conditions, a hydrodynamic surface water model (RMA10) was developed for the 2017 PEA to predict changes to lake currents, sediment transport and water temperature during the Storage with Surveillance Phase. An updated lake data review was completed as part of this PEA Addendum (see Section 4.2.2) which concluded that lake conditions during the previously modelled periods (2011-2012) were similar to recent years (i.e., 2016-2020) and that the model results completed for the 2017 PEA are still applicable to present-day conditions. Additionally, as discussed in Section 4.4, while changes to Lake Ontario water levels and water temperatures as a result of climate change are predicted to occur over the next century, the changes are expected to be bounded by the conditions modelled for the 2017 PEA.

In development of the RMA10 model, a water balance was developed for the model, assuming a station intake and discharge flow of approximately 50,000 m^3/day. It was also assumed that the cooling water intake would be drawn in via the PN U5-8 side, and the only inputs to the forebay would be stormwater runoff (Section 4.2.2.2 of the 2017 PEA). As identified previously in Table 4.1 the expected flow rate of cooling water intake into the station is now 2,899 L/s (250,500 m^3/day), an increase from the previous assumption of 50,000 m^3/day. The increased dilution at the outfall provided by the higher flows is expected to result in reduced radiological or chemical concentrations.

5.2.1.1 Potential Effects on Impingement and Entrainment

The increased flow rate (250,500 m^3/day) through the PN U5-8 CCW intake may affect fish impingement and entrainment during the Storage with Surveillance Phase. The 2017 PEA evaluated fish impingement and entrainment in the Tier 2 Assessment, looking at a volumetric flow rate through the cooling water intake of 0.57 m^3/s (50,000 m^3/day), and a maximum velocity of 7.1 mm/s that was determined through surface water modelling. These rates will increase based on the new flow rate of 250,500 m^3/day and therefore the potential effects on impingement and entrainment during the Storage with Surveillance Phase are further evaluated in the Tier 2 Assessment.

5.2.2 Surface Water Quality

5.2.2.1 Forebay Water Quality

For the 2017 PEA, the forebay was assessed as a potential aquatic habitat during the Storage with Surveillance Phase following reduced flows and removal of the FDS. The only input assumed into the forebay was stormwater. Concentrations of radiological and non-radiological contaminants via the PN U1-4 and U5-8 side stormwater drains were from stormwater collected during the 2015-2016 stormwater sampling campaign (Ecometrix, 2023). A mass balance box model was developed to predict surface water concentrations in the forebay during the Storage with Surveillance Phase based on contributions from the two stormwater outfalls. Radionuclides were carried forward to the Tier 2 Assessment considering public interest.

As identified in Table 4.1, current plans assume that groundwater contributions from the TAB inactive drainage (IAD) sumps and the VBRS will be routed to their respective PN U1-4 and U5-8 intake ducts instead of the discharge channel. The IAD discharges to the PN U5-8 side will be drawn in by the cooling water intake and thus will be negligible relative to the planned cooling water intake flows, whereas the IAD discharges to the PN U1-4 side will backflow into the forebay from the intake duct where there is no intake flow. These contributions were not included in the 2017 PEA, which only considered stormwater inputs to the forebay. The addition of groundwater contributions to the forebay represents a change that is not bounded by the 2017 PEA. Therefore, surface water quality in the forebay is re-evaluated in this PEA addendum.

Tritium is the only COPC in groundwater. Non-radiological COPCs (BTEX, petroleum hydrocarbons and volatile organic compounds) are included in the annual groundwater monitoring program at applicable areas of concern, but these parameters have not been detected above the analytical detection limits over the 2016-2019 period (OPG, 2017, 2018b, 2019b, 2020), with exception of a single location in 2018 where PHC F3 was detected at 183 µg/L, slightly above the detection limit of 100 µg/L. PHC F3 was not detected in the well during other years sampled. Non-radiological parameters were not sampled in 2020 (OPG, 2021b).

The VBRS is also monitored on a quarterly basis and reported annually as part of the PN Groundwater Monitoring Program (OPG, 2017, 2018b, 2019b, 2020, 2021b). Over the 2016-2020 period the highest measured tritium concentration in the VBRS sump was 1.75×10^{6} Bq/L, and the flows from the VBRS are assumed to be 12.5 m^3/day, consistent with the 2017 PEA. The reported concentrations are summarized in Table A.4 of Appendix A and were included in the estimation of tritium loadings to the forebay.

During the Storage with Surveillance Phase, the only inputs to the TAB IAD sumps will be groundwater. Each TAB IAD sump (one per unit) is connected to two foundation drain systems which were installed to collect groundwater seepage into the TAB basements. The most recent and complete study evaluating groundwater flow and quality through the foundation drain was conducted as part of the Tritium in Groundwater Study Addendum report (CH2M, 2002). The total combined maximum flow rate from the PN U1-4 side foundation drains was 46.5 m^3/day. Based on a combined maximum loading rate of 2.84×10^{10} Bq/day (CH2M, 2002), the predicted tritium concentration from the PN U1-4 IAD to the CCW intake duct in the forebay will be 6.11×10^{5} Bq/L.

For stormwater runoff into the forebay, the maximum concentrations in stormwater from sampling conducted in 2015-2016 were screened against surface water criteria protective of ecological health. The locations of the stormwater sampling locations are shown on Figure 5.2. Parameters that were included in the 2015-2016 sampling program included radiological parameters, petroleum hydrocarbons, BTEX, metals, and general parameters. The selected screening criteria were updated in the 2022 ERA (Ecometrix, 2023) and are presented in Table A.1 of Appendix A. Maximum concentrations at relevant stormwater sampling locations from each of Drain A (MH106 and MH85, from the PN U1-4 side) and Drain B (CB70 and MH20, from the PN U5-8 side) are presented in Tables A.2 and A.3 of Appendix A, along with the results of the screening. The screening found that several radiological and chemical concentrations of contaminants measured in undiluted stormwater exceed screening criteria for ecological health.

COPCs which exceeded screening criteria were carried forward for calculation of diluted forebay concentrations as shown in Table A.5 in Appendix A. Details of the updated forebay mass balance model used to develop concentration factors for the calculated diluted forebay concentrations are presented in Section 6.2.3.2. None of the predicted concentrations shown in Table A.5 exceed screening criteria; however, assessment of radionuclides in the forebay is re-evaluated in the Tier 2 Assessment considering public interest.

Figure 5.2: Stormwater Sampling Locations (Ecometrix and Golder, 2018)

5.2.2.2 Lake Water Quality

As previously discussed in Table 4.1 under Site Drainage and Waterborne Emissions, inactive drainage collected by the TAB foundation sumps and VBRS will not be re-routed to RLWMS, RBSW or the PN U5-8 discharge channel, a change from the 2017 PEA assumption. The revised strategy for inactive drainage is to discharge to the respective PN U1-4 or PN U5-8 CCW intake duct. As a result, less active discharges will be diverted to the RLWMS, and the 2017 PEA assessment of lake water quality remains bounding. In addition, the increase in expected flow rate of the cooling water pumps from 50,000 m^3/day to 250,500 m^3/day will improve the dilution of contaminants discharged at the outfall and will reduce the ΔT between the water intake and discharged water at the outfall. Therefore, with respect to lake water quality, no further Tier 1 or Tier 2 Assessment was required.

5.2.3 Summary of Updated Tier 1 Assessment – Surface Water Environment

- During the Storage with Surveillance Phase, the assumed/expected flow rate of cooling water pumps is increased to 2,899 L/s (250,500 m^3/day), an increase from the 2017 PEA assumption of 50,000 m^3/day. These changes to the predicted flows relative to the bounding scenario considered in the 2017 PEA are expected to improve the dilution of contaminants discharged at the outfall and will reduce the ΔT between the water intake and discharged water at the outfall. Therefore, with respect to lake water quality, no further Tier 2 Assessment is required.

- The increased flow of water through PN U5-8 CCW intake means the previous 2017 PEA assessment for fish impingement and entrainment is no longer bounding. Therefore, impingement and entrainment are further evaluated in the Tier 2 Assessment.

- A hydrodynamic surface water model was developed for the 2017 PEA to predict changes to lake currents, sediment transport and water temperature under current operational conditions and during the Storage with Surveillance Phase. To evaluate continued applicability of the model predictions, lake water physical conditions relevant to surface water modelling including water level, water temperature, and current speed were compared between the 2017 PEA conditions (2011 to 2012 data) and more recent conditions (2016 to 2020 data, and additional data as needed) in Section 4.2.2. Future trends predicted based on climate change models and their impact on the continued applicability of model predictions to 2039 (the time frame for this PEA) was evaluated in Section 4.4. It was concluded that the model provides a reasonable representation of the current and future conditions, and that the concentration factors used in the 2017 PEA are still applicable.

- The 2017 PEA assumed that groundwater contributions to the forebay from the TAB IAD sumps and VBRS would be diverted to the RLWMS during the Storage with Surveillance Phase. Under current planning, the TAB IAD sumps and VBRS will be discharged into the forebay during the Storage with Surveillance Phase, representing a change that is not bounded by the 2017 PEA. The primary contaminant of concern in groundwater is tritium. As such, forebay water quality is re-evaluated in the updated Tier 2 Assessment with the new tritium waterborne contribution.

5.3 Sediment Quality and Transport

As a result of nearshore changes in surface water flow during Stabilization and Storage with Surveillance activities relative to existing operations, the 2017 PEA considered changes to sediment deposition and quality as a result of change in the PN water balance, which could result in a change to water quality. The 2017 PEA considered changes in sediment deposition and erosion, and COPCs reporting to sediments in the forebay and Lake Ontario.

5.3.1 Sediment Transport

As identified previously in Table 4.1 the expected flow rate of cooling water intake into the station is now 2,899 L/s (250,500 m^3/day), an increase from the previous assumption of 50,000 m^3/day. The high flow rates under current operational conditions have historically scoured away sediments from nearshore areas. The 2017 PEA predicted that the reduction in current speed during the Storage with Surveillance phase will result in deposition of sediments to refill the discharge channels and within the forebay structure. Over time, the sediment accumulations were predicted to extend out along the nearshore, connecting to shallow beaches to the east and west of PNGS. The current intake rate of 250,500 m^3/day will still represent a substantial reduction from the operational cooling water flows which were previously discussed in Section 5.2.1. Therefore, the degree of sediment deposition would be expected to be the same or less than predicted for the 2017 PEA and, so the sedimentation effects will remain bounded by the 2017 PEA.

5.3.2 Sediment Quality

Potential effects on sediment were estimated in the 2017 PEA during the Storage with Surveillance Phase within the forebay, since the forebay may become nearshore aquatic habitat. As discussed previously in Section 5.2.2.1, groundwater contributions from the VBRS and the TAB IAD sumps on the PN U1-4 side will become new inputs to the forebay during the Storage with Surveillance Phase that were not previously assessed in the 2017 PEA. These contributions are assessed in an updated Tier 2 ecological risk assessment for the forebay in this PEA Addendum. The focus is on radionuclides as non-radionuclides did not screen in as part of the forebay surface water quality screening. Partitioning of radiological parameters to sediment within the forebay are assessed as part of this update.

Radiological effects on sediment were evaluated for human and ecological dose in the 2017 PEA at nearshore locations affected by concentrations of radiological contaminants at the outfall. Because the concentrations of contaminants at the outfall are not expected to increase based on the updated assumptions presented on Table 4.1, the 2017 PEA assessment for human and ecological dose remains bounding.

5.3.3 Summary of Updated Tier 1 Assessment – Sediment Quality and Transport

- Groundwater contributions to the forebay from the TAB IAD sumps and VBRS during the Storage with Surveillance Phase is considered in the Tier 2 Assessment. An updated ecological risk assessment for receptors in the forebay is conducted and the assessment considers partitioning of waterborne radiological emissions to sediment.

5.4 Groundwater

As described in the 2022 PN ERA, the groundwater flow in the area of the PN site is significantly influenced by the inactive TAB foundation drainage system located beneath the deep building foundations. The inactive TAB foundation drainage system is used to control groundwater beneath the floors. The drainage system has locally lowered groundwater levels below the level of Lake Ontario, creating a hydraulic sink that captures groundwater beneath and immediately adjacent to the PN reactor buildings. Groundwater from the TAB foundation drains flows into each unit's sump and then is discharged to the forebay via pumping. The TAB foundation drains from the PN U1-4 and PN U5-8 sides are discharged to their respective CCW intake ducts.

The VBRS is also a hydraulic sink for the south portion of the PN U1-4 side. The VBRS is located at the bottom of a truck ramp that is installed at basement elevation of the vacuum building and collects shallow groundwater in the vicinity of the building. During operations the groundwater collected in the VBRS is also discharged to the forebay.

Other subsurface features that have the potential to influence groundwater flow at the site include the RLWMS foundation drains and the reactor building (RB) foundation drains. The RLWMS foundation drains and sumps are located at a lower elevation than the TAB foundation drains. The RB foundation drains are installed at a higher elevation and may intercept shallow groundwater.

During the Stabilization and Storage with Surveillance Phases, the groundwater flow regime is not expected to change substantially because these drainage systems are expected to remain operational. However, the 2017 PEA had assumed that discharges from the TAB foundation drains and the VBRS would be routed to the RLWMS (see Section 4.2.3.2.1.4 of the 2017 PEA). As discussed in Table 4.1, the updated assumption is that groundwater discharges from the TAB foundation drains and VBRS will continue to be routed to CCW intake ducts, eventually reaching the forebay.

As a result of the additional groundwater contribution to the forebay from the TAB foundation drains and VBRS sumps during the Storage with Surveillance Phase, the conditions in the forebay have changed from the 2017 PEA. Because there will be intake flows through the PN U5-8 side, the drainage from the PN U5-8 TAB foundation drains will not have any residence time in the forebay; only the TAB foundation drains on the U1-4 side represent a new groundwater contribution. This additional input was previously discussed in the context of surface water quality in Section 5.2.2.1 and will also be assessed quantitatively in the updated Tier 2 Assessment (Section 6.0).

5.4.1 Summary of Updated Tier 1 Assessment – Groundwater

- The overall groundwater flow regime at the PN site was not expected to change in the 2017 PEA and this continues to be the case. The existing subsurface structures which influence groundwater flow and discharge will continue to operate during the Stabilization and the Storage with Surveillance Phases.

- The updated assumption is that groundwater collected from the U1-4 TAB foundation drains and the VBRS will be discharged to the forebay during the Storage with Surveillance Phase, and this represents a new radiological contribution to forebay water quality which is addressed in the Tier 2 Assessment.

5.5 Soil Quality

Historical operations of PNGS have resulted in isolated areas with chemical and radiological contaminants in soil. The 2017 ERA found risk to both human and ecological receptors to be low. No additional soil data was evaluated in the 2022 ERA.

The 2017 PEA predicted that tritium in soil pore water in the area of the PN site will be reduced over time as atmospheric emissions decrease in both the Stabilization and the Storage with Surveillance Phases, and with natural decay. Reduced atmospheric deposition of tritium is expected with the operation of the U4 microscrubber, which was brought into service in 2020, so the baseline tritium in soil may improve. Soil quality in areas outside the protected area is expected to remain in the current condition with the reduction of industrial activity, and with the potential for improvement over time. Therefore, the current soil conditions that were assessed in the 2017 and 2022 ERAs are considered bounding.

5.5.1 Summary of Updated Tier 1 Assessment – Soil Quality

- There are no changes to the soil quality assessment because the assessments in the 2017 and 2022 ERAs are considered bounding to the Stabilization and Storage with Surveillance Phases assessed in the 2017 PEA.

6.0 Updated Tier 2 Assessment – Ecological Risk Assessment for the Forebay

The quantitative portion of this 2022 PEA update is focused on an updated assessment of potential ecological risks in the forebay during the Storage with Surveillance Phase, when cooling water intake flows are expected to decrease, and groundwater contributions will be introduced to the forebay that were not previously assessed in the 2017 PEA.

Assessment of human health at potential critical group locations, and ecological health in the outfall and at Frenchman's Bay was part of the 2017 PEA but are not re-assessed in this 2022 PEA update because the updated Tier 1 Assessment did not identify any increased interactions to the environment, indicating that the previous assessments are considered bounding.

6.1 Ecological Conceptual Site Model

The conceptual model illustrates how receptors are exposed to contaminants of potential concern. It represents the relationship between the source and receptors by identifying the source of contaminants, receptor locations and the exposure pathways to be considered in the assessment for each receptor. Exposure pathways represent the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or (for radionuclides) how they may exert effects from outside the body.

6.1.1 Receptor Selection

Consistent with the 2017 PEA, the forebay structure will act as an artificial embayment, and as such will be more quiescent, warmer and more depositional than the adjacent lake (Lake Ontario). Hypothetical aquatic receptors, including fish, aquatic plants (macrophytes), invertebrates, and riparian mammals and birds, would potentially be present in the forebay during the Storage with Surveillance Phase.

VECs for the forebay were selected as receptors for the conceptual model based on the criteria in Table 4.1 of the PN ERA (Ecometrix, 2023), which are guided by the criteria for receptor selection identified in N288.6-12 (CSA, 2012). VEC species were selected to represent each major plant and animal group, reflecting the main ecological exposure pathways, feeding habits and habitats at or around the site. The criteria for selection began with previous rationale and was supplemented with other literature resources and recent information. Species that were ecologically similar to other species and could be represented by another species, were not included in the assessment to reduce redundancy in the exposure calculations.

The VECs for the forebay are a subset of VECs selected for the 2022 PN ERA and are consistent with those assessed in the 2017 PEA. The only exception is that Alewife *(Alosa pseudoharengus)* was replaced with Emerald Shiner *(Notropis atherinoides)* for one of the pelagic fish. This was consistent with the change that was made in the 2022 PN ERA where Emerald Shiner was selected as the VEC in place of Alewife, in order to address recommendations by Environment and Climate Change Canada (ECCC) to evaluate the area of thermal effects on Emerald Shiner habitat (OPG, 2018c). Any effects on the Emerald Shiner are considered representative of those for other small bodied pelagic fish.

Table 6.1 shows the VECs chosen for assessment of the forebay and the assessment models used in estimating their COPC exposure, dose and risk. While multiple fish species were selected, due to the limited species-specific exposure factor and toxicity data available, risks to fish are estimated by assessing the fish in two categories (benthic fish and pelagic fish) for the radiological assessment, using generic exposure and dose assessment models.

Table 6.1: Summary of VECs and their Assessment Models used in the EcoRA for the Forebay

VEC Category	Assessment Model	VEC
Aquatic Invertebrates	Benthic Invertebrate	Benthic Invertebrates
Aquatic Plants	Aquatic Plant	Macrophytes
Fish	Benthic Fish	American Eel
		Brown Bullhead
		Round Whitefish
		White Sucker
	Pelagic Fish	Emerald Shiner
		Lake Trout
		Northern Pike
		Smallmouth Bass
		Walleye
Riparian Birds	Bufflehead	Bufflehead
	Common Tern	Common Tern
	Trumpeter Swan	Trumpeter Swan
	Ring-billed Gull	Ring-billed Gull
Riparian Mammals	Muskrat	Muskrat

A review of all flora and fauna identified in the PN Site Study Area was performed as part of the PN ERA. Species at risk have been identified on site and are represented by other ecologically similar species.

As the focus of the forebay assessment is on the aquatic environment, only aquatic species at risk are relevant. Based on the PN ERA, the only aquatic species at risk identified was the American Eel. The American Eel is listed as endangered under Ontario's Endangered Species Act (ESA) and is listed as threatened under Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and not listed, but under consideration for addition to Schedule 1 of the federal Species at Risk Act. American Eel was identified as a VEC; however, since it is a species at risk, the assessment endpoint is the health of the individual. This is consistent with what is recommended in Clause 7.2.4.3 of CSA N288.6-12 (CSA, 2012), since effects on even a few individuals of species at risk may not be acceptable.

6.1.2 Assessment and Measurement Endpoints

Assessment endpoints are explicit expressions of the environmental values that are to be protected (FCSAP, 2012). Assessment endpoints should include the VEC and the attribute of the VEC that is to be protected (e.g. abundance or population viability) (FCSAP, 2012). The assessment endpoints to be evaluated in this predictive Ecological Risk Assessment (EcoRA) are presented in Table 6.2 and are consistent with those identified in the PN ERA.

Measurement endpoints are conceptually related to assessment endpoints and are defined as attributes that are used to measure or estimate effects on each VEC. Based on these measures, a potential for effect on the attribute of an assessment endpoint can be inferred. Measurement endpoints are the foundation for the lines of evidence that are used to estimate risks to VECs (FCSAP, 2012).

Measurement endpoints for COPCs are often linked to low-effect threshold concentrations or doses, also known as toxicological reference values (TRVs). The TRV represents the level of COPC exposure that is associated with a minimal and acceptable level of effect to the VEC. The TRVs typically used in EcoRA are based on growth, survival and reproduction measurement endpoints. They represent effects on individuals that are relevant to the viability of VEC populations.

For most VECs, the assessment endpoint is the viability of the population. This implies that very localized areas of effect on individuals may be tolerated, based on minimal expected effect at the population level. For species at risk (SAR), the assessment endpoint is individual health, recognizing that each individual is important to the population, thus any exceedance of a measurement endpoint is considered unacceptable.

Table 6.2: Assessment Endpoints, Measurement Endpoints, and Lines of Evidence

Valued Ecosystem Components	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Use of Measurement Endpoints for Specific LOEs
Benthic Fish (Brown Bullhead, Round Whitefish, White Sucker, American Eel *)	Population	Protect, restore, and sustain the diversity of the nearshore fish community, with an emphasis on self-sustaining native fishes	Viability of benthic fish populations	Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Pelagic Fish (Emerald Shiner, Smallmouth Bass, Lake Trout, Walleye, Northern Pike)	Population	Maintain the offshore pelagic fish community that is characterized by a diversity of trout and salmon species, in balance with prey-fish populations and lower trophic levels.	Viability of pelagic fish populations.	Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Aquatic Plants (Macrophytes)	Population	Maintenance of aquatic plant populations in the forebay as a source of food and cover for wildlife.	Viability of aquatic plant populations.	Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Benthic Invertebrates	Community	Maintenance of a diverse aquatic and benthic invertebrate community in the forebay as source of food for fish and wildlife.	Richness, diversity, abundance of benthic invertebrates.	Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Riparian Birds (Trumpeter Swan, Ring-billed Gull, Common Tern, Bufflehead)	Population	Maintenance of riparian bird populations along Lake Ontario shoreline as source of food for predatory wildlife.	Viability of aquatic riparian bird populations	Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Riparian Mammals (Muskrat)	Population	Maintenance of riparian mammal population along Lake Ontario shoreline as source of food for predatory wildlife.	Viability of aquatic riparian mammal populations.		

* For SAR, the goal is protection of all individuals, recognizing that each individual's health is important to the population, thus any toxicological reference value or radiation dose benchmark exceedance is considered unacceptable.

6.1.3 Selection of Exposure Pathways

Exposure pathways include the routes of contaminant dispersion from the source to receptor location and the routes of contaminant transport through the food chain to the receptor organism. Both are considered, as appropriate to the species and location, using predicted concentrations of COPCs for safe storage. Table 6.3 summarizes the relevant exposure pathways for each type of ecological receptor (VEC).

For fish and aquatic plants, contact with water and contaminant uptake from water via bioaccumulation represents the main exposure pathway. For riparian birds and mammals, dominant exposure pathways are through the uptake of contaminants via the ingestion of water, incidental ingestion of soil or sediment, and ingestion of food.

Airborne COPCs partition to soil and plants, and ingestion pathways dominate over inhalation and air immersion for most COPCs. The inhalation and immersion pathways will be omitted for ecological receptors in this assessment, and therefore are not included in Table 6.3.

The list of receptors and exposure pathways are unchanged from the 2017 PEA, with exception of the Emerald Shiner, which was selected as a VEC in place of Alewife, for consistency with the 2022 ERA.

Table 6.3: Complete Exposure Pathways for All Selected VEC Species in the Forebay

VEC Category	VEC	Exposure Pathways	Environmental Media
Aquatic Invertebrates	Benthic Invertebrates	Direct Contact*	Sediment
Aquatic Plants	Macrophytes	Direct Contact*	Water Sediment
Benthic Fish	American Eel	Direct Contact*	Water Sediment
	Brown Bullhead	Direct Contact*	Water Sediment
	Round Whitefish	Direct Contact*	Water Sediment
	White Sucker	Direct Contact*	Water Sediment
Pelagic Fish	Emerald Shiner	Direct Contact*	Water
	Lake Trout	Direct Contact*	Water
	Northern Pike	Direct Contact*	Water
	Smallmouth Bass	Direct Contact*	Water
	Walleye	Direct Contact*	Water
Riparian Birds	Bufflehead	Ingestion	Water Sediment Benthic Invertebrate Aquatic Plant
	Common Tern	Ingestion	Water Sediment Benthic Invertebrate

VEC Category	VEC	Exposure Pathways	Environmental Media
			Pelagic Fish
	Trumpeter Swan	Ingestion	Water Sediment Aquatic Plant
	Ring Billed Gull	Ingestion	Water Sediment Aquatic Plant Pelagic Fish Benthic Invertebrate Muskrat
Riparian Mammals	Muskrat	Ingestion	Water Sediment Aquatic Plant

*Direct contact for aquatic organisms includes their indirect uptake of contaminants through the food chain, which is included in the measured bioaccumulation factors.

6.1.4 Summary of Conceptual Site Model

The conceptual site model (CSM) illustrates how receptors are exposed to COPCs. It represents the relationship between the source and receptors by identifying the source of contaminants, receptor locations and the exposure pathways to be considered in the assessment for each receptor. The CSM for the forebay EcoRA is illustrated in Figure 6.1 and has not changed from the conceptual model presented in the 2017 PEA. For completeness, the air exposure pathway is shown, but can usually be ignored since it is usually minor compared to the soil or sediment ingestion exposure (CSA, 2012). Exposures to noble gases in air can be important, since air is the dominant pathway for noble gases; however, noble gas emissions are not expected during the Storage with Surveillance Phase; therefore, noble gases were not assessed.

In addition, the CSM figure incorporates generalizations where, for the ease of representation, some VECS are grouped together by category. For example, all the pelagic fish, regardless of size and habits, are shown to be consumed by the Common Tern and the Ring-billed Gull, although their diets would consist of differing types of fish.

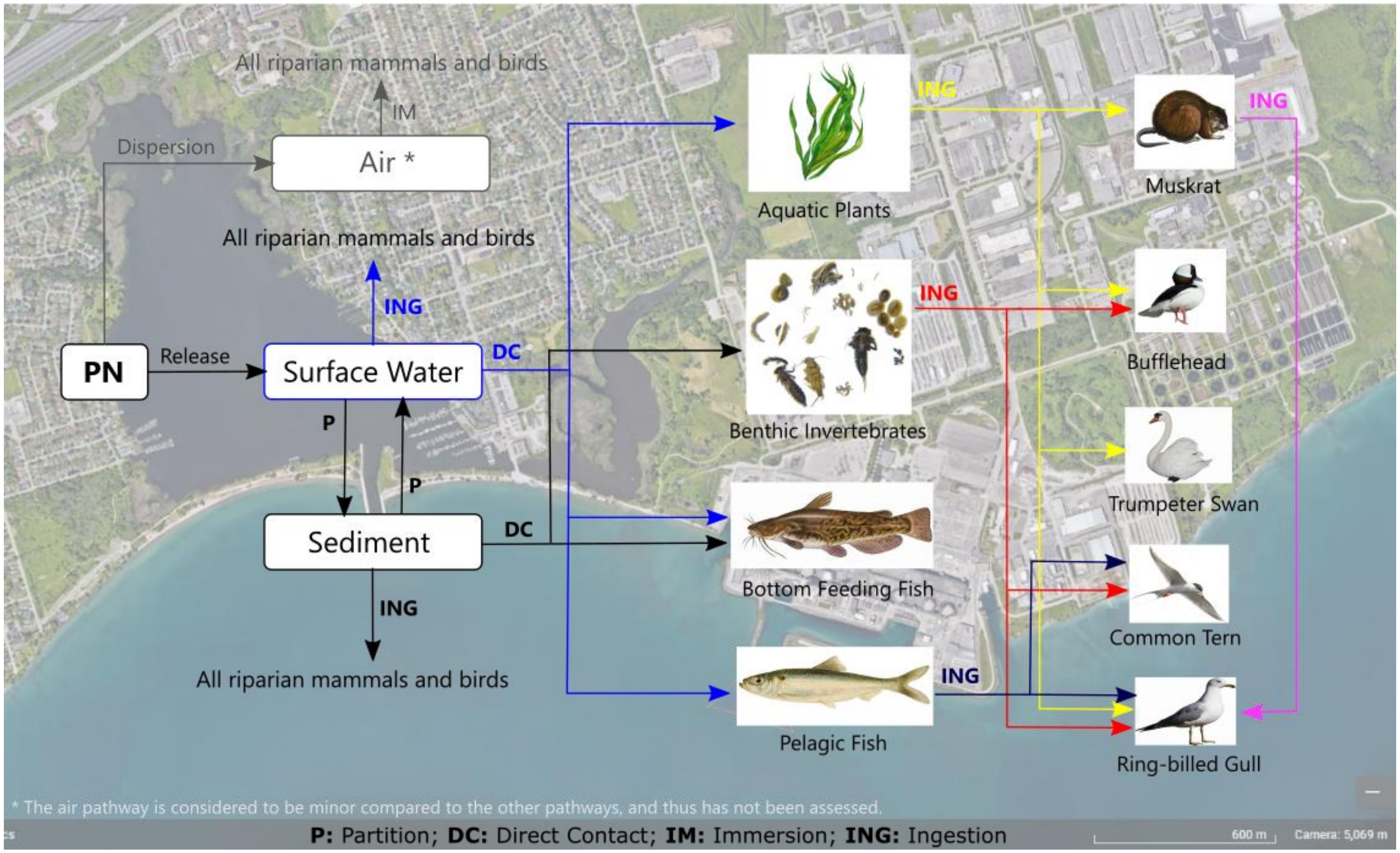


Figure 6.1: Conceptual Model for the Predictive Ecological Risk Assessment in the Forebay

6.2 Exposure Assessment

6.2.1 Exposure Point Concentrations

Exposure point concentrations at the receptor locations are estimated from the surface water model, using partitioning or bioconcentration factors to estimate other media concentrations. All ecological receptors evaluated are located in the forebay. The other locations assessed during the 2017 PEA were considered bounding in the 2017 PEA and are not updated for this PEA addendum.

6.2.1.1 Exposure Averaging

Receptors were exposed to maximum concentrations expected during the Storage with Surveillance Phase. Protection of receptors at maximum concentrations ensures that the assessment is bounding if concentrations are lower.

6.2.1.2 Environmental Partitioning

Water to sediment partitioning is described by the following equation:

$$k_d = \frac{C_{s(fw)}}{C_w}$$

where,

$C_{s(fw)}$ = concentration in sediment (Bq/kg FW)
C_w = concentration in water (Bq/L)
k_d = distribution coefficient (L/kg solid)

To estimate sediment concentrations in the forebay, sediment distribution coefficients (k_d) from CSA (2020) were used in the environmental partitioning calculations. They are listed in Table 6.4.

Table 6.4: Sediment Distribution Coefficients

COPC	Distribution Coefficient (k_d) (L/kg dw)	Reference
Tritium	0	CSA, 2020
Carbon-14	50	CSA, 2020
Cobalt-60	43,000	CSA, 2020
Cesium-134	9,500	CSA, 2020
Cesium-137	9,500	CSA, 2020

6.2.2 Exposure and Dose Calculations

6.2.2.1 Radiological Dose Calculations

Radiological doses were estimated using the Ecometrix software IMPACT DRL Version 5.5.2 (IMPACT). IMPACT is consistent with the equations outlined in CSA N288.1-14 (CSA, 2014) and CSA N288.1-20 (CSA, 2020) and the methods outlined in CSA N288.6-12. The equations are the same between the 2014 and 2020 versions of the CSA N288.1 standard; therefore the EcoRA is compliant with both the 2014 and 2020 versions of the standard. The updated database from CSA N288.1-20 was used for the radiological dose calculations, which includes an updated stable carbon content for freshwater invertebrates.

The radiation doses for the aquatic biota were estimated using the methods outlined in CSA N288.6-12 (CSA, 2012). The dose for each radionuclide is comprised of an internal dose component, and an external dose component, which is driven by water and sediment. The 0.5 multiplication factor in the equation is for semi-infinite exposure to activity in water, for the time the organism spends at water surface, and a semi-infinite exposure to activity in sediment, for the time the organism spends at sediment surface. The aquatic biota dose was calculated using the following equations:

$$D_{int} = DC_{int} \cdot C_t$$

$$D_{ext} = DC_{ext} \cdot [(OF_w + 0.5 \cdot OF_{ws} + 0.5 \cdot OF_{ss}) \cdot C_w + (OF_s + 0.5 \cdot OF_{ss}) \cdot C_s]$$

where,

D_{int} = internal radiation dose (μGy/d)
D_{ext} = external radiation dose (μGy/d)
DC_{int} = internal dose conversion factor ((μGy/d)/(Bq/kg))
DC_{ext} = external dose coefficient ((μGy/d)/(Bq/kg))
C_t = whole body tissue concentration (Bq/kg fw)
C_w = water concentration (Bq/L)
C_s = sediment concentration (Bq/kg fw)
OF_w = occupancy factor in water (unitless)
OF_{ws} = occupancy factor at water surface (unitless)
OF_{ss} = occupancy factor at sediment surface (unitless)
OF_s = occupancy factor in sediment (unitless)

The radiation dose to riparian wildlife is estimated using the equation for terrestrial biota, with the external dose component driven sediment, since riparian animals are typically in shoreline situations. The equations used to estimate radiation dose riparian wildlife are:

$$D_{int} = DC_{int} \cdot C_t$$

$$D_{ext} = DC_{ext,s} \cdot OF_s \cdot C_s + DC_{ext,ss} \cdot OF_{ss} \cdot C_s$$

where,

DC_{int}	=	internal dose coefficient ((μGy/d)/(Bq/kg))
$DC_{ext,s}$	=	external dose coefficient (in sediment) ((μGy/d)/(Bq/kg))
$DC_{ext,ss}$	=	external dose coefficient (on sediment surface) (μGy/d)/(Bq/kg))
C_t	=	whole body tissue concentration (Bq/kg fw)
C_s	=	sediment concentration (Bq/kg dw)
OF_s	=	occupancy factor in sediment (unitless)
OF_{ss}	=	occupancy factor at sediment surface (unitless)

The total radiation dose to biota is the sum of the internal and external dose components for each radionuclide (D_{int} + D_{ext}). External exposures through the air immersion and inhalation pathway are considered to be minor compared to the ingestion pathway, and were not included in the assessment (CSA, 2012). The emissions of noble gases are expected to be minor or eliminated during the Storage with Surveillance Phase. As discussed in Section 4.1.2.2 of the 2017 PEA (Golder and Ecometrix, 2017), the primary source term for radioactive noble gases will be eliminated from the reactor buildings once the units are defueled, although a minor source could remain in the IFBs Currently noble gas emissions from the IFBs are typically at detection limits.

The dose coefficients and occupancy factors used in the radiological dose estimation are provided in Section 6.2.2.4.

6.2.2.2 Non-Radiological Dose Calculations

No non-radiological contaminants of potential concern were carried forward from the screening assessment, therefore non-radiological exposure and dose calculations were not required.

6.2.2.3 Tissue Concentration Calculations

In cases where tissue concentrations (C_t) were not measured in aquatic plants, invertebrates or fish, the tissue concentrations were derived using bioaccumulation factors (BAFs), as per CSA N288.6-12, as follows:

$$C_t = C_m \cdot BAF$$

where,

C_t	=	whole body tissue concentration (Bq/kg fw)
C_m	=	media concentration (Bq/L or Bq/kg)
BAF	=	bioaccumulation factor (L/kg or kg/kg)

For riparian birds and mammals, tissue concentrations were estimated using transfer factors (TFs), or biomagnification factors (BMFs) and the concentrations in their food, as follows:

$$C_t = \Sigma\, C_x \cdot I_x \cdot TF = C_f \cdot BMF$$

where,

C_x	=	concentration in the ingested item x (Bq/kg fw)
I_x	=	ingestion rate of item x (kg fw/d)
TF	=	ingestion transfer factor (d/kg)
C_f	=	average concentration in food (Bq/kg fw)
BMF	=	biomagnification factor (unitless)

The BMF is equivalent to the total food intake rate times the transfer factor:

$$BMF = \Sigma I_x \cdot TF$$

The BAFs, TFs and ingestion rates used for the calculation of tissue concentrations in biota are further described in Section 6.2.2.4.

6.2.2.4 Exposure Factors

There are several COPC- and biota-specific exposure factors required for the dose calculations discussed in Section 4.2.3. These parameters include intake rates, body weights, occupancy factors, BAFs, TFs, and dose coefficients (DCs).

6.2.2.4.1 Body Weight and Intake Rates

The body weight and intake rates are required for the calculation of exposure to birds and mammals. The body weights and total feed intake rates are consistent with those in the 2022 PN ERA (Ecometrix, 2023), except that the ring-billed gull at the outfall for this assessment had the same diet as the ring-billed gull at Frenchman's Bay in the PN ERA. These were taken from the 2000 ERA (SENES, 2000), where the assumptions and values were considered to be applicable. For receptors not assessed in the 2000 ERA, body weights were found in literature, as identified on Table 6.5, and feed intake rates were proportioned to body weight using allometric equations from the U.S. EPA (US EPA, 1993). The water intake and inhalation rates were determined using allometric equations for all birds and mammals. The incidental ingestion of soil and sediment was estimated based on the feed intake. The incidental ingestion varied from 2% to 10.4% of dry weight food intake depending on the biota. The values are summarized in Table 6.5.

Table 6.5: Bird and Mammal Body Weights and Intake Rates

Receptor	Body Weight	Total Feed Intake		Dietary Components	Feed Type Fraction		Feed Intake Rate		Moisture [g]	Percentage of Soil & Sediment [b, e]	Total Soil/ Sediment Intake Rate [f]	Water Intake Rate [c]	Inhalation Rate [c]
	kg	kg dw/d	kg fw/d		fw	dw	kg dw/d	kg fw/d	unitless	%	kg dw/d	L/d	m^3/day
Trumpeter Swan	11 [a, b]	0.347 [a, b]	1.39	Aquatic plants (cattail)	1.0	1.0	0.347	1.39	0.75	3.3	1.14E-02	0.29	2.59
Ring-Billed Gull	0.7 [a]	0.0498 [a]	0.195	Aquatic plants (cattail)	0.2	0.20	0.0098	0.039	0.75	3.3	1.64E-03	0.0465	0.311
				Fish (pelagic forage)	0.6	0.59	0.0293	0.117	0.75				
				Benthic invertebrates	0.1	0.10	0.0049	0.020	0.75				
				Muskrat	0.1	0.12	0.0059	0.020	0.70				
Common Tern	0.125 [b]	0.0150 [b]	0.060	Fish (pelagic forage)	0.9	0.90	0.014	0.054	0.75	2.0	3.00E-04	0.015	0.08
				Benthic invertebrates	0.1	0.10	0.002	0.006	0.75				
Bufflehead	0.473 [b]	0.045	0.179 [b]	Aquatic plants (cattail)	0.1	0.10	0.004	0.018	0.75	10.4	4.65E-03	0.036	0.23
				Benthic Invertebrates	0.9	0.90	0.040	0.161	0.75				
Muskrat	1.175 [a, c]	0.088	0.353 [a]	Aquatic plants (cattail)	1.0	1.0	0.088	0.353	0.75	3.3	2.91E-03	0.114	0.62

Notes:
a – (SENES, 2000)
b – (Ecometrix and Golder, 2018)
c – (US EPA, 1993)
d – (CSA, 2020)
e – Total obtained from (Beyer et al., 1994). The % intake of soil and/or sediment is calculated from the combined intake of soil and sediment and based on the relative proportions of terrestrial vs. aquatic dietary components for each receptor.
f – Total Feed Type x Fraction of Soil & Sediment
g – (Beresford et al., 2008) for earthworm and (CSA, 2020) for all others.

6.2.2.4.2 Occupancy Factors

The fraction of time the biota resides in the PN site area is assumed to be one. An occupancy factor is defined as the fraction of time the receptor species spends in or on various media. The occupancy factors are consistent with those used in the 2022 ERA (Ecometrix, 2023). For new biota, the occupancy factors are based on the experience and judgement of the risk assessor and the known behaviour of the receptor. The occupancy factors used in the radiological dose estimation are given in Table 6.6, and are applied to the equations discussed in Section 6.2.2.1.

Table 6.6: Receptor Occupancy Factors

Aquatic Biota	OF_s	OF_{ss}	OF_w	Terrestrial Biota	OF_s	OF_{ss}
Benthic Fish	-	0.5	0.5	Riparian Birds	-	0.5
Pelagic Fish	-	-	1.0	Muskrat	-	0.5
Benthic Invertebrates	1.0	-	-			
Aquatic Plants	-	0.5	0.5			

Notes:
OF_s = occupancy factor in soil/sediment
OF_{ss} = occupancy factor on soil/sediment surface
OF_w = occupancy factor in water

6.2.2.4.3 Bioaccumulation Factors

Bioaccumulation factors relate the COPCs in the environmental media to the concentration in the receptor. Since tissue concentrations were not available for the receptors at the PN site, BAFs were used to calculate COPC concentrations in plant, invertebrate and fish tissues. These factors vary throughout the literature. For the exposure assessment, BAFs were taken from N288.1-20 (CSA, 2020). The BAFs used in the assessment are presented in Table 6.7. Bioaccumulation factors for tritium and carbon-14 are calculated using the specific activity model, which is discussed in Section 6.2.2.4.6 and 6.2.2.4.7.

Table 6.7: Bioaccumulation Factors (BAFs) for Fish, Amphibians, Benthic Invertebrates, and Aquatic Plants (L/kg fw)

COPC	Fish	Benthic Invertebrate	Aquatic Plant
Cobalt-60	5.40E+01	1.10E+02	7.90E+02
Cesium-134	3.50E+03	9.90E+01	2.20E+02
Cesium-137	3.50E+03	9.90E+01	2.20E+02

Notes:
All from CSA N288.1-20 (CSA, 2020)

6.2.2.4.4 Transfer Factors

Transfer factors represent the fraction of daily COPC intake transferred to the tissue of birds and mammals. Ingestion transfer factors are COPC and biota-specific. Transfer factors from feed to tissue for agricultural livestock are available in CSA (CSA, 2020). An allometric equation (transfer proportional to a -3/4 power of body weight) (CSA, 2012), was applied to transfer factors available for beef, rabbit and poultry, to estimate the transfer factors for the bird and mammal receptors. The derived transfer factors are presented in Table 6.8. The transfer factors for tritium and carbon-14 were derived using specific activity methods, which are discussed in Section 6.2.2.4.6 and 6.2.2.4.7.

Table 6.8: Transfer Factors for Riparian Birds and Mammals (d/kg fw)

COPC	Trumpeter Swan	Ring-Billed Gull	Common Tern	Bufflehead	Muskrat
Cobalt-60	2.70E-01	2.13E+00	7.76E+00	2.86E+00	4.62E-02
Cesium-134	7.52E-01	5.93E+00	2.16E+01	7.96E+00	2.36E+00
Cesium-137	7.52E-01	5.93E+00	2.16E+01	7.96E+00	2.36E+00

Notes:
Derived from beef and poultry transfer factors from (CSA, 2020)

6.2.2.4.5 Dose Coefficients

Radiation dose coefficients (DCs) used for terrestrial and aquatic biota are shown in Table 6.9. These DCs were taken from ICRP (ICRP, 2008) and the ERICA Tool 1.2.1, 2016 (Beresford et al., 2008). The surrogate species from these sources were selected to represent the VECs in this ERA, considering similarities in body size and likely external exposure media. The DC values for tritium in both sources (ICRP, 2008) and ERICA Tool 1.2.1, 2016 (Beresford et al., 2008) do not incorporate radiation quality factors for relative biological effectiveness (RBE). Therefore, the "low beta" components of the DCs were multiplied by 2 (as per CSA N288.6-12) in order to represent its greater relative effectiveness.

Table 6.9: Dose Coefficients of Surrogate Receptors Used for Radiological Exposure Calculations

Radionuclide	Rat		Trout		Seaweed	
	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (on soil) (μGy/hr)/(Bq/m^2)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (in water) (μGy/hr)/(Bq/kg ww or Bq/L)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (μGy/hr)/(Bq/kg ww or Bq/L)
Carbon-14	2.83E-05	0.00E+00	2.83E-05	1.79E-08	2.83E-05	2.17E-07
Cobalt-60	1.67E-04	7.92E-06	2.13E-04	1.29E-03	8.75E-05	1.42E-03
Cesium-134	1.71E-04	5.00E-06	2.04E-04	7.92E-04	1.13E-04	8.75E-04
Cesium-137	1.71E-04	1.88E-06	1.83E-04	2.83E-04	1.38E-04	3.29E-04
Tritium	5.76E-06	0.00E+00	5.76E-06	3.54E-13	5.76E-06	2.33E-09

Radionuclide	Tadpole		Duck		Insect Larvae	
	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (in water) (μGy/hr)/(Bq/kg ww or Bq/L)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (on soil) (μGy/hr)/(Bq/m^2)	Internal DC (μGy/hr)/(Bq/kg fw)	External DC (μGy/hr)/(Bq/kg ww or Bq/L)
Carbon-14	2.83E-05	2.29E-07	2.83E-05	0.00E+00	2.80E-05	8.20E-07
Cobalt-60	6.25E-05	1.42E-03	2.38E-04	7.50E-06	5.20E-05	1.40E-03
Cesium-134	9.58E-05	9.17E-04	2.21E-04	5.00E-06	7.20E-05	9.20E-04
Cesium-137	1.33E-04	5.42E-07	1.88E-04	1.79E-06	9.80E-05	3.70E-04
Tritium	5.76E-06	1.33E-11	5.76E-06	0.00E+00	5.78E-06	2.40E-13

Notes:
Seaweed, rat, trout, tadpole and duck DCs from (ICRP, 2008)
Insect larvae DC from ERICA Assessment Tool 1.2.1 (Brown et al., 2008)
Insect larvae is used for benthic invertebrates, seaweed for aquatic plants, rat for muskrat, and duck for all riparian birds.

6.2.2.4.6 Specific Activity Model for Tritium

IMPACT was used to estimate tritium and C-14 tissue concentrations using specific activity models as outlined in CSA N288.1 (2020) and as recommended in Clause 7.3.4.3.7 of CSA N288.1-16 (CSA, 2012).

Aquatic BAFs for tritium assume that the specific activity in the aqueous component of the aquatic animal or plant is the same as the specific activity in the water. BAFs are used to calculate tritium concentrations in plant, invertebrate and fish tissues. Therefore, the BAF (L/kg-fw) is:

$$BAF_{a\_HTO} = 1\text{-}DW_a$$

or

$$BAF_{p\_HTO} = 1\text{-}DW_p$$

where,

$1\text{-}DW_a$ = water content of the animal (L water /kg-fw)
$1\text{-}DW_p$ = water content of the plant (L water /kg-fw plant)

Aquatic BAFs for OBT assume that the specific activity of tritium in the combustion water of the dry matter of the organism is equal to the specific activity in the aqueous phase, apart from an isotopic discrimination factor. Because the concentration in the aqueous phase is equal to the surface water concentration, the BAF from HTO concentration in surface water to OBT in aquatic organism (L/kg-fw) is:

$$BAF_{a\_OBT} = DW_{aa} \cdot ID_{aa} \cdot WE_{aa}$$

or

$$BAF_{p\_HTO} = DW_{ap} \cdot ID_{ap} \cdot WE_{ap}$$

where,

DW_{aa} = dry weight of aquatic animal tissue per total fresh weight (kg dw/kg fw)
ID_{aa} = isotopic discrimination factor for aquatic animal metabolism (unitless)
WE_{aa} = water equivalent of the aquatic animal dry matter (L/kg dw)
Dwap = dry weight of aquatic plant per total fresh weight (kg dw/kg fw)
ID_{ap} = isotopic discrimination factor for aquatic plant metabolism (unitless)
WE_{ap} = water equivalent of the aquatic plant dry matter (L/kg dw)

All aquatic BAFs for HTO and OBT, which are derived from a specific activity model, are summarized in Table 6.10.

Table 6.10: Summary of BAFs for Tritium, OBT and Carbon-14

Receptor	Units	Tritium	OBT	Carbon-14	References
Fish	L/kg fw	7.50E-01	1.4E-01	5.70E+03	(CSA, 2020)
Aquatic Plants	L/kg fw	7.50E-01	1.1E-01	5.90E+03	(CSA, 2020)
Benthic Invertebrates	L/kg fw	7.50E-01	1.4E-01	5.20E+03	(CSA, 2020)

For HTO and OBT, the majority of the tritium taken into a bird or mammal is from water ingestion and food consumption. The sediment ingestion pathway is negligible for HTO and OBT. Consistent with the CSA equations, IMPACT was used to determine the transfer of HTO to animals ($P_{HTOwater\_animal}$, L/kg-fw) through water ingestion and is calculated as follows (CSA, 2020):

$$P_{HTOwater\_animal} = k_{aw} \cdot f_{w\text{-}w} \cdot (1\text{-}DW_a)$$

where,

k_{aw} = fraction of water from contaminated sources
$f_{w\text{-}w}$ = fraction of the animal water intake derived from direct ingestion of water
DW_a = dry/fresh weight ratio for animal tissue (kg-dw/kg-fw), 0.3 from N288.1-20 (CSA, 2020)

A portion of the HTO transferred from water to animal is metabolically converted to OBT ($P_{OBTwater\_animal}$, L/kg-fw), which is calculated as follows:

$$P_{OBTwater\_animal} = P_{HTOwater\_animal} \cdot f'_{OBT}$$

where,

$P_{HTOwater\_animal}$ = transfer of HTO from drinking water to the portion of water in the animal derived from drinking water.
f'_{OBT} = OBT/HTO ratio in the animal as a result of HTO ingestion (unitless)

The transfer of HTO to animals through food ingestion ($P_{HTOfood\_animal}$, unitless) was also determined in IMPACT using the specific activity model from CSA, and is calculated as follows:

$$P_{HTOfood\_animal} = k_{af} \cdot ((1\text{-}f_{OBT}) \cdot f_{w\text{-}pw} + 0.5 \cdot f_{w\text{-}dw}) \cdot (1\text{-}DW_a) / (1\text{-}DW_p)$$

where,

k_{af} = fraction of food from contaminated sources
$f_{w\text{-}pw}$ = fraction of the animal water intake derived from water in plant/food
$f_{w\text{-}dw}$ = fraction of the animal water intake that results from the metabolic decomposition of the organic matter in food
f_{OBT} = fraction of total tritium in the animal tissue in the form of OBT as a result of HTO ingestion

$1\text{-}DW_a$ = water content of the animal tissue (L water/kg-fw)
$1\text{-}DW_p$ = water content of the plant/food (L water/kg-fw plant)

The transfer of OBT to animals through food ingestion ($P_{OBTfood\_animal}$, unitless) was also determined in IMPACT using the specific activity model from CSA, and is calculated as follows (CSA, 2020):

$$P_{OBTfood\_animal} = k_{af} \cdot (f_{OBT} \cdot f_{w\text{-}pw} + 0.5 \cdot f_{w\text{-}dw}) \cdot DW_a \cdot WE_a / (DW_p \cdot WE_p)$$

where,

k_{af} = fraction of food from contaminated sources
$f_{w\text{-}pw}$ = fraction of the animal water intake derived from water in plant/food
$f_{w\text{-}dw}$ = fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the plant/food
f_{OBT} = fraction of total tritium in the animal tissue in the form of OBT as a result of HTO ingestion
WE_a = water equivalent of the animal tissue dry matter (L water/kg dw product)
WE_p = water equivalent of the plant/food dry matter (L water/kg dw product)
DW_a = dry/fresh weight ratio for animal tissue (L water/kg-fw)
DW_p = dry/fresh weight ratio for the plant/food (L water/kg-fw plant)

For each receptor, the transfer from each food item is calculated separately based on the water content of the individual food items in the receptor's diet.

Input parameters for the specific activity models can be found in Table 6.11.

Table 6.11: Input Parameters for Specific Activity Calculations for Tritium

Receptor	f_{w_ww}	f_{w_pw}	f_{w_dw}	f_{OBT}
Trumpeter Swan	0.22	0.65	0.121	0.1
Ring-billed Gull	0.22	0.65	0.121	0.1
Common Tern	0.22	0.65	0.121	0.1
Bufflehead	0.22	0.65	0.121	0.1
Muskrat	0.413	0.509	0.071	0.11

Notes:
From Table 16 and 17 in CSA N288.1-20 (2020)

6.2.2.4.7 Specific Activity Model for Carbon-14

Aquatic BAFs for carbon-14 assume that the carbon-14 to stable carbon ratio in aquatic animals is equal to the ratio in dissolved inorganic carbon in the water. Therefore, the BAF (L/kg-fw) for aquatic animals, invertebrates, and plants is calculated as follows:

$$BAF_{C14} = S_a/S_w$$

where,

S_a = stable carbon content in the aquatic animal/invertebrate/plant (gC/kg-fw)
S_w = mass of stable carbon in the dissolved inorganic phase in water (gC/L)

Consistent with N288.1-20 (CSA, 2020), S_w is 0.0213 gC/L. The stable carbon content for fish of 121.75 gC/kg-fw was used (CSA, 2020). For freshwater invertebrates the stable carbon content of 120 gC/kg-fw or 480 gC/kg-dw was considered appropriate based on zooplankton and benthic insects (CSA, 2020). For aquatic plants the stable carbon content for terrestrial plants of 500 gC/kg-dw or 125 gC/kg-fw was considered appropriate (CSA, 2020). A dry weight fraction of 0.25 was assumed for aquatic plants to convert the stable carbon content from dry weight to fresh weight (CSA, 2020; US EPA, 1993). The stable carbon concentrations for all food types are presented in Table 6.12.

Table 6.12: Stable Carbon Content for Food Types

Food Type	Stable Carbon Content (S_a, S_p) (gC/kg fw)	Reference
aquatic plants	125	CSA N288.1-20 (CSA, 2020)
fish	122	
small mammals	201	
benthic invertebrates	120	
birds	244	

6.2.3 Models

6.2.3.1 IMPACT model

The IMPACT model was used to evaluate the transport and effects of radiological contaminants to ecological receptors. Details of the modeling assumptions and inputs have been described previously in Section 6.2.2 and are consistent with the 2022 ERA (Ecometrix, 2023).

6.2.3.2 Forebay Discharge Modelling

As part of the 2017 PEA, a mass balance model was developed for the forebay to predict tracer concentrations in the forebay for the Storage with Surveillance Phase. The results were used to develop forebay/inflow concentration factors used to estimate exposure concentrations in the forebay, as presented in Table A-5 of Appendix A and discussed previously in Section 5.2.2.1. The modelling study was also conducted to estimate water current speeds at several locations within the forebay for comparison to threshold values for fish swimming speeds to evaluate risk of increased impingement and entrainment during the Storage with Surveillance Phase.

Updated modelling was conducted in support of the 2022 PEA Addendum to reflect the following differences from the previous study:

- Potential increase to the flow through the PN U5-8 intake to 250,500 m^3/day (previously, 50,000 m^3/day);
- Addition of groundwater inputs from the TAB IAD sumps on the PN U1-4 side discharging to the PN U1-4 intake duct, which would ultimately discharge to the forebay;
- Addition of groundwater inputs from the VBRS to the forebay via Drain A; and
- Increased Lake Ontario water levels observed over recent years (i.e., 2016 to 2020), including the extremely high-water events recorded in 2017 and 2019.

6.2.3.2.1 Model Description

The following points outline the development of the mass balance model for the forebay.

- It was assumed that the forebay could be represented as six sequential compartments (boxes), as shown in Figure 6.2.
- The forebay was estimated to have a surface area of approximately 6.2 ha (62,000 m^2), a total volume of approximately 412,000 m^3, and an average water depth of approximately 6.7 m based on the average water level of 74.81 metres above sea level (masl) for Lake Ontario (1958 to 2019).
- The vertical extents of the bathymetry were increased to accommodate the higher Lake Ontario water levels in 2017 and 2019 (discussed previously in Section 4.3.1). The average water level in 2019 was approximately 0.6 m higher than in 2011 and 2012.
- Water exchanges between the forebay and Lake Ontario were based on hourly changes in the Lake Ontario water level. If there was an increase in the water level over an hour, then it was assumed that the volume of water that flows into the forebay was equal to the change in water level times the surface area of the forebay. An outflow occurred when there was a decrease in the hourly water level. Factors such as waves, upwelling events, and density currents that may affect exchange flows between the forebay and the lake were not represented in the model. As such, the modelling approach is considered conservative.
- Exchange flows between individual model compartments were based on water level changes, the volumes pumped into PN U5-8, and discharges from Drain A (including VBRS), Drain B, and the IAD into the PN U1-4 intake duct.
- Current velocities were estimated for flows between each of the model compartments by dividing the flows by the estimated cross-sectional area on an hourly basis.

- Three modelling periods (2012, 2018 and 2019) were selected for use in the model to represent low, typical and high water-level years.

The inflows and outflows that were modelled are summarized on Table 6.13.

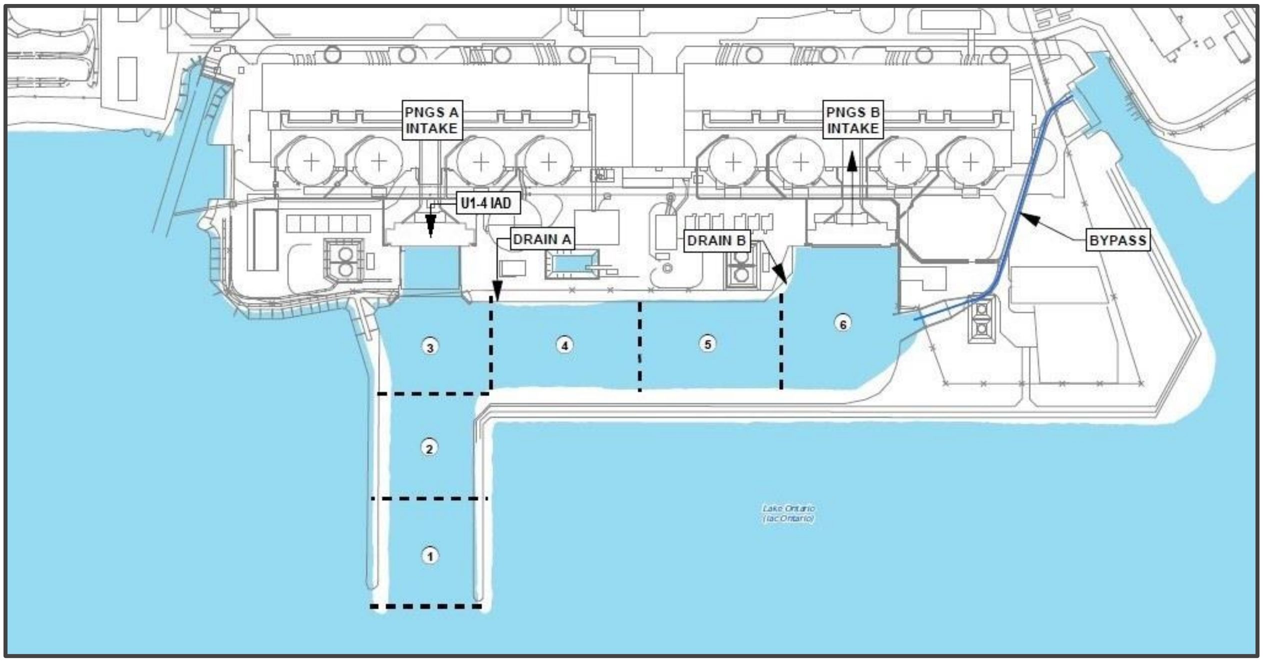


Figure 6.2: Schematic of the Updated Forebay Box Model

Table 6.13: Flows Used in the Updated Forebay Model

<table>
<tr><th colspan="2">Location / Source</th><th>Flows (m³/day)</th><th>Rationale and Reference</th></tr>
<tr><td colspan="4">Inputs:</td></tr>
<tr><td rowspan="2">Drain A (Box 4)</td><td>Storm Water</td><td>101</td><td>Stormwater runoff estimated based on drainage areas to Drain A (Section A.6.1 of 2017 PEA)</td></tr>
<tr><td>Groundwater (VBRS)</td><td>12.6</td><td>Flow rate reported in Section 4.2.3.2.1.4 of the 2017 PEA</td></tr>
<tr><td>Drain B (Box 6)</td><td>Storm Water</td><td>114</td><td>Stormwater runoff estimated based on drainage areas to Drain B (Section A.6.1 of 2017 PEA)</td></tr>
<tr><td>PN U1-4 Intake Duct (Box 3)</td><td>Groundwater (PN U1-4 TAB IAD)</td><td>46.5</td><td>Sum of the maximum flows measured from the PN U1-4 foundation drains into the IAD sumps (CH2M, 2002).</td></tr>
<tr><td colspan="4">Outflows (Pumping):</td></tr>
<tr><td colspan="2">PN U1-4 Intake</td><td>0</td><td>No flow anticipated through the PN U1-4 intake.</td></tr>
<tr><td colspan="2" rowspan="2">PN U5-8 Intake</td><td>50,000 (Scenario 1)</td><td>Bounding assumption for the 2017 PEA with respect to forebay water quality. Used to calculate concentration factors to estimate concentrations in forebay water.</td></tr>
<tr><td>250,500 (Scenario 2)</td><td>Updated assumption during the Storage and Surveillance Phase that is not bounded by the 2017 PEA assessment for fish impingement and entrainment.</td></tr>
<tr><td colspan="2">Bypass</td><td>0</td><td>No flow anticipated through the bypass.</td></tr>
</table>

6.2.3.2.2 Results

The average concentration factors determined from the updated forebay modelling based on a intake flow rate of 50,000 m^3/day are summarized in Table 6.14. The concentration factors are provided as mg/L concentrations for a nominal discharge concentration of 1,000 mg/L. Thus, predicted concentration factors reported as less than 0.001 indicate that the discharge is diluted more than 1,000,000:1 and are considered negligible as they are beyond the expected accuracy of the forebay model.

The results of the modelling for current speeds in the forebay based on a flow rate of 250,500 m^3/day are summarized on Table 6.15. Within the table, a positive current speed indicates current flow from the forebay intake towards the PN U5-8 intake. The model results found that the predicted current speeds are within 3 mm/s of the average over 95% of the time, and that negative current speeds (i.e., movement of water from the forebay into the lake) occur very infrequently, less than 1% of the time. The current speed results are further discussed in Section 6.4.3.

Table 6.14: Summary of Average Forebay Concentration Factors

Scenario	Source	Year	Average Predicted Model Box Concentration Factors (g/m^3 or mg/L)[1]					
			1	2	3	4	5	6
50,000 m^3/d to PN U5-8	PN U1-4 IAD	2012 (low water levels)	<0.001	0.003	0.935	0.934	0.934	0.932
		2018 (typical water levels)	<0.001	0.004	0.934	0.933	0.933	0.931
		2019 (high waters)	<0.001	0.005	0.933	0.932	0.932	0.930
	Drain A	2012 (low water levels)	<0.001	<0.001	0.003	2.278	2.281	2.276
		2018 (typical water levels)	<0.001	<0.001	0.004	2.276	2.278	2.273
		2019 (high waters)	<0.001	<0.001	0.004	2.274	2.277	2.272
	Drain B	2012 (low water levels)	<0.001	<0.001	<0.001	<0.001	<0.001	2.282
		2018 (typical water levels)	<0.001	<0.001	<0.001	<0.001	<0.001	2.280
		2019 (high waters)	<0.001	<0.001	<0.001	<0.001	<0.001	2.280

Notes:
1. Estimated concentration factors based on constant discharge concentration of 1,000 g/m^3 (1,000 mg/L).

Table 6.15: Summary of Predicted Forebay Current Speeds

Scenario	Year	Result Type	Current Speed (mm/s)					
			Lake to Box 1	Lake to Box 1	Lake to Box 1	Lake to Box 1	Lake to Box 1	Lake to Box 1
250,500 m^3/d to PN U5-8	2012 (low water levels)	Minimum	-2.80	-0.99	0.89	2.12	4.34	3.58
		Average	5.03	5.27	4.97	6.19	8.56	5.20
		Maximum	11.10	10.11	8.07	9.22	11.52	6.33
	2018 (typical water levels)	Minimum	0.20	1.42	2.48	3.71	5.70	4.06
		Average	4.86	5.10	4.81	5.94	8.08	5.01
		Maximum	10.79	9.77	7.75	8.69	10.81	6.06
	2019 (high water levels)	Minimum	-2.31	-0.64	1.08	2.26	4.37	3.56
		Average	4.63	4.86	4.58	5.60	7.47	4.76
		Maximum	10.37	9.43	7.54	8.48	10.41	5.91

Notes:
A positive current speed represents flow from the forebay intake towards the PNGS B intake. A negative current speed represents a flow from the PNGS B intake towards the lake.
The values presented in the table represent statistical values and do not necessarily occur at the same time.

6.2.4 Exposure Point Concentrations and Doses

6.2.4.1 Exposure Point Concentrations

The surface water and sediment concentrations used for the exposure evaluation in the forebay are listed in Table 6.16. The maximum surface water concentrations calculated using the concentration factors for box 6 (presented previously in Table 6.14) were used as exposure concentrations since they represent the highest estimated concentrations in the forebay. Similar to the 2017 PEA, the average surface water concentrations were calculated as an average of the six boxes modelled in the forebay. Maximum and average sediment concentrations were calculated from the corresponding surface water concentrations using a partitioning equation as described previously in Section 6.2.1.2. The exposure values are based on predicted surface water concentrations in the forebay during the Storage with Surveillance Phase.

Table 6.16: Environmental Media Concentrations in the Forebay

COPC	Surface Water (Bq/L)		Sediment (Bq/kg dw)	
	Max	Average	Max	Average
C-14	2.02E-03	5.35E-04	1.01E-01	5.42E-05
Co-60	4.56E-03	1.52E-03	1.96E+02	2.98E-01
Cs-134	4.56E-03	1.52E-03	4.33E+01	6.59E-02
Cs-137	4.56E-03	1.52E-03	4.33E+01	6.59E-02
Tritium	1.09E+03	6.21E+02	0	0

Table 6.17 presents the calculated concentrations of radiological COPCs in the tissues of each ecological receptor in the forebay. Sample calculations are presented in Appendix C.

Table 6.17: Radiological Tissue Concentrations by Receptor

VEC	Units	C-14		Co-60		Cs-134		Cs-137		HTO		OBT	
		Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
Benthic Fish	Bq/kg(fw)	1.2E+01	3.0E+00	2.5E-01	8.2E-02	1.6E+01	5.3E+00	1.6E+01	5.3E+00	8.2E+02	4.7E+02	1.5E+02	8.7E+01
Pelagic Fish	Bq/kg(fw)	1.2E+01	3.0E+00	2.5E-01	8.2E-02	1.6E+01	5.3E+00	1.6E+01	5.3E+00	8.2E+02	4.7E+02	1.5E+02	8.7E+01
Aquatic Plants	Bq/kg(fw)	1.2E+01	3.2E+00	3.6E+00	1.2E+00	1.0E+00	3.3E-01	1.0E+00	3.3E-01	8.2E+02	4.7E+02	1.2E+02	6.8E+01
Benthic Invertebrates	Bq/kg(fw)	1.1E+01	3.0E+00	5.0E-01	1.7E-01	4.5E-01	1.5E-01	4.5E-01	1.5E-01	8.2E+02	4.7E+02	1.5E+02	8.7E+01
Bufflehead	Bq/kg(fw)	4.8E+01	1.3E+01	3.0E+00	1.0E+00	2.3E+00	7.8E-01	2.3E+00	7.8E-01	1.2E+03	6.6E+02	4.5E+01	2.5E+01
Common Tern	Bq/kg(fw)	2.3E+01	6.2E+00	5.8E-01	1.9E-01	1.9E+01	6.3E+00	1.9E+01	6.3E+00	6.6E+02	3.8E+02	4.5E+01	2.5E+01
Trumpeter Swan	Bq/kg(fw)	2.3E+01	6.2E+00	2.0E+00	6.5E-01	1.4E+00	4.7E-01	1.4E+00	4.7E-01	6.6E+02	3.8E+02	1.8E+01	1.1E+01
Ring-Billed Gull	Bq/kg(fw)	7.0E+01	1.9E+01	1.1E+00	3.6E-01	1.2E+01	4.0E+00	1.2E+01	4.0E+00	1.6E+03	9.1E+02	4.9E+01	2.8E+01
Muskrat	Bq/kg(fw)	1.9E+01	5.1E+00	8.5E-02	2.8E-02	1.1E+00	3.8E-01	1.1E+00	3.8E-01	6.9E+02	3.9E+02	3.8E+01	2.2E+01

6.2.4.2 Exposure Doses

The exposure concentrations presented in Section 6.2.4.1, along with the exposure factors in Section 6.2.2.4, were applied to the equations in Section 6.2.2.1 to estimate the radiological dose to all biota. The estimated radiological doses are presented in the risk characterization (Section 6.4.1). Sample calculations are presented in Appendix C.

6.2.5 Uncertainties in the Exposure Assessment

Uncertainties in the exposure assessment include the representativeness of media concentrations used in the assessment at each location. The average concentrations of COPCs across the six modelled boxes in the forebay were used to estimate water and sediment exposure concentrations, where possible, and are considered to be representative for all mobile receptors. Maximum concentrations were also used as an upper bound on exposure.

Average concentration factors were used to estimate concentrations in the forebay. Based on maximum and minimum lake water conditions, the concentration factors can vary slightly but as shown in Section 6.2.3.2, Table 6.14, the differences between high and low water level years are negligible. Nonetheless, the highest concentrations for each discharge location and box were used out of the three years modelled.

The groundwater flow and quality from the IAD foundation drains were obtained from a 2002 tritium study (CH2M, 2002). Older data were used because the foundation drains are not routinely sampled as part of the PN Groundwater Monitoring Program. However, as presented in the risk characterization (Section 6.4.1), the radiological dose to ecological receptors is currently well below benchmarks and this uncertainty is unlikely to change the conclusions of the assessment.

Partitioning coefficients were used to estimate COPC concentrations in sediment from estimated surface water concentrations in the forebay. Uncertainties in organism exposure arise from these estimated concentrations and from the use of BAFs to calculate uptake into tissues. In some cases, BAFs for a species of interest were unavailable, and surrogate values were used. The partition coefficients and BAFs used for the exposure assessment were not site-specific, but were taken from reputable sources and are considered to be representative of the conditions found at the site.

Wildlife exposure factors, such as intake rates and diets, are a potential source of uncertainty. Reputable sources are used for these factors and are considered to be representative of the organisms assessed.

Dose coefficients were obtained from reputable sources for reference organisms, but have not been derived specifically for all the organisms assessed. Dose coefficients for surrogate organisms were often used. They were selected with attention to similar body size and exposure habits and are believed to adequately represent the organism assessed. Dose coefficients for each receptor were not adjusted for body size and dimensions.

A radiation weighting factor (relative biological effectiveness, RBE) of 2 was applied to the low beta component of the tritium DCs, as recommended by CSA N288.6-12. Since a RBE range of 1 to 3 is used in the literature. the tritium internal dose coefficient for all ecological receptors could be either higher (by 1.43 if a RBE of 3 is applied to the low beta portion of the internal dose coefficient) or lower (by 0.57 if a RBE of 1 is applied to the low beta portion of the internal dose coefficient).

Radiation doses were calculated from measured concentrations of radionuclides such as cobalt-60, cesium-134, and cesium-137 in water. The majority of stormwater samples had radionuclide concentrations below the detection limit. Doses were calculated assuming these concentrations were at the detection limit. This is likely a conservative assumption and doses resulting from these radionuclides are likely lower than presented.

6.3 Effects Assessment

6.3.1 Radiation Benchmarks

Radiation dose benchmarks of 400 µGy/h (9.6 mGy/d) and 100 µGy/h (2.4 mGy/d) (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial/riparian biota, respectively, as recommended in the CSA N288.6-12 standard. This is a total dose benchmark, therefore the dose to biota due to each radionuclide of concern is summed to compare against this benchmark.

The aquatic biota dose benchmark of 10 mGy/d was initially developed by the National Council on Radiation Protection and Measurement (NCRP, 1991) and was recommended by the International Atomic Energy Agency (IAEA) which concluded that limiting the dose rate to individuals in an aquatic population to a maximum of 10 mGy/d would provide adequate protection for the population (IAEA, 1992). Later reviews by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) have supported this recommendation (UNSCEAR, 1996, 2008).

The aquatic biota considered by UNSCEAR are organisms such as fish and benthic invertebrates that reside in water. Birds and mammals with riparian habits are considered to be terrestrial biota. Dose calculations in this updated Tier 2 ERA follow the same convention.

For terrestrial biota, a level of 1 mGy/d has been widely used as an acceptable level based on IAEA and UNSCEAR (IAEA, 1992; UNSCEAR, 1996). More recently, UNSCEAR has supported a slightly higher exposure level of 100 µGy/h (2.4 mGy/d) as the threshold for effects of population significance in terrestrial organisms (UNSCEAR, 2008). UNSCEAR updated its review of radiation effects on natural biota, and noted that the 0.04 mGy/h (1 mGy/d) exposure produced no effect in the most sensitive mammalian study (with dogs), while 0.18 mGy/h produced eventual sterility (UNSCEAR, 2008). Therefore, UNSCEAR chose an intermediate exposure level of 0.1 mGy/h (2.4 mGy/d) as the threshold for effects of population significance in terrestrial organisms. UNSCEAR concluded that lower dose rates to the most highly exposed individuals would be unlikely to have significant effects on most terrestrial communities.

It is recognized that the selection of reference dose levels is a topic of ongoing debate. For example, the CNSC has recommended dose limit values of 0.6 mGy/d for fish, 3 mGy/d for aquatic plants (algae and macrophytes), 6 mGy/d for invertebrates, and 3 mGy/d for mammals and terrestrial plants (EC and HC, 2003). The dose limit value for fish was based on a reproductive effects study in carp in a Chernobyl cooling pond with a history of higher exposures (Makeyeva et al., 1995). A value of 0.6 mGy/d was found to be in the range where both effects and no effects were observed. The aquatic plant benchmark was based on information related to terrestrial plants (conifers), which are considered to be sensitive to the effects of radiation. Reproductive effects in polychaete worms were used to derive the dose limit for benthic invertebrates.

The International Commission on Radiological Protection (ICRP) has suggested "derived consideration levels" as a range of dose rates reflecting a range in potential for effect, for each of several taxonomic groups (ICRP, 2008). The ICRP states that the ranges of dose rates they provide are preliminary and need to be revised as more data become available.

Considering the history and discussions surrounding the selection of radiation benchmarks, 400 µGy/h (9.6 mGy/d) and 100 µGy/h (2.4 mGy/d) (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively. These benchmarks were recommended in CSA N288.6-12 (CSA, 2012), and are appropriate for this assessment.

6.3.2 Uncertainties in the Effects Assessment

While there is uncertainty related to some low values that have been suggested as radiation dose benchmarks based on field studies around Chernobyl, the radiation dose benchmarks chosen follow UNSCEAR and CSA N288.6-12 in giving more credence to values based on controlled laboratory studies and demonstrated low levels of effect.

6.4 Risk Characterization

6.4.1 Risk Estimation

A summary of the radiation doses to each receptor by COPC is presented in Table 6.18.

Table 6.18: Summary of Radiation Dose Estimates for Biota in the Forebay During Storage with Surveillance (mGy/d)

COPC		Pelagic Fish	Benthic Fish	Benthic Invertebrate	Aquatic Plant	Bufflehead	Common Tern	Trumpeter Swan	Ring-Billed Gull	Muskrat
C-14	Max	7.83E-06	7.83E-06	7.64E-06	8.10E-06	3.28E-05	1.58E-05	1.58E-05	4.75E-05	1.30E-05
	Avg	2.07E-06	2.07E-06	2.02E-06	2.15E-06	8.69E-06	4.19E-06	4.19E-06	1.26E-05	3.45E-06
Co-60	Max	1.40E-06	3.05E-04	1.32E-03	3.41E-04	3.70E-04	3.56E-04	3.64E-04	3.59E-04	3.73E-04
	Avg	4.66E-07	1.02E-04	4.39E-04	1.14E-04	1.23E-04	1.19E-04	1.21E-04	1.20E-04	1.24E-04
Cs-134	Max	7.83E-05	1.19E-04	1.92E-04	4.83E-05	6.43E-05	1.52E-04	5.95E-05	1.15E-04	5.66E-05
	Avg	2.61E-05	3.98E-05	6.40E-05	1.61E-05	2.14E-05	5.08E-05	1.98E-05	3.85E-05	1.89E-05
Cs-137	Max	7.03E-05	8.50E-05	7.80E-05	2.04E-05	2.91E-05	1.04E-04	2.50E-05	7.25E-05	2.42E-05
	Avg	2.34E-05	2.83E-05	2.60E-05	6.82E-06	9.70E-06	3.46E-05	8.34E-06	2.42E-05	8.05E-06
Tritium (HTO+OBT)	Max	1.34E-04	1.34E-04	1.34E-04	1.30E-04	1.66E-04	9.75E-05	9.38E-05	2.28E-04	1.00E-04
	Avg	7.64E-05	7.64E-05	7.66E-05	7.39E-05	9.43E-05	5.55E-05	5.35E-05	1.30E-04	5.72E-05
Total Dose	**Max**	**2.92E-04**	**6.52E-04**	**1.73E-03**	**5.48E-04**	**6.62E-04**	**7.26E-04**	**5.58E-04**	**8.22E-04**	**5.67E-04**
	Avg	**1.28E-04**	**2.48E-04**	**6.08E-04**	**2.13E-04**	**2.58E-04**	**2.64E-04**	**2.07E-04**	**3.25E-04**	**2.12E-04**

Notes:
Shaded values exceed the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d (no exceedances in table).

6.4.2 Discussion of Radiation Effects

There are no exceedances of the 9.6 mGy/d aquatic radiation benchmark for any aquatic receptors at or in the forebay based on updated assumptions for the Storage with Surveillance Phase. There are also no exceedances of the 2.4 mGy/d terrestrial radiation benchmark for riparian birds and mammals in the forebay.

6.4.3 Entrainment/Impingement

Cooling water flows are expected to decrease throughout the Stabilization and Storage with Surveillance Phases. During the Stabilization Phase, the Fish Diversion System (FDS) is presently expected to remain in place seasonally while the CCW pumps are operating. The current operational conditions are considered bounding in this case.

During Storage with Surveillance activities, an alternative bounding condition was evaluated for potential entrainment and impingement effects. In the 2017 PEA, the reduced cooling water flow was 50,000 m^3/day to PN U5-8. Current assumptions indicate a higher flow rate of 250,500 m^3/day is planned during the Storage with Surveillance Phase, along with removal of the FDS.

The velocity associated with the updated reduced flow relative to operational conditions (now assumed to be 250,500 m^3/day) was calculated in the forebay modelling update to be a maximum of 11.5 mm/s from the lake toward PN U5-8 (Table 6.15). Maximum and minimum velocities occur infrequently and are related to short-term changes in Lake Ontario water levels in combination with the number of operational units and unit power. Within the forebay, the highest average predicted velocity was 8.5 mm/s (Table 6.15). At these velocities, the effects of impingement are expected to be reduced substantially as this is less than the mean swim speed of the local species for the VECs evaluated in the PN ERA as shown in Table 6.19. This table, however, is not an exhaustive list of fish species and may not apply to all life stages.

Table 6.19: Fish Swim Speeds for Local Species

Species	Swim Speed (mm/s)		
	Mean	Minimum	Maximum
Alewife	2890	1330	4795
Smallmouth Bass	879	271	1088
Northern Pike	221	126	435
Brown Bullhead[a]	791	600	1200
Round Whitefish[b]	430	430	430
White Sucker	3612	483	6587
Emerald Shiner	814	814	814
Lake Trout	1044	900	1150
Walleye	2601	340	5292
American Eel[c]	759	205	1284

Source: (Katopodis and Gervais, 2016)
Notes:

a. Data for Family Ictaluridae
b. Data for Genus *Prosopium*
c. Data for Genus *Anguilla*

In the U.S., impingement is not considered an issue if the intake water velocity is less than 0.5 fps (150 mm/s). Swim speed studies demonstrated that an intake velocity of 0.5 fps or less resulted in 96 percent or better reductions in impingement mortality for most species (US EPA, 2014). The maximum predicted velocities from the lake into the forebay, as well as within the forebay, are considerably less than the US EPA guidance value.

Generally, entrainment is considered to be less of a concern when the volume of flow is 1.25 million gallons per day (mgd) (5.5 m^3/s) or lower (US EPA, 2014). The proposed flow during the Storage with Surveillance Phase, when the CCW pumps are no longer used, will be 2.9 m^3/s, which is less than this value.

Because ichthyoplankton are generally suspended in the water column and typically "go with the flow", it can be expected that a reduction in flow would result in a proportional reduction in entrainment. Estimated ichthyoplankton entrainment losses at PNGS between 1975 and 2006 were summarized by OPG (2012). During the most recent monitoring study (undertaken in 2006), Alewife (*Alosa pseudoharengus*), Common Carp (*Cyprinus carpio*) and Freshwater Drum (*Aplodinotus grunniens*) eggs and larvae; and Round Goby (*Neogobius melanostomus*) larvae were reported. All species are invasive to Lake Ontario, with exception of Freshwater Drum (Morrison, 2019). It is acknowledged that Alewife and Common Carp entered Lake Ontario many decades ago and have since naturalized. Round Goby, however, remain a Regulated Species, and are excluded from the 2018 Fisheries Act Authorization value for the PN Generating Station.

Additionally, during the Storage with Surveillance Phase, the forebay will not receive thermal loading from the PN Generating Station (Golder and Ecometrix, 2017). As a result, thermal stress induced mortality of entrained organisms passing through the cooling water system is expected to be considerably less than that under current operating conditions.

Facilities using less than 125 L/s of intake water may not require impingement and entrainment monitoring if mitigation measures are employed that are consistent with the Fisheries and Oceans Canada (DFO) Freshwater Intake End-of-Pipe Fish Screen Guideline (CSA, 2018). During the Storage with Surveillance Phase, however, flow volumes are anticipated to be much greater (i.e., 2,899 L/s); accordingly, monitoring is expected to continue.

In the future, OPG may seek regulatory approval to cease the use of the FDS, when deemed feasible. In the current *Fisheries Act* Authorization for PNGS, which was issued in January 2018 (DFO, 2018), FDS use has been committed through the remainder of the Operations Phase, and during the Stabilization Phase. An amendment to cease using the FDS may be conducted when there is more certainty regarding the flows required during different periods of the Storage with Surveillance Phase. The current Authorization ends in 2028 which is one year prior to the expected end of the Stabilization Phase. As such, OPG may need to seek an amendment to the existing Authorization if the objective is for the Authorization to include the remaining Operations Phase and entire Stabilization Phase, which was the case for the current Authorization. If an amendment is sought, it would be rationalized and would need to be approved by DFO.

6.4.4 Uncertainties in the Risk Characterization

There are uncertainties associated with the components contributing to the overall risk assessment. This includes receptor exposure factors, such as transfer factors, intake rates and bioaccumulation factors, partition coefficients, dose coefficients and averaging assumptions (uncertainties discussed in Section 6.2.5), as well as benchmark values used to determine risk of potential effects (uncertainties discussed in Section 6.3.2).

A probabilistic risk assessment to quantify uncertainty in the risk estimate has not been performed and is not considered necessary, since it is not likely to provide a better basis for risk management/decision making. According to CSA N288.6-12 (CSA, 2012), a qualitative or semi-quantitative evaluation of uncertainty is considered sufficient for evaluation of uncertainty.

Average concentration factors were used to estimate exposure concentrations in the forebay. Based on maximum and minimum lake water conditions, the concentration factors can vary slightly but as shown in Section 6.2.3.2, Table 6.14, the differences between high and low water level years are negligible.

7.0 Environmental Monitoring and Protection Programs

Table 7.1 summarizes the environmental monitoring programs anticipated to continue through the Stabilization and Storage with Surveillance Phases. The table is based on the detailed descriptions presented in the 2017 PEA, updated as applicable. The updates include:

- Updates to the O. Reg. 419/05 ECA requirements for air;
- Inclusion of MISA requirements into ECA requirements for water;
- Adoption of a N288.7-compliant groundwater monitoring program;
- Consideration of the Stabilization and Storage with Surveillance activities during 5-year review of the GWPP in accordance with CSA Standard N288.7-15; and
- Identification of impingement and entrainment monitoring requirements. Annual impingement monitoring is also anticipated to continue through to the end of 2028, consistent with the *Fisheries Act* authorization for PNGS issued to OPG on January 17, 2018 (DFO, 2018). Mitigation performance monitoring of the FDS will continue as per the Fisheries Act Authorization.

Continued execution of these environmental programs and associated monitoring will continue to provide data to help reduce uncertainty in the predicted future environmental conditions.

Table 7.1: Monitoring Programs through Stabilization and Storage with Surveillance

Environment Programs	Program Description	Objective	Monitoring Programs
Effluent Monitoring – Hazardous Substances Emissions	Update the ECA/ESDM report as required to incorporate the final heating steam boiler requirements during the Stabilization Phase, as needed; and incorporation of land use changes as a result of re-purposing the PN site.	Confirm compliance with MECP ECA requirements based on s. 20 of O. Reg. 419/05.	N/A
	Update the ECAs (industrial sewage works) with liquid effluents and other changes once detailed design information is available.	Confirm compliance with MECP ECA requirements. Effective July 1, 2021, requirements under the MISA program have been transferred to the existing site ECA via ECA Notice No. 1.	Monitoring as specified under ECA requirements.

Environment Programs	Program Description	Objective	Monitoring Programs
Effluent Monitoring–Radiological Emissions	Update Derived Release Limits (DRLs) based on reduced cooling water flows and land use changes as a result of re-purposing the PN site, which will be identified through future Site-Specific Surveys carried out in support of the EMP.	Confirm compliance with CNSC licensing requirements.	Effluent monitoring of radionuclides shall continue until it is demonstrated that monitoring is no longer required.
	Update Action Levels in accordance with CSA Standard N288.8, *Establishing and implementing action levels to control releases to the environment from nuclear facilities*.	Confirm compliance with CNSC licensing requirements.	Effluent monitoring to continue as agreed with CNSC.
Environmental Monitoring Program (EMP)	Update EMP design as determined through outcome of other environmental programs, as described in this table.	Demonstrate that doses remain below the regulatory limit; demonstrate the effectiveness of containment and effluent control, independent of effluent monitoring; provide environmental information for future ERA updates.	Environmental monitoring requirements will be determined as part of the EMP design and associated pathways analysis.
Groundwater Protection Program (GWPP)	Consideration of the Stabilization and Storage with Surveillance activities during 5-year review of the GWPP in accordance with CSA Standard N288.7-15.	Confirm that the groundwater Conceptual Site Model has not changed as a result of the final configuration of the groundwater hydraulic sinks.	Groundwater monitoring requirements will be determined as part of the GWPP design review for safe storage, but could be combined into existing N288.7-15 compliant GWPP and GWMP, which only considers current operations.
Environmental Risk Assessment	Inclusion of updated information identified through the periodic review, including changes to site ecology or surrounding land use; new environmental and effluent monitoring data; and new	Confirm emissions and physical stressors do not pose an unacceptable risk to the environment.	Provision of risk-based recommendations for effluent monitoring and EMP, as required.

Environment Programs	Program Description	Objective	Monitoring Programs
	or previously unrecognized environmental issues that have been revealed by the EMP.		
Impingement Monitoring	Monitor impingement to end of 2028. Impingement monitoring during the Storage for Surveillance Phase will be subject to the outcomes of a future Fisheries Act request for review.	Continue to evaluate performance of the Fish Diversion System through the Stabilization Phase. Demonstrate impingement impacts during the Storage with Surveillance Phase are aligned with regulatory approvals.	Where required by regulatory approvals, Impingement monitoring to continue to evaluate effects predictions and regulatory compliance.
Entrainment Monitoring	If entrainment monitoring is required, incorporate CSA N288.9-18, *Guidance for Design of Fish Impingement and Entrainment Programs at Class I Nuclear facilities*, where feasible and applicable.	Document effects of fish entrainment during the Storage with Surveillance Phase.	Whether entrainment monitoring is required or not is to be determined in consultation with DFO.

8.0 Conclusions

Updated baseline conditions and assumptions for the Stabilization and Storage with Surveillance Phase activities were documented in this report and evaluated for any new assumptions or conditions that are no longer bounded by the 2017 PEA. New assumptions, which would result in a decrease in predicted interactions with the environment, were identified in Table 4.1 and not discussed further, as these new assumptions would not increase risks to human health and the environment. Any assumptions or conditions which could change or increase predicted interactions with the environment were further addressed in the updated Tier 1 Assessment.

8.1 Tier 1 Assessment Conclusions

The following section summarizes key findings of the updated Tier 1 Assessment.

Radiological Air Emissions

- The updated 2016-2020 baseline emissions from the site were compared against the predicted emissions during the Storage with Surveillance Phase determined in the 2017 PEA, for which no updates have been identified. The comparison finds that the overall predicted C-14 and tritium emissions during the Storage with Surveillance Phase remain well below current baseline conditions. Therefore, no further Tier 2 Assessment is required.

- There may be increased movement of heavy water on the PN site including a potential transfer of approximately 1,500 Mg of heavy water to the DN site towards the end of the Stabilization Phase. Assuming the existing process and practices are in place for transporting heavy water, and the frequency for transporting heavy water will not be greater than the current frequency, no additional impact on tritium release is expected. This change was not carried forward to the Tier 2 Assessment.

- A microscrubber was installed on the U4 stack in October 2020 and was placed into service in 2021. The microscrubber is expected to reduce airborne emissions of tritium. This change may reduce airborne tritium emissions for the baseline condition but will not change previous conclusions regarding tritium emissions during the Stabilization and Storage with Surveillance Phases once Unit 4 is taken out of service. This change was not carried forward to the Tier 2 Assessment.

Radiological Air Emissions – Pickering Waste Management Facility Phase II Expansion

- PWMF dose rates resulting from the storage of up to 100 DSCs containing 6-year decayed used fuels in SB3 and additional storage in the newly constructed SB4 were considered. The expansion of the PWMF Phase II site will accommodate storage capacity requirements as shut-down proceeds. The predicted annual dose at the PNGS east property boundary of no more than 0.00356 μSv/a, based on SB3 and SB4 filled at design capacity, is well below the public dose limit for radiation protection of 1 mSv/a.

The maximum dose rate along the PWMF Phase II protected area fence of 0.85 µGy/hr is well below the terrestrial dose benchmark of 100 µGy/hr. No further Tier 2 Assessment is considered necessary for the PWMF Phase II site expansion.

Non-Radiological Air Emissions

- The existing Auxiliary Boiler will be upgraded and modified to be the primary source of building heating and process steam during the Stabilization Phase, and an alternative heating source, considered in the 2017 PEA, is no longer required. In addition, there will be a transition to electrical heating sources during the Storage with Surveillance Phase. These changes represent a decreased interaction with respect to air emissions and noise. Re-evaluation of predicted air emissions from the Auxiliary Boiler confirmed that the air concentrations at potential critical group locations would be less than the O. Reg. 419/05 POI limit for sulphur dioxide which comes into effect on July 1, 2023; and CAAQS for nitrogen oxide and sulphur dioxide which were introduced in 2020 and will decrease further by 2025. No further Tier 2 Assessment is required.

Surface Water Flow and Quality

- During the Storage with Surveillance Phase, the assumed/expected flow rate of cooling water pumps is increased to 2,899 L/s (250,500 m^3/day), an increase from the 2017 PEA assumption of 50,000 m^3/day. These changes to the predicted flows relative to the bounding scenario considered in the 2017 PEA are expected to improve the dilution of contaminants discharged at the outfall and will reduce the ΔT between the water intake and discharged water at the outfall. Therefore, with respect to lake water quality, no further Tier 2 Assessment is required.

- The increased flow of water through PN U5-8 CCW intake means the previous 2017 PEA assessment for fish impingement and entrainment is no longer bounding. Therefore, impingement and entrainment were further evaluated in the Tier 2 Assessment.

- A hydrodynamic surface water model was developed for the 2017 PEA to predict changes to lake currents, sediment transport and water temperature under current operational conditions and during the Storage with Surveillance Phase. To evaluate continued applicability of the model predictions, lake water physical conditions relevant to surface water modelling including water level, water temperature, and current speed were compared between the 2017 PEA conditions (2011 to 2012 data) and more recent conditions (2016 to 2020 data, and additional data as needed) in Section 4.2.2. Future trends predicted based on climate change models and their impact on the continued applicability of model predictions to 2039 (the time frame for this PEA) was evaluated in Section 4.4. It was concluded that the model provides a reasonable representation of the current and future conditions, and that the concentration factors used in the 2017 PEA are still applicable.

- The 2017 PEA assumed that groundwater contributions to the forebay from the TAB IAD sumps and VBRS would be diverted to the RLWMS during the Storage with Surveillance Phase. Under current planning, the TAB IAD sumps and VBRS will be discharged into the forebay during the Storage with Surveillance Phase, representing an assumption with respect to surface water quality that is no longer bounded by the 2017 PEA. The primary contaminant of concern in groundwater is tritium. As such, forebay water quality is re-evaluated in the updated Tier 2 Assessment with the new tritium waterborne contribution.

Sediment Quality and Transport

- Groundwater contributions to the forebay from the TAB IAD sumps and VBRS during the Storage with Surveillance Phase are considered in the Tier 2 Assessment. An updated ecological risk assessment for receptors in the forebay was conducted and the assessment considered partitioning of waterborne radiological emissions to sediment.

Groundwater

- The overall groundwater flow regime at the PN site is not expected to change in the 2017 PEA and this continues to be the case. The existing subsurface structures which influence groundwater flow and discharge will continue to operate during the Stabilization and the Storage with Surveillance Phases.

- The updated assumption is that groundwater collected from the U1-4 TAB foundation drains and the VBRS will be discharged to the forebay during the Storage with Surveillance Phase, and this represents a new radiological contribution to forebay water quality which will be addressed in the Tier 2 Assessment.

Soil Quality

- There are no changes to the soil quality assessment because the assessments in the 2017 and 2022 ERAs are considered bounding to the Stabilization and Storage with Surveillance Phases assessed in the PEA. No further Tier 2 Assessment is required.

8.2 Tier 2 Assessment Conclusions

The Tier 2 Assessment consisted of a re-assessment of any conditions identified in the Tier 1 Assessment that are no longer bounded by the 2017 PEA. This included assessment of the forebay as ecological habitat, and assessment of fish impingement and entrainment in consideration of the potential effects, applied mitigation, and residual impacts during the Storage for Surveillance Phase if the FDS is removed after 2028 (i.e., the end of the Stabilization Phase). The Tier 2 Assessment was conducted in accordance with N288.6-12 and relied on the 2022 PN ERA as its basis. The findings of the Tier 2 Assessment are as follows.

- Ecological Risk Assessment in the Forebay. The forebay was assessed as a habitat for aquatic and riparian ecological receptors during the Storage with Surveillance Phase, with loadings contributing to the forebay from stormwater and the additional tritium contribution from groundwater collected in the TAB foundation IAD sumps on the PN U1-4 side and the VBRS sump. Total doses to ecological receptors in the forebay were calculated using measured concentrations of tritium, carbon-14, cobalt-60, cesium-134 and cesium-137. Based on the modelling results, there were no potential adverse effects identified. All doses to the receptors assessed were below the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d.

- Ecological Risk Assessment – Entrainment and Impingement. Potential entrainment and impingement effects were re-assessed due to the current plan for a higher flow rate of 250,500 m^3/day through the PN U5-8 intake compared to the 2017 PEA assumption of 50,000 m^3/day during the Storage with Surveillance Phase, along with the assumed removal of the FDS. This flow of 250,500 m^3/day translates to a maximum velocity of 11.5 mm/s. This maximum velocity remains less than the mean swim speed of pertinent local fish species considered in the PEA, which range from 221 mm/s for Northern Pike to 3,612 mm/s for White Sucker; therefore, impingement rates will decrease because of the significant reduction in flow volume into the station. The proposed flow during the Storage with Surveillance Phase when cooling requirements are reduced will be 2.9 m^3/s, which is less than the flow of 5.5 m^3/s identified as the volume of flow where entrainment may be of concern (US EPA, 2014). Therefore, entrainment remains negligible.

Based on the updated Ecological Risk Assessment, no potential adverse effects are predicted from the updated assumptions affecting forebay water and sediment quality, and fish entrainment and impingement, which have been evaluated for the Storage with Surveillance Activities in the Tier 2 Assessment.

The results of the Tier 1 and Tier 2 Assessments conclude that there continues to be no potential adverse effects predicted from the proposed Stabilization and Storage with Surveillance Activities based on assumptions presented in the 2017 PEA and updated assumptions in this 2022 PEA Addendum.

8.3 Additional Risk Management Recommendations

No new interactions were identified in this PEA update that are expected to pose an unacceptable risk to human health or the environment based on current plans for the Stabilization and Storage with Surveillance Phases. There are no additional risk management recommendations based on the outcome of the updated Tier 1 and Tier 2 Assessments.

There is uncertainty associated with the assumptions of groundwater flow and concentration to the forebay via the TAB IAD sumps that were used in both the 2017 PEA and the current PEA update because these assumptions were based on the data documented in the 2002 Tritium in

Groundwater Addendum Report (CH2M, 2002), in which monthly flows and concentrations from the IAD foundation drains were collected. These data were collected 20 years ago, and an updated study would be helpful to provide a more accurate prediction of the current and future groundwater contribution into the forebay and reduce uncertainty in the results. The impact on risk is considered minimal, since the calculated radiological doses to ecological receptors in the forebay using the 2002 values are well below benchmark values.

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Appendix A Screening Tables

Table A.1 - Selection of COPC Screening Criteria for Ecological Health

Parameter	Unit	Screening Criteria		Criteria Selection [1]							
				1° Guideline				2° Guideline	3° Guideline		4° Guideline
		Selected Benchmark	Reference	PWQO[2]	CEQG[3]	FEQG[4]	Draft FEQG[4]	iPWQO[5]	Suter and Tsao, 1996[6]	Borgmann et al, 2005[7]	2015 Mean Background[8]
Radiological											
Carbon-14	Bq/L	<0.1	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<0.1
Cesium-134	Bq/L	<0.1	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<0.1
Cesium-137	Bq/L	50	PWQO (1°)	50	nv	nv	nv	nv	nv	nv	<0.1
Cobalt-60	Bq/L	<0.1	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<0.1
Iodine-131	Bq/L	10	PWQO (1°)	10	nv	nv	nv	nv	nv	nv	--
Manganese-54	Bq/L	nv	nv	nv	nv	nv	nv	nv	nv	nv	--
Tritium (Hydrogen-3)	Bq/L	7000	PWQO (1°)	7000	nv	nv	nv	nv	nv	nv	<4.4
Zinc-65	Bq/L	nv	nv	nv	nv	nv	nv	nv	nv	nv	--
Petroleum Hydrocarbons (and BTEX)[5]											
Benzene	µg/L	100	iPWQO (2°)	nv	370	nv	nv	100	--	--	--
Toluene	µg/L	0.8	iPWQO (2°)	nv	2	nv	nv	0.8	--	--	--
Ethylbenzene	µg/L	8	iPWQO (2°)	nv	90	nv	nv	8	--	--	--
o-Xylene	µg/L	40	iPWQO (2°)	nv	nv	nv	nv	40	--	--	--
m,p-Xylenes	µg/L	2	iPWQO (2°)	nv	nv	nv	nv	2	--	--	--
Xylenes, Total	µg/L	2	iPWQO (2°)	nv	nv	nv	nv	2	--	--	--
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	<25	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<25
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	<25	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<25
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	<100	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<100
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	<200	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<200
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	<200	Background (4°)	nv	nv	nv	nv	nv	nv	nv	<200
General											
Chloride	mg/L	120	CEQG (1°)	nv	120	nv	nv	nv	--	--	--
Conductivity	mS/cm	---	See note [1]	--	--	--	--	--	--	--	0.3135
Hardness, Calcium Carbonate	mg/L	See (9)	PWQO (1°)	See (9)	nv	nv	nv	nv	--	--	127.5
pH	pH units	6.5 - 8.5	PWQO (1°)	6.5-8.5	6.5 - 9.0	nv	nv	nv	--	--	7.9025
Phosphorous	mg/L	0.01	PWQO (1°)	0.01	depends	nv	--	--	--	--	--
Total Suspended Solids (TSS)	mg/L	---	See note [1]	nv	5 mg/L above background	nv	nv	nv	--	--	<1 - <10
Toxicity											
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	--	--	--	--	--	--	--	--	--	--
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	--	--	--	--	--	--	--	--	--	--
Metals											
Aluminum	µg/L	100	CEQG (1°)	nv	100	nv	130	75	--	--	7.075
Antimony	µg/L	20	iPWQO (2°)	nv	nv	nv	nv	20	--	--	<0.5
Arsenic	µg/L	5	CEQG (1°)	100	5	nv	nv	5	--	--	<1
Barium	µg/L	4	Suter and Tsao (3°)	nv	nv	nv	nv	nv	4	315	22.25
Beryllium	µg/L	1100	PWQO (1°)	1100	nv	nv	nv	nv	--	--	<0.5
Bismuth	µg/L	254.3	Borgmann et al (3°)	nv	nv	nv	nv	nv	nv	254.3	<1
Boron	µg/L	1500	CEQG (1°)	nv	1500	nv	nv	200	--	--	25.5
Cadmium	µg/L	0.16	CEQG (1°)	0.2	0.16	nv	nv	0.5	--	--	0.0095
Calcium	µg/L	11600	Suter and Tsao (3°)	nv	nv	nv	nv	nv	11600	--	34000
Chromium	µg/L	8.9	PWQO, CEQG (1°)	8.9	8.9	nv	nv	nv	--	--	<5
Cobalt	µg/L	1	FEQG (1°)	nv	nv	1	nv	0.9	--	--	<0.5
Copper	µg/L	2.36	CEQG (1°)	nv	2.36	nv	nv	5	--	--	<1
Iron	µg/L	300	PWQO, CEQG (1°)	300	300	nv	658	nv	--	--	<100
Lead	µg/L	2.8	FEQG (1°)	25	7	2.8000	nv	5	--	--	<0.5
Lithium	µg/L	14	Suter and Tsao (3°)	nv	nv	nv	nv	nv	14	313	<5
Magnesium	µg/L	8200	Suter and Tsao (3°)	nv	nv	nv	nv	nv	8200	nv	8775
Manganese	µg/L	370	CEQG (1°)	nv	370	nv	nv	nv	--	--	<2
Mercury (filtered)	µg/L	0.026	CEQG (1°)	0.2	0.026	nv	nv	nv	--	--	0.01
Molybdenum	µg/L	73	CEQG (1°)	nv	73	nv	nv	40	--	--	1.3
Nickel	µg/L	25	PWQO (1°)	25	95.98	nv	nv	nv	--	--	1.025
Potassium	µg/L	5300	Suter and Tsao (3°)	nv	nv	nv	nv	nv	5300	nv	1625

Table A.1 - Selection of COPC Screening Criteria for Ecological Health

Parameter	Unit	Screening Criteria		Criteria Selection (1)							
		Selected Benchmark	Reference	1° Guideline				2° Guideline	3° Guideline		4° Guideline
				PWQO(2)	CEQG(3)	FEQG(4)	Draft FEQG(4)	iPWQO(5)	Suter and Tsao, 1996(6)	Borgmann et al, 2005(7)	2015 Mean Background(8)
Selenium	µg/L	1	CEQG (1°)	100	1	nv	nv	nv	--	--	0.13875
Silicon	µg/L	260	Background (4°)	nv	nv	nv	nv	nv	nv	nv	260
Silver	µg/L	0.1	PWQO (1°)	0.1	0.25	nv	nv	nv	--	--	<0.1
Sodium	µg/L	68000	Suter and Tsao (3°)	nv	nv	nv	nv	nv	68000	nv	14500
Strontium	µg/L	2500	FEQG (1°)	nv	nv	2500	2500	nv	--	--	180
Tellurium	µg/L	151.9	Borgmann et al (3°)	nv	nv	nv	nv	nv	nv	151.9	<1
Thallium	µg/L	0.8	CEQG (1°)	nv	0.8	nv	nv	0.3	--	--	<0.05
Tin	µg/L	73	Suter and Tsao (3°)	nv	nv	nv	nv	nv	73	315	<1
Titanium	µg/L	315	Borgmann et al (3°)	nv	nv	nv	nv	nv	nv	315	<5
Tungsten	µg/L	30	iPWQO (2°)	nv	nv	nv	nv	30	--	--	<1
Uranium	µg/L	15	CEQG (1°)	nv	15	nv	nv	0.5	--	--	0.3675
Vanadium	µg/L	120	FEQG (1°)	nv	nv	120	120	6	--	--	<0.5
Zinc	µg/L	30	PWQO (1°)	30	66.404	nv	nv	20	--	--	<5
Zirconium	µg/L	4	iPWQO (2°)	nv	nv	nv	nv	4	--	--	<1

Notes:

Bq/L = Becquerel per litre; mg/L = miligram per litre; µg/L = micrograms per litre; mS/cm = microsievert per centimetre; COPC = contaminant of potential concern; BTEX = benzene, toluene, ethylbenzene and xylene.

nv = no value in guideline; "---" = not determined due to availability of guideline in higher tier

1. Risk-based guidelines are not applicable to water quality parameters such as temperature, conductivity, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.
2. PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998
3. CEQG = Canadian Environmental Quality Guidelines, current to September 2021
4. FEQG = Federal Environmental Quality Guidelines, current to September 2021
5. iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, updated July 1998. Interim PWQO was set based on readily available information and was not peer reviewed, therefore the PWQO, CEQG or FEQG were used in preference.
6. Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.
7. Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.
8. Background = Mean background concentration measured in Lake Water (LWC-1), as presented in Section 3.1.2.2.2 of the 2022 PN ERA.
9. PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration

Table A.2 - Screening of Stormwater COPCs for Ecological Health - Drain A

Station ID		MH106								MH85				Maximum Conentration At Discharge	Screening Criteria		Retained For Further Assessment?
Sample Name		MH106	MH106-Dup	MH106	Dup B	MH106	Dup A	MH106	DUP B	MH85	MH85	MH85	MH85		Selected Benchmark	Reference	
Sampling Date		20-Aug-15		28-Oct-15		19-Nov-15		11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16				
	Unit																
Radiological																	
Carbon-14 (12)	Bq/L	**< 20**	**< 20**	**< 20**	**< 20**	**< 20**	**< 20**	**<20**	**<20**	**< 20**	**< 20**	**< 20**	**<20**	**< 20**	<0.1	Background (8)	Yes (10)
Cesium-134	Bq/L	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**<1**	**<1**	**< 1**	**< 1**	**< 1**	**<1**	**< 1**	<0.1	Background (8)	Yes (10)
Cesium-137	Bq/L	< 1	< 1	< 1	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	50	PWQO (2)	Yes (10)
Cobalt-60	Bq/L	-	-	**< 1**	**< 1**	**< 1**	**< 1**	**<1**	**<1**	-	**< 1**	**< 1**	**<1**	**< 1**	<0.1	Background (8)	Yes (10)
Iodine-131	Bq/L	< 1	< 1	< 1	< 1	< 1	< 1	<1	<1	< 1	< 1	< 1	<1	< 1	10	PWQO (2)	No
Manganese-54	Bq/L	< 1	< 1	-	-	-	-	-	-	< 1	-	-	-	< 1	nv	nv	No
Tritium (Hydrogen-3)	Bq/L	1140	1150	**8560**	**8510**	**14400**	**14400**	1960	1950	4550	1690	1050	1190	**14400**	7000	PWQO (2)	Yes
Zinc-65	Bq/L	< 1	< 1	-	-	-	-	-	-	< 1	-	-	-	< 1	nv	nv	No
Petroleum Hydrocarbons (and BTEX) (5)																	
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	<0.20	<0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	100	iPWQO (5)	No
Toluene	µg/L	0.38	0.3	< 0.20	<0.20	< 0.20	<0.20	0.26	0.22	0.23	< 0.20	< 0.20	<0.20	0.38	0.8	iPWQO (5)	No
Ethylbenzene	µg/L	0.69	0.46	0.39	0.34	< 0.20	<0.20	1.1	1	< 0.20	< 0.20	< 0.20	<0.20	1.1	8	iPWQO (5)	No
o-Xylene	µg/L	2.7	2.4	2	2	< 0.20	<0.20	3.8	3.6	< 0.20	< 0.20	< 0.20	<0.20	3.8	40	iPWQO (5)	No
m,p-Xylenes	µg/L	**3**	**2.4**	1.7	1.6	< 0.40	<0.40	**6.5**	**6.6**	< 0.40	< 0.40	< 0.40	<0.40	**6.6**	2	iPWQO (5)	Yes
Xylenes, Total	µg/L	**5.7**	**4.9**	**3.8**	**3.6**	< 0.40	<0.40	**10**	**10**	< 0.40	< 0.40	< 0.40	<0.40	**10**	2	iPWQO (5)	--
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	< 25	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	<25	Background (8)	Yes (11)
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	< 25	< 25	< 25	< 25	<25	<25	< 25	< 25	< 25	<25	< 25	<25	Background (8)	Yes (11)
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	< 100	< 100	< 100	<100	<100	< 100	< 100	< 100	<100	< 100	<100	Background (8)	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	<200	Background (8)	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	< 200	< 200	< 200	<200	<200	< 200	< 200	< 200	<200	< 200	<200	Background (8)	No
General																	
Chloride	mg/L	6.9	7.4	3	2.4	8	8.1	3.8	3.2	26	21	27	24	27	120	CEQG (3)	Yes (11)
Conductivity	mS/cm	0.131	0.131	0.112	0.113	0.189	0.189	0.098	0.1	0.295	0.255	0.322	0.3	0.322	---	See note (1)	--
Hardness, Calcium Carbonate	mg/L	50	53	50	50	81	83	32	32	110	110	130	120	130	See (9)	PWQO (2)	--
pH	pH units	7.75	7.78	7.78	7.73	7.86	7.84	7.65	7.66	8.16	7.95	8.08	8.05	8.16	6.5 - 8.5	PWQO (2)	No
Phosphorous	mg/L	**0.14**	**0.14**	**0.077**	**0.072**	**0.069**	**0.073**	**0.069**	**0.067**	**0.035**	**0.064**	**0.049**	**0.023**	**0.14**	0.01	PWQO (2)	Yes
Total Suspended Solids (TSS)	mg/L	60	58	46	39	11	15	<10	<10	< 10	27	15	<10	60	---	See note (1)	No
Toxicity																	
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	0	-	0	-	0	-	0	0	0	0	0	--	--	--
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	0	-	0	-	0	-	0	0	0	0	0	--	--	--
Metals																	
Aluminum	µg/L	**650**	**600**	**370**	**360**	**320**	**410**	**110**	84	**110**	**500**	**170**	16	**650**	100	CEQG (3)	Yes
Antimony	µg/L	2.6	2.6	1.5	1.5	1.4	1.5	2	2	0.71	< 0.50	< 0.50	<0.50	2.6	20	iPWQO (5)	No
Arsenic	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	5	CEQG (3)	Yes (11)
Barium	µg/L	**17**	**16**	**13**	**12**	**18**	**19**	**7.5**	**7.1**	**23**	**23**	**25**		**25**	4	Suter and Tsao (6)	Yes
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	<0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	1100	PWQO (2)	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	254.3	Borgmann et al (7)	No
Boron	µg/L	29	26	12	13	14	15	16	14	23	16	27	15	29	1500	CEQG (3)	No
Cadmium	µg/L	**0.19**	0.15	**0.18**	**0.2**	**0.22**	**0.18**	0.15	0.15	< 0.10	< 0.10	< 0.10	<0.10	**0.22**	0.16	CEQG (3)	Yes
Calcium	µg/L	**31000**	**29000**	**26000**	**27000**	**32000**	**33000**	**12000**	**12000**	**32000**	**35000**	**38000**	**34000**	**38000**	11600	Suter and Tsao (6)	Yes
Chromium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	<5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	8.9	PWQO (2), CEQG (3)	No
Cobalt	µg/L	0.58	0.53	< 0.50	<0.50	< 0.50	<0.50	<0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	0.58	1	FEQG (4)	Yes (11)
Copper	µg/L	**21**	**17**	**7.2**	**7.1**	**13**	**14**	**9.7**	**9.4**	**23**	**7.4**	**5.4**	**2.6**	**23**	2.36	CEQG (3)	Yes
Iron	µg/L	**1000**	**970**	**710**	**700**	**480**	**500**	110	<100	180	**860**	260	<100	**1000**	300	PWQO (2), CEQG (3)	Yes
Lead	µg/L	**4.3**	**4**	**3.7**	**3.9**	1.6	1.7	1.2	1.1	0.67	1.9	< 0.50	<0.50	**4.3**	2.8	FEQG (4)	Yes
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	<5.0	<5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	14	Suter and Tsao (6)	No
Magnesium	µg/L	1300	1300	1100	1100	1300	1300	440	430	8000	6900	**8800**	7900	**8800**	8200	Suter and Tsao (6)	Yes
Manganese	µg/L	51	48	39	40	26	28	10	9.8	11	45	15	3.2	51	370	CEQG (3)	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	0.02	< 0.01	< 0.01	<0.01	0.02	0.026	CEQG (3)	Yes (11)
Molybdenum	µg/L	0.68	0.67	< 0.50	<0.50	0.55	0.58	1	1	1.1	0.85	1.2	1.1	1.2	73	CEQG (3)	No
Nickel	µg/L	2.4	2.7	1.6	1.5	1.9	1.7	1.1	1.3	4.5	2.2	2.3	1.2	4.5	25	PWQO (2)	No
Potassium	µg/L	1400	1400	1600	1600	1400	1500	3800	3700	1600	1500	1700	1700	3800	5300	Suter and Tsao (6)	Yes (11)
Selenium	µg/L	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2.0**	**<2.0**	**<2.0**	**<2.0**	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2**	1	CEQG (3)	Yes
Silicon	µg/L	**1800**	**1700**	**1200**	**1100**	**1600**	**1900**	**810**	**760**	**330**	**1100**	**560**	**380**	**1900**	260	Background (8)	No (13)
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	<0.10	<0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	0.1	PWQO (2)	No
Sodium	µg/L	6600	6300	2800	2900	6700	6800	3400	3400	16000	12000	15000	14000	16000	68000	Suter and Tsao (6)	Yes (11)

Table A.2 - Screening of Stormwater COPCs for Ecological Health - Drain A

Station ID		MH106								MH85				**Maximum Conentration At Discharge**	**Screening Criteria**		**Retained For Further Assessment?**
Sample Name		MH106	MH106-Dup	MH106	Dup B	MH106	Dup A	MH106	DUP B	MH85	MH85	MH85	MH85		**Selected Benchmark**	**Reference**	
Sampling Date		20-Aug-15		28-Oct-15		19-Nov-15		11-Jun-16		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16				
	Unit																
Strontium	µg/L	90	87	61	63	87	89	58	58	180	140	180	170	180	2500	FEQG [4]	No
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	151.9	Borgmann et al [7]	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	<0.050	<0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	< 0.05	0.8	CEQG [3]	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	73	Suter and Tsao [6]	No
Titanium	µg/L	23	20	15	16	14	21	<5.0	5	5.5	23	9.5	<5.0	23	315	Borgmann et al [7]	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	30	iPWQO [5]	No
Uranium	µg/L	< 0.10	< 0.10	< 0.10	<0.10	0.12	0.14	0.29	0.16	0.55	0.31	0.4	0.5	0.55	15	CEQG [3]	No
Vanadium	µg/L	3.7	3.2	1.8	1.8	1.4	1.9	2.5	2.6	0.86	1.5	0.63	0.72	3.7	120	FEQG [4]	No
Zinc	µg/L	**190**	**190**	**160**	**170**	**130**	**150**	**120**	**120**	25	**34**	18	7.9	**190**	30	PWQO [2]	**Yes**
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	4	iPWQO [5]	No

Notes:

Bq/L = Becquerel per litre; mg/L = miligram per litre; µg/L = micrograms per litre; mS/cm = microsievert per centimetre; CCME = Canadian Council of Ministers of Environment; COPC = contaminant of potential concern;

PWQO = Provincial Water Quality Objective; BTEX = benzene, toluene, ethylbenzene and xylene.

(1°-4°) = Benchmark Screening Heirarchy

Bold and shaded indicates exceedance of selected surface water quality benchmark. Concentrations of parameters that exceeded background by <20% were not identified as exceedances in the table.

Stormwater sampling locations are shown on Figure 5.2 of the 2022 PEA Addendum report

1. Risk-based guidelines are not applicable to water quality parameters such as temperature, conductivity, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.
2. PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998
3. CEQG = Canadian Environmental Quality Guidelines, current to September 2021
4. FEQG = Federal Environmental Quality Guidelines, current to September 2021
5. iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, updated July 1998
6. Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.
7. Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.
8. Background = Mean background concentration measured in Lake Water (LWC-1), as presented in Section 3.1.2.2.2 of the 2022 PN ERA. Results screened for further evalation if greater than 20% above LWC-1.
9. PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration
10. Value retained due to public interest.
11. Value retained due to findings in the other Drain.
12. Stormwater sampling conducted in 2015/2016 does not fully represent potential C-14 effects. Results from 2006 and 2000-2001 were preferentially selected for use in discharge concentrations calculations.
13. Not retained for further consideration due to lack of toxicity to aquatic organisms

Table A.3 - Screening of Stormwater COPCs for Ecological Health - Drain B

Station ID		CB70				MH20				Maximum Contration At Discharge	Screening Criteria		Retained For Further Assessment?
Sample Name		CB70	CB70	CB70	CB70	MH20	MH20	MH20	MH20		Selected Benchmark	Reference	
Sampling Date		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16				
	Unit												
Radiological													
Carbon-14(12)	Bq/L	**< 20**	**< 20**	**< 20**	**<20**	**< 20**	**< 20**	**< 20**	**<20**	**< 20**	<0.1	Background (8)	**Yes**
Cesium-134	Bq/L	**< 1**	**< 1**	**< 1**	**<1**	**< 1**	**< 1**	**< 1**	**<1**	**< 1**	<0.1	Background (8)	**Yes**
Cesium-137	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	50	PWQO (2)	**Yes(10)**
Cobalt-60	Bq/L	-	**< 1**	**< 1**	**<1**	-	**< 1**	**< 1**	**<1**	**< 1**	<0.1	Background (8)	**Yes**
Iodine-131	Bq/L	< 1	< 1	< 1	<1	< 1	< 1	< 1	<1	< 1	10	PWQO (2)	No
Manganese-54	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	nv	nv	No
Tritium (Hydrogen-3)	Bq/L	188	6450	**11600**	**13800**	2300	**35300**	**19300**	**13700**	**35300**	7000	PWQO (2)	**Yes**
Zinc-65	Bq/L	< 1	-	-	-	< 1	-	-	-	< 1	nv	nv	No
Petroleum Hydrocarbons (and BTEX)													
Benzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	<0.20	< 0.2	100	iPWQO (5)	No
Toluene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	0.35	0.35	0.8	iPWQO (5)	No
Ethylbenzene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	1.1	1.1	8	iPWQO (5)	No
o-Xylene	µg/L	< 0.20	< 0.20	< 0.20	<0.20	< 0.20	< 0.20	< 0.20	1.2	1.2	40	iPWQO (5)	No
m,p-Xylenes	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	**2.8**	**2.8**	2	iPWQO (5)	**Yes**
Xylenes, Total	µg/L	< 0.40	< 0.40	< 0.40	<0.40	< 0.40	< 0.40	< 0.40	**4.1**	**4.1**	2	iPWQO (5)	--
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	µg/L	< 25	< 25	**190**	<25	< 25	< 25	< 25	<25	**190**	<25	Background (8)	**Yes**
Petroleum Hydrocarbons - F1 (C6-C10)	µg/L	< 25	< 25	**190**	<25	< 25	< 25	< 25	<25	**190**	<25	Background (8)	**Yes**
Petroleum Hydrocarbons - F2 (C10-C16)	µg/L	< 100	< 100	< 100	<100	< 100	< 100	< 100	<100	< 100	<100	Background (8)	No
Petroleum Hydrocarbons - F3 (C16-C34)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	<200	Background (8)	No
Petroleum Hydrocarbons - F4 (C34-C50)	µg/L	< 200	< 200	< 200	<200	< 200	< 200	< 200	<200	< 200	<200	Background (8)	No
General													
Chloride	mg/L	45	23	**140**	7.3	19	4.2	31	2.2	**140**	120	CEQG (3)	**Yes**
Conductivity	mS/cm	0.267	0.193	1.18	0.079	0.181	0.101	0.301	0.064	1.18	---	See note (1)	--
Hardness, Calcium Carbonate	mg/L	47	48	120	19	52	43	110	29	120	See (9)	PWQO (2)	--
pH	pH units	7.84	7.64	7.27	7.68	7.58	7.64	7.85	7.53	7.85	6.5 - 8.5	PWQO (2)	No
Phosphorous	mg/L	**0.13**	**0.055**	**3.7**	**0.098**	**0.16**	**0.072**	**0.075**	**0.078**	**3.7**	0.01	PWQO (2)	**Yes**
Total Suspended Solids (TSS)	mg/L	< 10	< 10	< 10	11	29	17	< 10	<10	29	---	See note(1)	No
Toxicity													
% Mortality of Daphnia Magna in 100% Effluent Treatment	%	0	0	100	0	0	0	0	0	100	--	--	--
% Mortality of Rainbow Trout in 100% Effluent Treatment	%	0	0	100	0	0	0	0	0	100	--	--	--
Metals													
Aluminum	µg/L	**190**	**160**	**320**	**240**	**420**	**200**	**290**	**160**	**420**	100	CEQG (3)	**Yes**
Antimony	µg/L	8.7	2.6	1.6	1.2	2.4	0.88	0.9	0.8	8.7	20	iPWQO (5)	No
Arsenic	µg/L	< 1.0	< 1.0	**9**	<1.0	< 1.0	< 1.0	< 1.0	<1.0	**9**	5	CEQG (3)	**Yes**
Barium	µg/L	**13**	**10**	**31**	**4.7**	**16**	**7.5**	**24**	**7**	**31**		Suter and Tsao (6)	**Yes**
Beryllium	µg/L	< 0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	< 0.50	<0.50	< 0.5	1100	PWQO (2)	No
Bismuth	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	254.3	Borgmann et al (7)	No
Boron	µg/L	27	12	49	<10	23	< 10	26	<10	49	1500	CEQG (3)	No
Cadmium	µg/L	0.13	< 0.10	**0.44**	<0.10	**0.24**	0.16	< 0.10	0.15	**0.44**	0.16	CEQG (3)	**Yes**
Calcium	µg/L	**17000**	**15000**	**41000**	**8400**	**24000**	**15000**	**34000**	**12000**	**41000**	11600	Suter and Tsao (6)	**Yes**
Chromium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	8.9	PWQO (2), CEQG (3)	No
Cobalt	µg/L	< 0.50	< 0.50	**1.8**	<0.50	0.56	< 0.50	< 0.50	<0.50	**1.8**	1	FEQG (4)	**Yes**
Copper	µg/L	**20**	**3.8**	**23**	**6.9**	**17**	**8.5**	**7**	**13**	**23**	2.36	CEQG (3)	**Yes**
Iron	µg/L	**400**	280	**950**	**500**	**750**	**380**	**640**	240	**950**	300	PWQO (2), CEQG (3)	**Yes**
Lead	µg/L	**3**	1.4	2.6	2.1	**4.7**	2.3	2.8	1.7	**4.7**	2.8	FEQG (4)	**Yes**
Lithium	µg/L	< 5.0	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	< 5.0	<5.0	< 5	14	Suter and Tsao (6)	No
Magnesium	µg/L	1600	1600	6500	440	1700	1100	6200	1200	6500	8200	Suter and Tsao (6)	**Yes(11)**
Manganese	µg/L	20	26	180	25	37	24	45	18	180	370	CEQG (3)	No
Mercury (filtered)	µg/L	< 0.01	< 0.01	**0.03**	<0.01	< 0.01	< 0.01	< 0.01	<0.01	**0.03**	0.026	CEQG (3)	**Yes**
Molybdenum	µg/L	0.9	0.91	1.9	<0.50	0.82	< 0.50	1.1	<0.50	1.9	73	CEQG (3)	No
Nickel	µg/L	1.4	< 1.0	7.2	1.1	1.7	1.1	1.9	<1.0	7.2	25	PWQO (2)	No
Potassium	µg/L	850	1300	**31000**	600	2900	1600	2400	1500	**31000**	5300	Suter and Tsao (6)	**Yes**
Selenium	µg/L	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2.0**	**< 2.0**	**< 2.0**	**<2.0**	**< 2**	1	CEQG (3)	**Yes**
Silicon	µg/L	**840**	**690**	**2000**	**690**	**1600**	**880**	**1300**	**720**	**2000**	260	Background (8)	No (13)
Silver	µg/L	< 0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	< 0.10	<0.10	< 0.1	0.1	PWQO (2)	No
Sodium	µg/L	36000	20000	**110000**	6400	14000	3200	19000	8300	**110000**	68000	Suter and Tsao (6)	**Yes**
Strontium	µg/L	200	120	570	47	110	41	170	42	570	2500	FEQG (4)	No

Table A.3 - Screening of Stormwater COPCs for Ecological Health - Drain B

Station ID		CB70				MH20				Maximum Contration At Discharge	Screening Criteria		Retained For Further Assessment?
Sample Name		CB70	CB70	CB70	CB70	MH20	MH20	MH20	MH20		Selected Benchmark	Reference	
Sampling Date		20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16	20-Aug-15	28-Oct-15	19-Nov-15	11-Jun-16				
	Unit												
Tellurium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	151.9	Borgmann et al (7)	No
Thallium	µg/L	< 0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	< 0.050	<0.050	< 0.05	0.8	CEQG (3)	No
Tin	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	73	Suter and Tsao (6)	No
Titanium	µg/L	9.6	5.9	20	12	20	8.6	14	14	20	315	Borgmann et al (7)	No
Tungsten	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	30	iPWQO (5)	No
Uranium	µg/L	0.3	0.33	0.48	0.13	0.25	< 0.10	0.26	<0.10	0.48	15	CEQG (3)	No
Vanadium	µg/L	2.5	0.95	2.1	1.6	2.8	1.2	1.5	1.1	2.8	120	FEQG (4)	No
Zinc	µg/L	**100**	**38**	**140**	**55**	**370**	**210**	**110**	**170**	**370**	30	PWQO (2)	**Yes**
Zirconium	µg/L	< 1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	<1.0	< 1	4	iPWQO (5)	No

Notes:

Bq/L = Becquerel per litre; mg/L = miligram per litre; µg/L = micrograms per litre; mS/cm = microsievert per centimetre

CCME = Canadian Council of Ministers of Environment; COPC = contaminant of potential concern; PWQO = Provincial Water Quality Objective; BTEX = benzene, toluene, ethylbenzene and xylene.

(1°-4°) = Benchmark Screening Heirarchy

Bold and shaded indicates exceedance of selected surface water quality benchmark. Concentrations of parameters that exceeded background by <20% were not identified as exceedances in the table.

Stormwater sampling locations are shown on Figure 5.2 of the 2022 PEA Addendum report

1. Risk-based guidelines are not applicable to water quality parameters such as temperature, conductivity, biological oxygen demand, chemical oxygen demand, and total suspended solids and therefore are excluded from screening.
2. PWQO = Ontario Provincial Water Quality Objectives, MOEE 1994, updated July 1998
3. CEQG = Canadian Environmental Quality Guidelines, current to September 2021
4. FEQG = Federal Environmental Quality Guidelines, current to September 2021
5. iPWQO = Interim Ontario Provincial Water Quality Objectives, MOE 1994, updated July 1998
6. Suter and Tsao, (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision.
7. Borgmann et al., (2005). Toxicity of Sixty-Three Metals and Metalloids to Hyalella Azteca at Two Levels of Water Hardness.
8. Background = Mean background concentration measured in Lake Water (LWC-1), as presented in Section 3.1.2.2.2 of the 2022 PN ERA. Results screened for further evalation if greater than 20% above LWC-1.
9. PWQO state that alkalinity should not be decreased by more than 25% of the natural concentration
10. Value retained due to public interest.
11. Value retained due to findings in the other Drain.
12. Stormwater sampling conducted in 2015/2016 does not fully represent potential C-14 effects. Results from 2006 and 2000-2001 were preferentially selected for use in discharge concentrations calculations.
13. Not retained for further consideration due to lack of toxicity to aquatic organisms

Table A.4: Discharge Concentrations - Vacuum Building (VB) Ramp Sump

Sample Date	Source	Units	Tritium
2016 Q1	Groundwater	Bq/L	1,217,300
2016 Q2	Groundwater	Bq/L	1,036,000
2016 Q3	Groundwater	Bq/L	873,200
2016 Q4	Groundwater	Bq/L	1,132,200
2017 Q1	Groundwater	Bq/L	706,700
2017 Q2	Groundwater	Bq/L	466,200
2017 Q3	Groundwater	Bq/L	315,240
2017 Q4	Groundwater	Bq/L	577,200
2018 Q1	Groundwater	Bq/L	821,400
2018 Q2	Groundwater	Bq/L	1,750,100
2018 Q3	Groundwater	Bq/L	973,100
2018 Q4	Groundwater	Bq/L	1,080,400
2019 Q1	Groundwater	Bq/L	703,000
2019 Q2	Groundwater	Bq/L	348,540
2019 Q3	Groundwater	Bq/L	361,860
2019 Q4	Groundwater	Bq/L	777,000
2020 Q1	Groundwater	Bq/L	NA
2020 Q2	Groundwater	Bq/L	NA
2020 Q3	Groundwater	Bq/L	1,132,200
2020 Q4	Groundwater	Bq/L	NA

Notes:
Bq/L = Becquerel per litre
NA = results were not available because samples could not be collected

Table A.5: Screening of Diluted Forebay Concentrations for Ecological Health

COPC	Units	Concentration of Loadings				Diluted Forebay Concentration [1]						Selected Screening Level	Source / Basis
		Drain A Stormwater	Drain B Stormwater	VBRS	U1-4 IAD	Box 1	Box 2	Box 3	Box 4	Box 5	Box 6		
Tritium [9]	Bq/L	9475	24550	1750100	611000	8.38E-01	3.28E+00	5.72E+02	1.03E+03	1.03E+03	1.09E+03	7000	PWQO [3]
Carbon-14 [10]	Bq/L	0.259	0.629	-	-	8.88E-07	8.88E-07	1.67E-06	5.91E-04	5.91E-04	2.02E-03	<0.1	Background [8]
Cesium-134	Bq/L	1	1	-	-	2.00E-06	2.00E-06	5.00E-06	2.28E-03	2.28E-03	4.56E-03	<0.1	Background [8]
Cesium-137	Bq/L	1	1	-	-	2.00E-06	2.00E-06	5.00E-06	2.28E-03	2.28E-03	4.56E-03	50	PWQO [3]
Cobalt-60	Bq/L	1	1	-	-	2.00E-06	2.00E-06	5.00E-06	2.28E-03	2.28E-03	4.56E-03	<0.1	Background [8]
PHC F1	mg/L	0.025	0.19	-	-	2.15E-07	2.15E-07	2.90E-07	5.71E-05	5.72E-05	4.90E-04	<0.025	Background [8]
m,p-xylenes	mg/L	0.0066	0.0028	-	-	9.40E-09	9.40E-09	2.92E-08	1.50E-05	1.51E-05	2.14E-05	0.002	iPWQO [6]
Chloride	mg/L	27	140	-	-	1.67E-04	1.67E-04	2.48E-04	6.16E-02	6.17E-02	3.81E-01	120	CEQG [4]
Aluminum	mg/L	0.65	0.42	-	-	1.07E-06	1.07E-06	3.02E-06	1.48E-03	1.48E-03	2.44E-03	0.1	CEQG [4]
Arsenic	mg/L	0.001	0.009	-	-	1.00E-08	1.00E-08	1.30E-08	2.29E-06	2.29E-06	2.28E-05	0.005	CEQG [4]
Barium	mg/L	0.025	0.031	-	-	5.60E-08	5.60E-08	1.31E-07	5.70E-05	5.71E-05	1.28E-04	0.004	Suter and Tsao [7]
Cadmium	mg/L	0.00022	0.00044	-	-	6.60E-10	6.60E-10	1.32E-09	5.02E-07	5.02E-07	1.50E-06	0.00016	CEQG [4]
Calcium	mg/L	38	41	-	-	7.90E-05	7.90E-05	1.93E-04	8.66E-02	8.67E-02	1.80E-01	11.6	Suter and Tsao [7]
Cobalt	mg/L	0.00058	0.0018	-	-	2.38E-09	2.38E-09	4.12E-09	1.32E-06	1.32E-06	5.43E-06	0.0009	FEQG [5]
Copper	mg/L	0.023	0.023	-	-	4.60E-08	4.60E-08	1.15E-07	5.24E-05	5.25E-05	1.05E-04	0.00236	CEQG [4]
Iron	mg/L	1	0.95	-	-	1.95E-06	1.95E-06	4.95E-06	2.28E-03	2.28E-03	4.44E-03	0.3	PWQO [3], CEQG [4]
Lead	mg/L	0.0043	0.0047	-	-	9.00E-09	9.00E-09	2.19E-08	9.80E-06	9.81E-06	2.05E-05	0.0028	FEQG [5]
Magnesium	mg/L	8.8	6.5	-	-	1.53E-05	1.53E-05	4.17E-05	2.01E-02	2.01E-02	3.49E-02	8.2	Suter and Tsao [7]
Mercury	mg/L	0.00002	0.00003	-	-	5.00E-11	5.00E-11	1.10E-10	4.56E-08	4.57E-08	1.14E-07	0.000026	CEQG [4]
Phosphorus	mg/L	0.14	3.7	-	-	3.84E-06	3.84E-06	4.26E-06	3.23E-04	3.23E-04	8.76E-03	0.02	PWQO [3]
Potassium	mg/L	3.8	31	-	-	3.48E-05	3.48E-05	4.62E-05	8.69E-03	8.70E-03	7.94E-02	5.3	Suter and Tsao [7]
Selenium	mg/L	0.002	0.002	-	-	4.00E-09	4.00E-09	1.00E-08	4.56E-06	4.56E-06	9.12E-06	0.001	CEQG [4]
Sodium	mg/L	16	110	-	-	1.26E-04	1.26E-04	1.74E-04	3.66E-02	3.66E-02	2.87E-01	68	Suter and Tsao [7]
Zinc	mg/L	0.19	0.37	-	-	5.60E-07	5.60E-07	1.13E-06	4.33E-04	4.34E-04	1.28E-03	0.03	PWQO [3]

Notes:

Bq = Becquerel; Bq/L = Becquerel per litre; CCME = Canadian Council of Ministers of Environment; COPC = contaminant of potential concern; FEQG = Federal Environmental Quality Guidelines;
IAD = Inactive drainage; kg = kilogram; mg/L = miligram per litre; NA = not analyzed; PHC = petroleum hydrocarbon; PWQO = Provincial Water Quality Objective; TSS = total suspended solids

1. Calculated using flow rates and concentration factors presented in Section 6.2.3.2 of the 2022 PEA Addendum report.
2. Bold and shaded indicates exceedance of selected benchmark.
3. PWQO Ontario MOE 1994 (https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives).
4. CCME (2008) aquatic protection value calculated for assumed composition of F1; other PHC fractions considered insufficiently soluble to be of concern as chemical toxicants in water
5. FEQG (2021), assumes water hardness of 100 mg/L and DOC of 0.5
6. Interim PWQO; set based on readily available information and was not peer reviewed.
7. LCV from Suter and Tsao (1996) modified to NOEC (No observed effect concentration)
8. Borgmann et al. (2005)
9. Tritium in stormwater is based on the average of the maximum concentrations from each location. VBRS concentrations are presented on Table A.4, and U1-4 IAD concentrations are from CH2M, 2002 as discussed in the 2022 PEA Addendum Report
10. C-14 in stormwater is maximum value from 2000/2001 and 2006, as 2016 sampling was non-detect but at elevated detection limits

Appendix B Prediction of Airborne Tritium and C-14 Emissions during the Storage with Surveillance Phase

B.1 Introduction

The purpose of this Appendix is to provide a bounding estimate of airborne tritium and C-14 emission streams expected to be released during the first 10 years of the Storage with Surveillance Phase on the Pickering site. The bounding estimate was used in the 2017 Predictive Effects Assessment (PEA) in support of the Pickering operating licence renewal process and the Safe Storage Project. The information has been provided in this Appendix to address CNSC's recommendation to provide in the next iteration of the PEA reference(s) and/or a summary of the historical tritium emissions data used for the 2017 PEA estimate (CNSC, 2017), and does not represent an update to the 2017 PEA.

B.2 Rationale for Airborne Tritium and C-14 Bounding Estimates

The estimate is based on operational assumptions about the Safe Storage State, including which systems will continue to operate and to what extent, as well as historical airborne tritium and C-14 emissions from units that are currently in Safe Storage (i.e., Units 2 and 3, which were permanently shut down in 1997 and subsequently placed into a Safe Storage State in 2010). The historical data utilized in this estimate was retrieved from OPG's Chemistry System database (CEMS). The estimates are broken down in the following tables:

- Table B.1 provides the bounding airborne tritium emissions in the Storage with Surveillance Phase, including all assumptions relating to potential tritium sources and streams;
- Table B.2 provides the bounding airborne C-14 emissions in the Storage with Surveillance Phase, including and all assumptions relating to potential C-14 sources and streams; and
- Table B.3 provides more details/justifications on bounding tritium emission estimates used for selected streams in Table B.1.

Table B.1. Predicted Airborne Tritium Emissions during the Storage with Surveillance Phase

Emission Stream	Bounding Estimate for the Storage with Surveillance Phase		Baseline Average [(1)] (2010-2015)	Notes/Assumptions
	Bq/yr	Basis	Bq/yr	
U1 Reactor Building	1.26E+13	U3 average (2010-2015)	7.83E+13	It is assumed that the emissions from the reactor building will be consistent with those seen for units in Safe Storage (U2 and U3). Annual averages from U2 and U3 were calculated for the period from 2010 to 2015, to reflect the period following completion of the dewatering activities. Conservatively, the unit with the higher average annual tritium emissions (U3) was used as a basis for estimation.
U2 Reactor Building	1.26E+13	U3 average (2010-2015)	6.44E+12	
U3 Reactor Building	1.26E+13	U3 average (2010-2015)	1.26E+13	
U4 Reactor Building	1.26E+13	U3 average (2010-2015)	6.46E+13	
Irradiated Fuel Bay A (IFB-A)	1.86E+13	100% of baseline average (2010-2015)	1.86E+13	Assumes the IFBs will operate during the Storage with Surveillance Phase as they are operating now. Therefore, the baseline (2010-2015) average is used.
Service Wing A (SW-A)	3.77E+12	30% of baseline average (2010-2015)	1.25E+13	Tritium sources from the SW-A include the fueling machine maintenance shop, a decontamination shop as well as the ion exchange and clean up (IXCU) area. These facilities will no longer be required during the Storage with Surveillance Phase (in particular, the IXCU systems, which are a primary contributor to the emissions). 30% of baseline (2010 to 2015) emissions was assumed to account for any residual contamination which may exist in SW-A and be released as a result of building ventilation. This proportion is consistent with the ratio between residual tritium emissions from the out-of-service Sulzer A building, and emissions from the still operational Sulzer B building (Section B.3).

Emission Stream	Bounding Estimate for the Storage with Surveillance Phase		Baseline Average (1) (2010-2015)	Notes/Assumptions
	Bq/yr	Basis	Bq/yr	
Upgrading Plant Pickering A (UPP-A)	1.59E+12	30% of baseline average (2010-2015)	5.29E+12	Heavy water (D_2O) will continue to be stored in existing heavy water storage tanks located in the UPP-A during the Storage with Surveillance Phase. Cover gas will be used to minimize evaporation (and consequently, atmospheric releases to the environment). It is anticipated that the need for movement or transfer of heavy water on site will be very limited during the Storage with Surveillance Phase (much less than 30% of current activity) which will result in significantly lower emissions.
Upgrading Plant Pickering B (UPP- B)	9.99E+11	30% of baseline average (2010-2015)	3.33E+12	Heavy water will continue to be stored in the feed storage tanks located in the UPP-B. It is anticipated that the need for movement or transfer of heavy water on site will be very limited during the Storage with Surveillance Phase (much less than 30% of baseline activity) which will result in significantly lower emissions.
Sulzer A	3.07E+12	100% of baseline average (2010-2015)	3.07E+12	Not in operation, it is assumed that releases may continue during the Storage with Surveillance Phase due to residual contamination.
Sulzer B	3.07E+12	100% of Sulzer-A baseline average (2010-2015)	4.00E+12	Heavy water upgrading will not be required during the Storage with Surveillance Phase and Sulzer B will not be used for D_2O storage. It is assumed that any continued releases due to residual contamination would be comparable to those from Sulzer A.

Emission Stream	Bounding Estimate for the Storage with Surveillance Phase		Baseline Average [1] (2010-2015)	Notes/Assumptions
	Bq/yr	Basis	Bq/yr	
West Annex	2.22E+11	30% of baseline average (2010-2015)	7.77E+11	Sources of emissions include an active liquid waste facility as well as decontamination shops. This area will no longer be in service during the Storage with Surveillance Phase. 30% of baseline (2010 to 2015) emissions was assumed to account for any residual contamination which may exist and be released as a result of building ventilation. This proportion is consistent with the ratio between residual tritium emissions from the out-of-service Sulzer A building, and emissions from the still operational Sulzer B building (Section B.3).
U1 Steam	0.00E+00	This stream is eliminated	1.28E+13	U1 steam emissions will no longer exist during the Storage with Surveillance Phase.
U4 Steam	0.00E+00	This stream is eliminated	1.05E+13	U4 steam emissions will no longer exist during the Storage with Surveillance Phase.
U5 Reactor Building	1.26E+13	U3 average (2010-2015)	4.92E+13	See notes/assumptions for the U1 to U4 Reactor Building emission streams.
U6 Reactor Building	1.26E+13	U3 average (2010-2015)	4.92E+13	
U7 Reactor Building	1.26E+13	U3 average (2010-2015)	4.94E+13	
U8 Reactor Building	1.26E+13	U3 average (2010-2015)	4.37E+13	

Emission Stream	Bounding Estimate for the Storage with Surveillance Phase		Baseline Average [1] (2010-2015)	Notes/Assumptions
	Bq/yr	Basis	Bq/yr	
Irradiated Fuel Bay B (IFB-B)	2.97E+13	100% of baseline average (2010-2015)	2.97E+13	Assumes the IFBs will operate during the Storage with Surveillance Phase as they are operating now. Therefore, the 2010-2015 average is used.
Service Wing B (SW-B)	7.81E+12	50% of baseline average (2010-2015)	1.57E+13	Tritium sources from the SW-B include active liquid drainage facilities, solid waste handling facilities, decontamination areas as well as fueling machine decontamination and dismantling areas. SW-B facilities will either be no longer in-service (in the case of fueling machine decontamination shops), or in-service but to a lesser extent as compared to operational requirements. For this reason, it is assumed that 50% of baseline (2010 to 2015) tritium emission levels would be a conservative estimate to account for any residual contamination as well as limited ongoing solid/liquid waste handling requirements.
D_2O Storage	1.04E+12	30% of baseline average (2010-2015)	3.48E+12	Heavy water will continue to be stored on site during the Storage with Surveillance Phase. It is anticipated that the need for movement or transfer of heavy water on site will be very limited during the Storage with Surveillance Phase (much less than 30% of baseline activity) which will result in significantly lower emissions.

Emission Stream	Bounding Estimate for the Storage with Surveillance Phase		Baseline Average [(1)] (2010-2015)	Notes/Assumptions
	Bq/yr	Basis	Bq/yr	
Pickering NGS Incoming/Outgoing D_2O Transfer System (PIOTs)	1.11E+11	30% of baseline average (2010-2015)	3.70E+11	Heavy water still stored in both PIOTs and storage and inventory (S&I) but minimal transfer/movement will be required. It is anticipated that the need for movement or transfer of heavy water on site will be very limited during the Storage with Surveillance Phase (much less than 30% of baseline activity) which will result in significantly lower emissions.
East Annex	9.25E+11	30% of baseline average (2010-2015)	3.07E+12	Tritium sources mainly include contaminated drum and equipment/tooling storage. The East Annex will no longer be required in the Surveillance phase. 30% of baseline (2010 to 2015) emissions was assumed to account for any residual contamination which may exist and be released as a result of building ventilation. This proportion is consistent with the ratio between residual tritium emissions from the out-of-service Sulzer A building, and emissions from the still operational Sulzer B building (Section B.3).
Service Wing Chem Lab	3.44E+12	30% of baseline average (2010-2015)	1.15E+13	The Service Wing Chem Lab may continue to operate during the Storage with Surveillance Phase in a very limited capacity. It is assumed that 30% of baseline (2010-2015) emissions would be a conservative estimate based on the very limited use of the facility.

Emission Stream	Bounding Estimate for the Storage with Surveillance Phase		Baseline Average (1) (2010-2015)	Notes/Assumptions
	Bq/yr	Basis	Bq/yr	
Tritium Off-gas Facility (TOF) / Laundry	1.70E+12	30% of baseline average (2010-2015)	5.70E+12	Tritium emissions include laundry dryer exhaust and the tritium off gas facility. Neither system will be in service during the Storage with Surveillance Phase. 30% of baseline (2010 to 2015) emissions was assumed to account for any residual contamination which may exist and be released as a result of building ventilation. This proportion is consistent with the ratio between residual tritium emissions from the out-of-service Sulzer A building, and emissions from the still operational Sulzer B building (Section B.3).
Unit 5 Steam	0.00E+00	Stream is eliminated	2.74E+12	Unit 5 steam emissions will no longer exist during the Storage with Surveillance Phase.
Unit 6 Steam	0.00E+00	Stream is eliminated	6.73E+12	Unit 6 steam emissions will no longer exist during the Storage with Surveillance Phase.
Unit 7 Steam	0.00E+00	Stream is eliminated	5.00E+12	Unit 7 steam emissions will no longer exist during the Storage with Surveillance Phase.
Unit 8 Steam	0.00E+00	Stream is eliminated	9.77E+12	Unit 8 steam emissions will no longer exist during the Storage with Surveillance Phase.
Total	**1.77E+14**			

Notes:

(1) The baseline average refers to the 2010-2015 period that was considered in the 2017 PEA. An updated average was not compiled for this PEA addendum report because the original estimate is still considered to be representative of emissions during the Storage with Surveillance Phase.

Table B.2. Predicted Airborne C-14 Emissions during the Storage with Surveillance Phase

Emission Stream	Bounding Estimate for the Storage with Surveillance Phase		Baseline Average (2010-2015)(1)	Notes/Assumptions
	Bq/yr	Basis	Bq/yr	
U1 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	6.14E+11	It is assumed that the emissions from the reactor building will be consistent with the those in Safe Storage (i.e., U2 and U3). Annual averages were calculated for the period from 2010 to 2015, to reflect the period following completion of the defueling activities. Conservatively, the unit with the higher average annual C-14 emissions (U3) was used as a basis of estimation.
U2 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	2.59E+09	
U3 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	3.70E+09	
U4 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	4.88E+11	
U5 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	1.33E+11	
U6 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	2.96E+11	
U7 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	2.89E+11	
U8 Reactor Building	3.70E+09	Use emission from U3 (2010-2015)	1.85E+11	
Total	**2.96E+10**			

Notes:

(1) The baseline average refers to the 2010-2015 period that was considered in the 2017 PEA. An updated average was not compiled for this PEA addendum report because the original estimate is still considered to be representative of emissions during the Storage with Surveillance Phase.

B.3 Rationale for the Percentage of Activity Reductions Assumed for the Storage with Surveillance Phase

Since the Sulzer A (Sul-A) facility has been out of operation since 1998 and the Sulzer B (Sul-B) facility is still in operation, a comparison of the results from the two emission streams can be used to qualitatively predict future tritium emissions from out-of-service systems resulting from residual contamination of streams with a similar proportion of activity reduction during the Storage with Surveillance Phase.

As shown in Table B.3 below, a comparison of the 2011-2015 annual tritium emission monitoring results from the Sul-A and Sul-B effluent streams shows that the Sul-A emission stream is approximately, on average, 30% of the Sulzer B emission stream.

Table B.3: Comparison of Sulzer-A and Sulzer-B Annual Tritium Emission Monitoring Results

Year	Sulzer-A (1) (Bq/yr)	Sulzer-B (Bq/yr)	Sul-A/Sul-B (%)
2011	1.30E+12	3.97E+12	33%
2012	8.10E+11	3.53E+12	23%
2013	1.05E+12	3.95E+12	27%
2014	1.30E+12	3.64E+12	36%
2015	1.50E+12	4.56E+12	33%
Average (2011-2015)	1.19E+12	3.93E+12	30%

Notes:
Emission results are obtained from the OPG chemistry database.
(1) Sulzer-A has been out of operation since 1998.

It is important to note that the tritium emission results from the Sul-A stream are influenced by active systems, which are interconnected to the Sul-A discharge stream. Active, interconnected systems include the IXCU (ion exchange & clean-up) system, PIOTS (Pickering (D_2O) incoming, outgoing & transfer system), and S&I (storage and inventory) tanks vent lines, which are vented to a vapour recovery drier located in the Sulzer A facility. As a result, using historical emissions from Sul-A and Sul-B to predict future emission trends resulting from residual contamination represents a highly conservative estimate of future tritium emissions from out of service systems.

B.4 Conclusion

Based on the assumptions made, it is expected that the total annual airborne tritium emissions from PNGS will not exceed 1.77×10^{14} Bq per year during the Storage with Surveillance Phase, which represents less than one third of the 2010-2015 baseline and current (2016-2020) annual tritium emissions at PNGS. Carbon-14 emissions are not expected to exceed 2.96×10^{10} Bq per year in the Storage with Surveillance Phase, which represents less than 1.5% of the 2010-2015 baseline and current (2016-2020) annual emissions. Based on the assumptions made, the bounding estimates provide a conservative, yet realistic estimate of expected emission rates during the Storage with Surveillance Phase.

B.5 References

CNSC (Canadian Nuclear Safety Commission), 2017. CNSC Letter, A. Viktorov to R. Lockwood, "Pickering NGS: Predictive Effects Assessment for Pickering Nuclear Safe Storage". CNSC e-Doc 5397038. November 22, 2017.

Appendix C Sample Calculations

Table C.1: Calculation of Tritium Concentration in the Forebay - Box 6

Parameter	Symbol	Calculation	Value	Unit	Source
Environmental Media Concentration					
Stormwater Concentration from Drain A	C_{w_StormA}	-	9.48E+03	Bq/L	Table A-5
Stormwater Concentration from Drain B	C_{w_StormB}	-	2.46E+04	Bq/L	Table A-5
Groundwater Concentration from VBRS	C_{w_VBRS}	-	1.75E+06	Bq/L	Table A-5
Groundwater Concentration from PN U-4 IAD	C_{w_IAD}	-	6.11E+05	Bq/L	Table A-5
Forebay Concentration Factors - Box 6					
Concentration Factor - Drain A	$CF_{Drain\ A}$	-	2.276	mg/L per 1000 mg/L	Table 6.14
Concentration Factor - Drain B	$CF_{Drain\ B}$	-	2.282	mg/L per 1000 mg/L	Table 6.14
Concentration Factor - PN U1-4 IAD	$CF_{PNU1\text{-}4}$	-	0.932	mg/L per 1000 mg/L	Table 6.14
Flow Rates					
Stormwater to Drain A	FR_{StormA}	-	101	m3/day	Table 6.13
VBRS to Drain A	FR_{VBRS}	-	12.6	m3/day	Table 6.13
Proportion of flow attributed to Stormwater	f_{StormA}	$FR_{StormA}/(FR_{StormA}+FR_{VBRS})$	0.89	unitless	Calculated
Proportion of flow attributed to VBRS	f_{VBRS}	$FR_{VBRS}/(FR_{StormA}+FR_{VBRS})$	0.11	unitless	Calculated
Forebay Concentration					
Diluted Forebay Concentration in Box 6	$C_{w\_Forebay}$	$C_{w\_Forebay} = [(C_{w\_StormA} * CF_{Drain\ A} * f_{StormA}) + (C_{w\_StormB} * CF_{Drain\ B}) + (C_{w\_VBRS} * CF_{Drain\ A} * f_{VBRS}) + (C_{w\_IAD} * CF_{PNU1\text{-}4})]/1000$	1.09E+03	Bq/L	Calculated

Table C.2: Sample Calculation - Pelagic Fish in Forebay - Radiological Dose for Tritium and Organically Bound Tritium

Parameter	Symbol	Calculation	Value	Unit	Source
Environmental Media Concentration					
Water Concentration - Tritium	C_{w_HTO}	-	1.09E+03	Bq/L	Table 6.16
Exposure Factor					
Fraction of Time Spent in the Forebay	f_0	-	1	unitless	Assumption
Internal Dose - Tritium					
Bioaccumulation Factor (HTO in Water to HTO in Fish)	BAF_{a_HTO}	-	7.50E-01	L/kg fw	Table 6.10
Tissue Concentration	C_{fish_HTO}	$C_{fish\_HTO} = C_{w\_HTO} * BAF_{a\_HTO}$	8.18E+02	Bq/kg fw	Calculation
Dose Conversion Factor (Internal) - Trout	DC_{int}	-	5.76E-06	(µGy/hr)/(Bq/kg fw)	Table 6.9
Internal Dose	D_{int_HTO}	$D_{int} = C_{fish\_HTO} * DC_{int}$	4.71E-03	µGy/hr	Calculated (Section 6.6.2.1)
Internal Dose (converted units)	D_{int_HTO}'	$D_{int\_HTO}' = D_{int\_HTO}$ * 24 h/d / 1000 µGy/mGy	1.13E-04	mGy/d	Calculated
Internal Dose - Organically Bound Tritium					
Bioaccumulation Factor (HTO in Water to OBT in Fish)	BAF_{a_OBT}	-	1.40E-01	L/kg fw	Table 6.10
Tissue Concentration	C_{fish_OBT}	$C_{fish\_OBT} = C_{w\_HTO} * BAF_{a\_OBT}$	1.53E+02	Bq/kg fw	Calculation
Dose Conversion Factor (Internal) - Trout	DC_{int}	-	5.76E-06	(µGy/hr)/(Bq/kg fw)	Table 6.9
Internal Dose	D_{int_OBT}	$D_{int} = C_{fish\_OBT} * DC_{int}$	8.79E-04	µGy/hr	Calculated (Section 6.6.2.1)
Internal Dose (converted units)	D_{int_OBT}'	$D_{int\_OBT}' = D_{int\_OBT}$ * 24 h/d / 1000 µGy/mGy	2.11E-05	mGy/d	Calculated
External Dose - Tritium					
Occupancy Factor, Water - Pelagic Fish	OF_w	-	1	unitless	Table 6.6
Dose Conversion Factor (External, in water) - Trout	DC_{ext}	-	3.54E-13	(µGy/hr)/(Bq/L)	Table 6.9
External Dose - Tritium	D_{ext_HTO}	$D_{ext\_HTO} = f_0 * C_w * OF_w * DC_{ext}$	3.86E-10	µGy/hr	Calculated (Section 6.6.2.1)
External Dose (converted units) - Tritium	D_{ext_HTO}'	$D_{ext\_HTO}' = D_{ext\_HTO}$ * 24 h/d / 1000 µGy/mGy	9.26E-12	mGy/d	Calculated

Parameter	Symbol	Calculation	Value	Unit	Source
External Dose - Organically Bound Tritium					
External Dose – OBT	D_{ext_OBT}	$D_{ext\_OBT} = f_0 * C_w * OF_w * DC_{ext}$	3.86E-10	µGy/hr	Calculated (Section 6.6.2.1)
External Dose (converted units) – OBT	D_{ext_OBT}'	$D_{ext\_OBT}' = D_{ext\_OBT}$ * 24 h/d / 1000 µGy/mGy	9.26E-12	mGy/d	Calculated
Total Radiological Dose					
Total Dose - HTO	D_{total_HTO}	$D_{total\_HTO} = D_{int\_HTO}' + D_{ext\_HTO}'$	1.13E-04	mGy/d	Calculation
Total Dose - OBT	D_{total_OBT}	$D_{total\_OBT} = D_{int\_OBT}' + D_{ext\_OBT}'$	2.11E-05	mGy/d	Calculation
Total Dose from Tritium (HTO + OBT)	D_{total}	$D_{total} = D_{total\_HTO} + D_{total\_OBT}$	1.34E-04	mGy/d	Calculation

Table C.3: Sample Calculation - Bufflehead at the Forebay - Radiological Dose for Cobalt-60

Parameter	Symbol	Calculation	Value	Unit	Source
Environmental Media Concentrations					
Water Concentration (Co-60)	C_w	-	4.56E-03	Bq/L	Table 6.16
Sediment Distribution Coefficient (Co-60)	k_d	-	4.30E+04	L/kg dw	Table 6.4
Sediment Concentration (dry weight)	$C_{s(dw)}$	-	1.96E+02	Bq/kg dw	Table 6.16
Sediment Dry Bulk Density	ρ_s	-	4.00E-01	kg dw/ L	CSA N288.1-20 clause 6.6.2.2
Mixing Depth	d	-	5.00E-02	m	Assumption
Sediment Surface Concentration (dry weight)	$C_{s(dw)}'$	$C_{s(dw)}' = C_{s(dw)} * \rho_s * d * 1000\ L/m^3$	3.92E+03	Bq dw/ m^2	Calculated
Aquatic Plant Concentration					
Bioaccumulation Factor - Aquatic Plant	$BAF_{aquatic\ plant}$	-	7.90E+02	L/kg fw	Table 6.7
Aquatic Plant Concentration (fresh weight)	$C_{aquatic\ plant}$	$C_{aquatic\ plant} = C_w * BAF_{aquatic\ plant}$	3.60E+00	Bq/kg fw	Calculated (Section 6.6.2.3)
Benthic Invertebrate Concentration					
Bioaccumulation Factor - Benthic Invertebrates	$BAF_{benthic\ inv}$	-	1.10E+02	L/kg fw	Table 6.7
Benthic Invertebrate Tissue Concentration	$C_{benthic\ inv}$	$C_{benthic\ inv} = C_w * BAF_{benthic\ inv}$	5.02E-01	Bq/kg fw	Calculated (Section 6.6.2.3)
Bufflehead Exposure Factors					
Intake Rate, Water	IR_w	-	3.60E-02	L/d	Table 6.5
Intake Rate, Sediment	IR_s	-	4.65E-03	kg dw/d	Table 6.5
Intake Rate, Aquatic Plant	$IR_{aquatic\ plant}$	-	1.80E-02	kg/d fw	Table 6.5
Intake Rate, Benthic Invertebrate	$IR_{benthic\ inv}$	-	1.61E-01	kg/d fw	Table 6.5
Fraction of Time Spent on Site	f_0	-	1	unitless	Assumption
Bufflehead Internal Dose (Radiological)					
Ingestion Transfer Factor - Bufflehead	TF_{ing}	-	2.86E+00	d/kg fw	Table 6.8
Bufflehead Tissue Concentration	C_t	$C_t = f_0 * TF_{ing} * (C_w * IR_w + C_{s(dw)} * IR_s + C_{aquatic\ plant} * IR_{aquatic\ plant} + C_{benthic\ inv} * IR_{benthic\ inv})$	3.02E+00	Bq/kg fw	Calculated (Section 6.6.2.3)
Dose Conversion Factor (Internal) - Duck	DC_{int}	-	2.38E-04	(µGy/hr)/(Bq/kg fw)	Table 6.9

Parameter	Symbol	Calculation	Value	Unit	Source
Internal Dose	D_{int}	$D_{int} = C_t * DC_{int}$	7.18E-04	µGy/hr	Calculated (Section 6.6.2.1)
Internal Dose (converted units)	D_{int}'	$D_{int}' = D_{int}$ * 24 h/d / 1000 µGy/mGy	1.72E-05	mGy/d	Calculated
Bufflehead External Dose (Radiological)					
Occupancy Factor, Sediment - Riparian Birds	OF_s	-	0	unitless	Table 6.6
Occupancy Factor, Sediment Surface - Riparian Birds	OF_{ss}	-	0.5	unitless	Table 6.6
Dose Conversion Factor (External, on soil) - Duck	$DC_{ext\ (on\ soil)}$	-	7.50E-06	(µGy/hr)/(Bq/m^2)	Table 6.9
External Dose	D_{ext}	$D_{ext} = f_0 * (C_{s(dw)}' * OF_{ss} * DC_{ext\ (on\ soil)})$	1.47E-02	µGy/hr	Calculated (Section 6.6.2.1)
External Dose (converted units)	D_{ext}'	$D_{ext}' = D_{ext}$ * 24 h/d / 1000 µGy/mGy	3.53E-04	mGy/d	Calculated
Bufflehead Total Dose (Radiological)					
Total Dose	D_{total}	$D_{total} = D_{int} + D_{ext}$	1.54E-02	µGy/hr	Calculated
Total Dose (converted units)	D_{total}'	$D_{total}' = D_{int}' + D_{ext}'$	3.70E-04	mGy/d	Calculated